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Evaluation of Shake Weight Protocol in Senior Populations

Evaluation of Shake Weight Protocol in Senior Populations

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Kinesiology

by

Isaac Cook
University of Arkansas
Bachelor Science in Education, 2011

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University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Ro DiBrezzo
Thesis Director

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ABSTRACT

The Shake Weight® (SW®) is designed to improve muscular fitness in a quick and inexpensive way. This study aimed to determine if the SW® was an effective tool at improving muscular fitness, body composition, and bone mineral density (BMD) in post-menopausal women. Participants were 17 healthy, post-menopausal women from aMidwestern University and divided into two training (SW® and HIT) interventions that lasted 10 weeks. HIT participants performed three sets of 8 repetitions at 80% of their estimated 1RM for the chest press, leg press, lat pulldown, and seated row. SW® participants performed the exercises prescribed by the SW® manufacturer. Changes in muscular strength were determined via handgrip dynamometry and muscular endurance was determined via a modified YMCA bench press test. Surface electromyography was used to determine changes in motor unit recruitment. Neither group showed significant improvements in handgrip strength, BMD, fat mass, and the SW® group showed no significant change in YMCA scores. The SW® group had a significant reduction in fat free mass after the intervention ($p = .033$). The HIT group showed significant improvements in YMCA bench press scores ($p = .013$) and all measures of muscular strength via 8RM ($p < .05$) except for the chest press. The HIT group showed significant increases in motor unit activity for the anterior deltoid and bicep while shaking either the dumbbell or the SW®. Neither group improved on any EMG measurement. This study indicates that the SW® is ineffective at altering muscular fitness, BMD, or body composition in post-menopausal women.

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First and foremost I want to thank Jesus Christ as my ultimate guide and savior. Without Him, none of my academic career would be possible.

I would like to thank the members of my thesis committee, Dr. DiBrezzo, Dr. Fort, and Dr. Gray for all of their help in guiding me through this process. They have provided great support, insight, and their own time to help me in this process and it would not have been possible to complete this process without their aid.

Special thanks in particular go to Dr. DiBrezzo, who has been a tremendous and leader throughout my academic career. She has guided through and given me great support throughout my time here at the University of Arkansas and it would not have succeeded without her help.

DEDICATION

I would like to dedicate this Master’s thesis, *Evaluation of Shake Weight Protocol in Senior Populations*, to my wife Maci Cook. She has been so very very important to me over the past two years and her love, wisdom, and support gave me strength throughout this process. I owe her a great deal of gratitude and thanks for what she has done.

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CHAPTER I

Introduction

A growing area of concern among health and fitness specialists is the level of physical activity and frailty among aging adults. With age, there is a consistent decline in muscle mass. This loss in muscle mass is known as sarcopenia, and it affects the aging individual from several standpoints. Evans et al. (2010) states that physical inactivity in conjunction with sarcopenia leads to frailty syndrome. This syndrome is a state of consistent frailty and weakness that leads to activity limitations, which in turn leads to greater levels of physical inactivity, which enhances the rate of sarcopenia.This process ultimately worsens the condition of the individual until demise. A great percentage of the problemin dealing with sarcopenia is the loss in muscular strength and endurance over time.

Previous research provides evidence that resistance training in older adults can be effective at improving both muscular strength and endurance (Murlasits, Reed, & Wells, 2012). These resistance training programs cover a wide array of modalities; including, but not limited to: free weights, resistance machines, yoga, Tai Chi, and other pieces of exercise equipment designed to improve muscular fitness. One of these pieces of exercise equipment is the Shake Weight® (SW®). The SW® is a product that utilizes a vibrating or shaking motion generated by the participant to elicit muscle activation. The originators of the SW® (Fitness IQ, LLC) purport that the SW® is able to generate size, definition, and strength through muscle activation that is equal to throwing an exercise ball weighing 5lbs. up to 240 times in one minute. The workout for the SW® is less than 10 minutes, and at $15-20, is a relatively inexpensive piece of exercise equipment. If the SW® is an effective tool to improve muscular strength and endurance in older adults, it may be an alternative form of resistance exercise to older adults with time or financial constraints.

Murlasits et al. (2012) emphasizes the importance that high-intensity resistance training (HIT) can have in the muscular fitness adaptations of older adults over low- and moderate-intensity resistance training. A meta-analysis by Peterson, Rhea, Sen, and Gordon (2010), had the same finding; HIT programs were more effective at improving muscular strength than lower intensity training programs in older adults. However, downsides to this type of training are the increased risk for injury, time, and potentially cost constraints. The isometric nature of the SW$^{®}$ may cause this form of exercise to be of relatively high intensity. In addition, the SW$^{®}$ manufacturers report that the SW$^{®}$ is a high-intensity resistance training exercise in saying the SW$^{®}$ elicits the same amount of muscle activation as throwing a 5lb. exercise ball 240 times in one minute. Thus, a vast amount of work is done in a very short time frame. If the SW$^{®}$ is an effective form of HIT, then it may be a fast, relatively inexpensive way for older adults to obtain resistance training. The higher-intensity associated with the SW$^{®}$ may elicit greater muscle activation as seen on electromyography (EMG) and could translate to improvements in muscular strength and endurance in older adults with a training program. To date, the changes in muscle activation, muscular strength, muscular endurance, and body composition as the result of a SW$^{®}$ intervention have yet to be evaluated in older adults.

Purpose

To provide evidence whether or not the SW$^{®}$ can be an effective exercise tool that generates greater changes in maximum isovolumetric contraction (MVIC), muscular strength, and muscular endurance than a traditional high-intensity resistance training program in older adults.

Research Hypothesis

1. Neither intervention group will have significantly greater improvements in muscular strength as measured via handgrip strength in comparison to one another after five and ten weeks of resistance training twice per week.
2. Neither intervention group will have significantly greater improvements in muscular endurance as measured via a modified YMCA bench press in comparison to one another after five and ten weeks of resistance training twice per week.
3. Neither intervention group will have significant changes in muscle activation as measured on an EMG in after ten weeks of resistance training.
4. No groups will have any significant changes in bone mineral density (BMD) after ten weeks of resistance training.
5. Neither intervention group will have significant increases in lean body mass after ten weeks.
6. The HIT group will show no significant improvements in muscular strength at either five or ten weeks as measured by the chest press, seated row, lat pulldown, and leg press.

Delimitations

1. Participants were volunteers from the University of Arkansas campus.
2. Measurements of muscular strength and endurance were relegated to a modified YMCA bench press test and the handgrip dynamometer test. These tests are only estimates of muscular strength and endurance in older populations and do not test the muscular strength and endurance of any posterior upper-extremity musculature.

3. No muscular strength or endurance tests were used to measure changes in muscular fitness of the lower-extremities.
4. The participants of this study were self-reported to be post-menopausal. No definitive proof of the cessation of menses was required.

Operational Definitions

1. High-intensity resistance training: moving loads that are near the one-repetition maximum (1RM), typically ≥ 80% 1RM, with the goal of improving muscular strength.
2. Total bone mineral density (TBMD): BMD of the spine, hips, skull, femur, and forearm.
3. Functional fitness: having the physical capacity to perform activities of daily living in a safe and independent manner without undue fatigue (American College of Sports Medicine, 2010).
4. Dual-energy x-ray absorptiometry (DEXA): a low dose x-ray that is able to determine the component parts of bone mineral density, lean body mass, fat mass, and body fat percentage.
5. Electromyography (EMG): the ability measure muscle action potentials (MAPS) from a motor neuron at the motor end plate; from this, the amount of muscle activation is estimated.

Significance of the Study

The current evidence that does exist in regards to the SW® is controversial, relies on younger population groups for study, and evaluates the amount of MAPS elicited from the SW® and traditional dumbbells. This makes it difficult to determine if the SW® is an efficacious piece of equipment for older adults when resistance training to improve muscular strength and endurance and ultimately combat the detrimental effects of sarcopenia. One study in 2011 conducted by Pocari, found that the SW® was more effective than traditional dumbbell exercises when comparing the isometric muscle activity of the SW® to the dynamic muscle activation of dumbbell exercise. However, another study conducted by Glenn et al. (2012) did not find a significant difference in MAPS in young adults (ages 18-25), when using either the SW® or traditional dumbbells for the exercises prescribed by Fitness IQ, LLC (2012). The study by Glenn et al. provides evidence that there is no intrinsic property of the SW® that makes it more advantageous than shaking a dumbbell with the same exercises as the SW®.

A second component of the SW® that has yet to be evaluated is the effectiveness of the SW® exercises themselves in terms of improving muscular fitness. Previous research indicates that approximately 60% of MVIC, as recorded on a surface EMG, is required to elicit gains in muscle strength from an activity or exercise (Andersen et al., 2006; Ayotte et al., 2007). Only one muscle's activity in one exercise (the triceps during the triceps shake using the dumbbell) was greater than 60% in any of the EMG trials conducted by Glenn et al. These results indicated the exercises developed by the SW® manufacturer may not be sufficient to elicit gains in muscular strength with loads of only 5 and 2.5 lbs., the respective weights of the male and female SW®. The use of larger loads or intensities may elicit increases in muscle activation that are sufficient to produce gains in muscular strength over time.

In a meta-analysis conducted by Rice and Keogh (2009), it was noted that a wide variety of training intensities could be used to elicit a variety of muscular and neuromuscular changes in older populations. Training intensities ranging from 35-75% of 1-repetition maximum (1RM) had been used to improve power, velocity, and strength (Rice and Keogh, 2009). In terms of higher training intensities, Caserotti, Aagaard, Larsen, and Puggaard (2008) conducted a study in which they used old (60-65 years old) and very old (80-89 years old) community dwelling women in a high-intensity resistance training program (75-80% 1RM). Their results indicated that a HIT program could improve MVIC, rate of muscle force development, power during countermovement jump and unilateral leg extension task in these older women, especially the very old (Caserotti et al., 2008). Thus, it seems apparent that HIT programs can be effective at improving muscular fitness in older adults. The SW® may be considered HIT, it is unknown if a traditional HIT program utilizing isotonic weight machines would be more, less, or equally effective to the SW® in improving muscular fitness and altering MAPS in older adults.

CHAPTER II: REVIEW OF LITERATURE

Muscular Strength and Endurance

Muscle weakness, particularly due to sarcopenia, is a common problem among aging adults. Resistance training is thought to be a positive intervention to prevent or reverse the process of muscle weakness with aging. Latham, Bennett, Stretton, and Anderson (2004) reviewed the effects of progressive resistance training (PRT) on strength, functional limitations, and physical disability in older adults. Only studies that included participants with a minimum mean group age of 60 years and randomized controlled trialswere included in the review. In addition, the only training intervention that could have been used was PRT. Studies were obtained by searching relevant databases, utilizing study reference lists, and contacting researchers. Sixty-two trials were evaluated, with a total of 3674 participants. The data were combined using fixed or random effect models to create weighted mean differences (WMD) and 95% confidence intervals (CI). Overall, the majority of the studies reviewed were of poor quality. However, PRT did elicit moderate-to-large improvements on muscular strength (95% CI = 0.52-0.82). Functional measures such as gait speed showed modest improvement, while measurements of disability were not significantly different post-intervention. PRT appears to be an effective intervention for the loss in muscular strength with age and potentially a moderately effective treatment for reductions in functional decline. However, the effects of PRT on physical disability in aging adults were unclear and further research was needed.

In 2008, Caserotti, Aagaard, Larsen, and Puggard conducted a study in which they evaluated the effects of explosive low-frequency, but high-intensity, resistance training on muscular strength and power in two groups of older women. Participants for this study were 56 elderly women of different age groups. One of the groups was aged between 60-65 years (62.7 ±

2.2 years) and the other was between 80-89 years (81.8 ± 2.7 years). Participants were relatively inactive, participating in moderate physical activity no more than one day per week and they had no recent history of resistance training. Participants were randomly assigned to either a control group (control group age 60 [CG60] or control group age 80 [CG80]) or a training group (training group age 60 [TG60] or training group age 80 [TG80]). Lower limb power was determined via a leg power rig and a countermovement jump from a force place. For the power rig, maximal power for both the left and right leg was summed. Muscular strength was then assessed via MVIC on a custom built forceplate attached to a fixed leg press. Participants would push against the forceplate and maximal strength was determined to be the greatest force produced in the first 200 ms after beginning to push. Training consisted of 4 sets of 8-10 repetitions at 75-80% of an estimated 1-repetition maximum (1RM) for the knee extension, hamstring curls, calf raises, horizontal leg press, and inclined leg press. Estimated 1RM consisted of 4-8 maximal repetitions of the previously mentioned exercises. Participants trained 2 days per week with at least 2 days between training sessions. The control groups were asked to maintain their current levels of physical activity. Post-intervention the TG60 group had significant reductions in body mass (3%) and fat mass (4%), while there were no other significant anthropometric changes in any other group. MVIC improved significantly more in both training groups in comparison to their age-matched controls. In addition, jump height of the countermovement jump and the calculated power from those jumps were significantly improved in both training groups in relation to age-matched controls. Leg power as measured on the power rig was significantly greater in comparison to control in the TG80 group and trended towards, but did not quite reach, significance in the TG60 group. When comparing the two training groups, improvements in MVIC and power were similar in both groups; however, the TG80 group did have greater relative increases in MVIC and power, though these findings were not significant. In conclusion, the findings of this study demonstrated that high-intensity, explosive resistance training programs in elderly women can be effective methods for improving muscular strength and muscular power.

Peterson, Rhea, Sen, and Gordon (2010) note that recorded improvements in muscular strength in older adults are inconsistent because of differences in training methodologies and measurement techniques. Peterson et al. conducted a meta-analysis to determine the effects of resistance training on muscular strength in older adults. A total of 47 studies with 72 cohorts of both men and women were included in the analysis. Data were retrieved on 1079 participants. The age range for participants was 50-92 with a mean age of 67.4 ± 6.3 years. Mean training length was 17.6 ± 8.6 weeks, with a training frequency ranging from 1-3 days per week. The training intensity ranged from 40-85% of 1RM, with a mean training intensity of 70% ± 12.7% of 1RM. Participants performed an average of 2.5 ± 1.0 sets, 8.3 ± 2.1 resistance exercises, and 10 ± 2.6 repetitions. Strength improvements ranged from 9.8-31.6 kg depending on the lift. Improvements in strength for each lift was 29% ± 2% for the leg press, 24% ± 2% for the chest press, 33% ± 3% for the knee extension, and 25% ± 2% for the lat pull-down. The higher training intensities were significantly associated with an increase in muscular strength ($p < .001$). These results are in alignment with many of the studies reported previously and provide good evidence that resistance training, particularly at a high training intensity, can cause improvements in muscular strength in older adults.

According to Ciolac and Greve (2011), knee osteoarthritis (KO) and total knee arthroplasty (TKA) are common consequences of aging in older adults, particularly older women. KO and TKA often lead to declines in functionality and increases in disability. Ciolac and Greve evaluated the muscle strength response and exercise intensity progression to resistance training in older women with KO and TKA. Participants for this study were 7 older women suffering from TKA, 8 older women without symptomatic KO, and 8 young and healthy women. All participants were relatively healthy, inactive, and had not participated in a resistance training program for the previous 12 months. Strength improvements and progressions in resistance were measured by 1RM for the leg press, leg curl, and calf raise. All exercises were assessed unilaterally and results were normalized via body weight. The resistance training intervention was 13 weeks in length and twice per week. Exercise training consisted of 2 sets of 8-12 repetitions for the leg press, leg curl, and calf raises. All exercises were performed unilaterally. The initial resistance for each exercise was 60% 1RM for the weaker leg and resistance was progressed 0.5-10 kg when participants could complete 2 sets of 12 repetitions without strain or improper form. Age of the participants was not reported. TKA participants had lower leg strength for all exercises before the start of the intervention in comparison to both KO and young participants. Leg strength increased significantly for all exercises and all groups from baseline. However, when comparing groups, only the osteoarthritic leg of the TKA group showed a significantly greater relative improvement when compared to the dominant leg of the young group. In relation to exercise intensity progression, TKA participants showed a greater resistance training progression over the course of the study in comparison to the young healthy group in all exercises and the KO group showed a greater improvement for the leg press and calf raise. There were no significant differences between the KO and the young groups in relation to exercise intensity progression. The results of the study indicate that PRT is an effective method at improving muscular strength of the lower limbs in those with KO and TKA at rates equal to or greater than young healthy women.

Sparrow, Gottlieb, DeMolles, and Fielding (2011) note that sedentary behavior is a common problem among older adults. This sedentary behavior can exacerbate the progression of losses in muscular strength and balance, leading to a greater fall potential and a reduced capacity to complete activities of daily living (ADLs). Resistance training is thought to be a good intervention to reverse the detrimental effects of this sedentary behavior; however, resistance training is often expensive and time consuming for many older adults. Thus, Sparrow et al. (2011) evaluated the effects of home-based telecommunication resistance training on strength, balance, and depression in older adults. Participants were 103 older men and women that were assigned to one of two groups, a telecommunications resistance training group (*n* = 52) or a control group (*n* = 51). All participants were relatively healthy and had not participated in regular physical activity for greater than 1 day per week and 20 minutes per session. Participants were shown the proper technique and form for the 8 exercises to be used in the intervention. The telecommunication system consisted of a headset and cordless phone to provide instruction for the resistance training sessions in the home. Over the first 3 months of study, participants received visits at weeks 2, 4, and 8 and received phone calls at weeks 1, 6, and 10 to ensure participants were performing the exercises correctly. Participants trained 3 days per week for 6 months, performing 2 sets of 12 repetitions using dumbbells and ankle weights for knee extension, leg curl, step-up, heel raise, chest fly, upright row, front shoulder raise, and bicep curl. Resistance started at 2 lbs for each exercise and was progressed 2 additional pounds once participants were able to successfully complete 2 sets of 10 repetitions with good form and without strain. Rating of perceived exertion (RPE) using the Borg scale was used to determine exercise intensity. An exercise intensity of 15-16 was desired. After the initial 6 month intervention participants entered a maintenance phase in which they were encouraged to perform the training program at least one day per week. Data on strength, balance, functional status, and mood were collected after 3, 6, and 12 months of the intervention. Muscular strength was measured via a dynamometer for knee flexion and extension on a hydraulic resistance system. Single-leg stance time and tandem stance time, both with eyes open, were measured up to 60 seconds to determine balance. Three balance trials were measured and the mean scores were recorded. Six-minute walk was used to measure functional status. Finally, mood was assessed on the revised Beck Depression Inventory. Mean age for participants was 71.0 ± 7.4 years, with 69% of the participants being men. At the end of the 12 month intervention, there were significant differences between group in knee flexion strength ($p = .035$), single-leg stance time ($p = .029$), and the Beck Depression Inventory ($p = .030$). This study provides evidence that simple, home-based exercise programs guided by a telecommunication system, can be effective at improving lower limb strength, balance, and depression and reducing the declines in functional capacity and reducing the increased risk for falls.

Another 2011 study by Rabelo et al. evaluated the effects of 24 weeks of resistance training on knee extensor torque and fat-free mass in older women. A total of 154 older women between the ages of 60 and 86 volunteered to participate for this study. Participants had to be relatively healthy, absent of significant metabolic, cardiovascular, or musculoskeletal dysfunction to participate in the study. In addition, participants must have been sedentary the 6 months prior to the training intervention. Participants were then divided into one of two groups. The groups were a resistance training group ($n = 78$) or a control group ($n = 76$). Body weight, height, body mass index (BMI), and body composition were obtained for all the participants. Body composition was determined via a DEXA scan. From this scan, participants' appendicular fat free mass (FFM) was determined by summing the FFM for both arms and legs. Isokinetic peak torque for the dominant knee extensors was determined on a Biodex System 3 dynamometer. The protocol used to determine peak torque consisted of 3 sets of 4 knee extensions at a rate of 60º/s with 30 seconds of rest between each set. Peak knee extensor torque was deemed the highest torque value throughout the three trials and the torques were expressed in both absolute and relative values. For training, participants exercised 3 times per week for 24 weeks, with each session lasting approximately 60 minutes. Participants completed a 5 minute warm-up and cool-down before and after each resistance training session. The exercises performed were the chest press, lat pulldown, knee extension, hamstring curls, leg press, hip abduction, shoulder abduction, orthostatic toe raises, sit-ups, and trunk extension. One repetition maximum was completed for all exercises listed previously except for trunk extension, toe raises, shoulder abduction, and trunk flexion to determine exercise intensity and improvements in muscular fitness. This testing was completed in 4-week intervals during the intervention. For the first four weeks of training participants completed 3 sets of 12 repetitions at 60% of 1RM. During the second four weeks participants completed 3 sets of 10 repetitions at 70% of 1RM, and during the final 16 weeks participants completed 3 sets of 8 repetitions at 80% of 1RM. Compliance for the resistance training group was 86.6% and the resistance trained group showed improvements in peak knee torque of 15.6% from baseline, with no significant differences in knee torque for the control group. Both FFM and appendicular FFM significantly improved in the resistance trained group, while there was a significant decrease in appendicular FFM for the control group over the course of the study. Significant improvements were also observed for every exercise tested via the 1RM ($p < .01$). This study supports the hypothesis that progressive resistance training does improve muscular strength as measured via peak torque and it also improves FFM in older women. In addition, the sedentary lifestyle of the control group caused a progressive loss in muscle mass.

A final study by Romero-Arenas (2013) evaluated the effects of 12 weeks of high resistance circuit training in comparison to traditional heavy resistance training in 37 older men and women between the ages of 55-75. Participants were divided into a circuit training group (n=16), a regular high-intensity resistance training group (*n* = 14), or a control group (*n* = 7). The main outcome measures for this study were muscular strength, body composition, BMD, and cardiovascular fitness. It was hypothesized that the high resistance circuit training would elicit improvements in cardiovascular fitness as well as improvements in muscular strength and muscle mass. To test improvements in muscular strength, peak muscle torque for knee flexion and extension and elbow flexion and extension were measured on an isokinetic dynamometer. Participants performed 3 repetitions at 90º/s for each movement and 5 repetitions at 270º/s for each movement. Body composition (FFM and fat mass) and BMD were determined via a DEXA scan. The Naughton treadmill protocol was used to determine changes in aerobic power. Utilizing the information gathered from this test, peak VO_2, 14entilator threshold, and an estimation of energy expenditure were all determined. For the regular high-intensity group, participants exercised twice per week for 12 weeks on non-consecutive days. For each training session, participants of this group performed 2 sets of the fly, leg curl, seated calf raise, seated row, leg extensions, and preacher curl using the following protocol: 12 repetitions at 50% of 6RM, then 10 repetitions at 75% of 6RM, then finally 100% of 6RM. There was a 1-minute rest period between each set for each exercise and then a rest period of 3-minutes between each exercise. The training program for the circuit training group was identical to the training program for the regular high-intensity group except for the timing between sets and exercises. Participants would complete one full circuit of each exercise with ~35s between exercises. After completion of one rotation, participants would be given a 5 minute break and would then complete a second rotation. This pattern would be repeated a third time. Dietary and physical activity habits were recorded in journals by the participants to ensure adherence to the study.

The results of the study by Romero-Arenas (2013) showed that there were significant improvements in all measures at the end of the training program for both training groups, with no changes in the control group. Peak torque for all movements and both velocities were significantly greater for both groups in comparison to the control group, with no significant differences between the two training groups. There were significant changes in fat mass, lean body mass, body fat percentage, and BMD for the circuit training group from baseline, while the regular high-intensity group improved significantly in lean body mass and BMD. The decrease in body fat percentage was significantly greater for the circuit training group than both the high-intensity group and the control group. The circuit training group also had significant improvements from baseline in terms of walking economy; however, these improvements were not significantly different from the other 2 groups. Both high-intensity resistance training groups elicited significant improvements in BMD, lean body mass and muscular strength, while the circuit training group was the only one to improve components of cardiovascular fitness.

Bone Mineral Density

There is growing concern in the health community about the importance of preventative medicine in regards to BMD in aging women. BMD is an important marker of the strength of a bone. When severe enough, losses in BMD are often categorized as one of two ailments, osteopenia and osteoporosis. According to Looker et al. (1995) a person is categorized with having osteopenia between 1 and 2.5 standard deviations (SD) below the mean BMD for their age and gender, and a person is categorized with osteoporosis if their BMD is more than 2.5 SD below the mean. In 2010, Bemben, Palmer, Bemben, and Knehans reported that 10 million people over the age of 50 suffered from osteoporosis. This disease is particularly important in older women, of whom, 75% of all osteoporotic fractures were reported in 2005 (Bemben and Bemben, 2011). However, Stengel, Kemmler, Lauber, Kalender, and Engelke (2007) provide evidence that resistance training can have positive effects on BMD in postmenopausal women. For this reason, BMD in older adults will be measured in the present study and discussed in further detail.

In an earlier piece of literature, Kerr, Morton, Dick, and Prince (1996) evaluated resistance training in relation to BMD in postmenopausal women. At the time of their study, Kerr et al. (1996) noted that the literature was controversial in relation to exercise and its effects on BMD, possibly due to the focus on aerobic activities rather than resistance training. Kerr et al. (1996) evaluated the effects that 12 months of resistance training could have on BMD in postmenopausal women.

Kerr et al. (1996) recruited participants via media articles. Women were required to be between 1 and 15 years postmenopausal and between the ages of 40 and 75. In addition, participants could not have been exercising vigorously 3 hours/week, have been in any racquet sports, have participated in resistance training, or have any cardiovascular, metabolic, or orthopedic contraindications to exercise. BMD was measured at the femoral neck, greater trochanter, the intertrochanter, and the distal radius via a DEXA scan. After BMD testing, participants were randomized into one of two resistance training groups. The HIT group performed three sets of 8RM for each exercise session, while the low-intensity group performed three sets of 20RM. Participants in each group were encouraged to attempt more repetitions than

8 or 20 to promote continual strength gains. At the point when participants could perform three sets of 10 in the high-intensity group and three sets of 25 in the low-intensity group then the resistance was adjusted accordingly. Both groups performed the following exercises: biceps curl, wrist curl, reverse wrist curl, triceps extension, forearm pronation and supination, leg press, hip abduction, hip adduction, leg curl, hip flexion, and hip extension. Strength changes were measured via a 1RM for each lift. Finally, all participants served as their own control for this study, performing all of the listed exercises on only one side of the body. All exercise sessions were conducted three times per week on non-consecutive days.

Adherence to the study by Kerr et al. (1996) was 82% and the compliance for both the high- and low-intensity strength groups was 87%. There were no significant differences between the two groups except that the high-intensity group was significantly older ($p < 0.05$). BMD was significantly greater in the exercising limb of the high-intensity group in comparison to the non-exercising limb at the trochanter, intertrochanteric hip, and Ward’s triangle ($p < 0.05$). In contrast, no significant differences in the exercising and non-exercising limbs of the low intensity group were seen. When comparing the two training programs, the high intensity group had significantly higher increases in BMD of the radius, the intertrochanteric hip, and the Ward’s triangle ($p < 0.05$). Significant increases for strength were apparent for all 10 exercises; however, no significant differences between groups existed. Finally, the improvements in strength were positively correlated to the increases in BMD of the hip ($p < 0.05$). What can be taken away from this study is that higher intensity resistance training programs appear to more effective at improving the BMD in postmenopausal women than lower intensity resistance training programs in relation to the load being moved. Additionally, the loads appeared to be site specific in relation to the improvements in BMD.

Several studies have demonstrated that resistance training can both increase and prevent further declines in BMD in postmenopausal women (Maddalozzo and Snow, 2000). In 2000, Maddalozzo and Snow aimed to determine if high-intensity free weight based resistance training was more effective at sustaining or increasing bone mass and altering insulin-like growth factor 1 (IGF-1) in older men and women. Participants of their study were 28 men and 26 postmenopausal women that had no chronic metabolic or cardiovascular disease, no orthopedic problems, consumed no more than 2 alcoholic drinks per day, and had not regularly participated in an exercise program for at least 2 years. The mean age for men was 54.58 ± 3.20 years, and the mean age for women was 52.83 ± 3.26 years. Participants served as their own controls for the first 12 weeks of the study; after which, participants were evenly divided into a moderate-intensity resistance training group (n = 27) or a HIT group (n = 27). BMDand body composition were assessed at baseline, after the 12 week control period, and at week 36 after the 24 week resistance training program. BMD was assessed at the lumbar spine (L_2-L_4), proximal femoral neck, Ward's triangle, greater trochanter, and the entire body via DEXA. Body composition was also measured via a DEXA scan. Muscle strength, hormonal status, and anaerobic power were measured before the control period, after the 12 week control period, after week 24 (12 weeks into the resistance training program), and after week 36. Blood samples of 10-15 mL were taken after an 8 hour fast. Blood samples were then assayed for IGF-1 and IGFBP-3.

For each of the resistance training protocols, Maddalozzo and Snow (2000) determined each of the participants 1RM for all of the major muscle groups. The moderate intensity seated training program included the following exercises: leg extension, leg press, hamstring curls, arm curl, triceps press, chest press, chest fly, shoulder press, side lateral raise, lat pulldown, seated row, abdominal crunch, and calf raise. The moderate intensity group would perform three sets of 10-13 repetitions at 40% of 1RM for the first 3 weeks of the study and then 1RM was reassessed. Participants in this group then performed the same number of repetitions and sets at 50% of their new 1RM for 6 weeks, at which point 1RM was reassessed. For the final 15 weeks of the training program, those in the moderate-intensity group performed the same number of repetitions and sets at 60% of their newly defined 1RM. The high-intensity group performed the following exercises: free weight back squat, deadlift, biceps curls, sit-ups, triceps extensions, chest press, incline chest press, shoulder press, high lat pull down, leg curl, gripper (for wrist strength), and calf raise. Reassessment of 1RM and associated loads were taken and adjusted every 6 weeks. For the first 6 weeks of the training program, participants in the high-intensity group performed three sets of 10 repetitions at 70% of their 1RM, for the next 4 weeks they performed three sets of 6 repetitions at 80% of their 1RM, and for the final two weeks of the training program they performed three sets of 2-4 repetitions at 90+% of their 1RM. Participants were then given a 1-week rest period to recover from the high-intensity training and then they repeated the same 12 week high-intensity program.

For the results of their study, Maddalozzo and Snow (2000) had an attrition rate of 22%, which meant that a total of 42 participants (24 men and 18 women) remained in the study for final testing. There were no significant differences between men or women in terms of compliance and there were also no significant between the high-intensity and moderate-intensity resistance training groups at 92% and 94%, respectively. In terms of BMD, men in the high-intensity resistance training significantly improved lumbar BMD ($p < 0.01$). Significant improvements in the BMD of the greater trochanter in both male training groups were elicited ($p < 0.03$). In addition, significant ($p < 0.03$) differences were seen between the two male resistance training groups in relation to total body BMD, while no significant changes were apparent at the femoral neck or total hip BMD. No significant differences in BMD were apparent in either female training group at any site. Changes in either IGF-1 or the IGFBP3 to IGF-1 ratio were not significantly different between either group or gender. Finally, no significant changes in lean body mass were observed after the first 12 weeks; however, there were significant improvements in lean body mass for both training groups and genders after the 24 week resistance training period ($p < 0.05$). This study demonstrated that resistance training (in particular high-intensity regimens) can be effective methods to improve BMD in older men, but may have limited effects on improving the BMD in older women.

In 2006, Chubak et al. evaluated effects of physical activity on the bone mineral density of 173 overweight or obese postmenopausal women in a randomized controlled trial. Women were randomized to a physical activity group or stretching group. The women were ages 50-75 years old, sedentary (exercised < 60 minutes per week), were overweight (BMI 25.0 < 30.0 kg/m^2, or percent body fat > 33%) or obese (BMI > 30.0 kg/m^2), lived in the Seattle, WA area, and were deemed to be postmenopausal (at least 12 months without a menstrual period). Exclusion criteria included: major hormone replacement therapy, too physically inactive, medical contraindications to moderate-to-vigorous exercise, having a clinical diagnosis of diabetes, or currently using tobacco.

The exercise prescriptions consisted of at least 45 minutes of moderate-intensity exercise, 5 days per week for at least 12 months. Three of the sessions were performed within the facility and the other two sessions were performed at home. The initial exercise program consisted of walking or stationary cycling for 16 minutes at 40% maximal heart rate, and eventually progressing to 60-75% of maximal heart rate for 45 minutes by the eighth week. Resistance training consisted of two sets of 10 repetitions for the leg extension, leg curls, leg press, chest press, and seated dumbbell row were recommended, but not formally monitored. Participants' adherence was self-monitored via a log that categorized any aerobic activity that was at least three metabolic equivalents (METs).VO_{2max} was assessed at baseline and at the end of the 12 month intervention period using a graded exercise treadmill test. BMD, diet, body fat, and lean mass were assessed at baseline, after 3 months, and at the end of the intervention period via a DEXA scan.

No significant differences between the exercise and stretching group in terms of age, BMI, and total BMD. There was also no significant difference between groups in the consumption of vitamin D, calcium, caffeine, and alcohol. Post-intervention, total body BMD, bone mineral content, and lean body mass were not significantly different in the exercise group in comparison to stretchers. BMD in the exercise group improved from 1.035 g/cm^2 to 1.040 g/cm^2 post-intervention, and BMD in the stretching group improved from 1.039 g/cm^2 to 1.042 g/cm^2. These increases in BMD were not significant. There were also no significant differences in BMD when controlling for BMI, body fat, weight, or hormone concentration. Overall, this study demonstrated that 1 year of moderate-intensity aerobic training was not an effective method to improve BMD in overweight/obese, postmenopausal women without known osteoporosis or osteopenia.

More recently, Winters-Stone, Leo, and Schwartz (2011) conducted a study that aimed to determine the exercise effects on BMD in postmenopausal breast cancer survivors. The study was a randomized controlled trial that compared a group performing moderate-intensity impact exercise and resistance training (POWIR) to a group that performed an exercise placebo (FLEX). Participants were postmenopausal women (without menstruation for > 12 months) and had been diagnosed with stage 0-3a breast cancer at ≥ 50 years old. Participants must have been ≥ 1 year removed from chemo- or radiation therapy, non-osteoporotic, have physician's clearance, and have not participated in a resistance or impact training program on a regular basis. A total of 106 women (52 in the POWIR group and 54 in the FLEX group) participated in this study. Both groups were given an exercise program that included two guided exercises classes and one home based exercise program each week, with each exercise session lasting 45-60 minutes. Participants were asked to log exercise time and activity for each exercise class and home exercise sessions. Resistance training for the POWIR group utilized dumbbells, weighted vests, and a standard barbell and consisted of 1-3 sets of 8-12 repetitions at 60-70% 1RM for the following lifts: wall-sits, 90° squats, bent-knee dead lifts, forward lunges, lateral lunges, 1-arm row, chest press, lateral raise, and push-ups. Impact exercise involved jumping with a weighted vest onto a 1" high box. Participants in the FLEX group performed whole body stretching and relaxation exercises from a seated or lying position. DEXA scans were utilized to determine BMD of the total hip, greater trochanter, femoral neck, and anterior-posterior lumber spine (L_1-L_4), as well as bone-free lean mass and fat free mass. Assessment of BMD was conducted at baseline, half-way through the intervention, and at the end of the intervention. Bone turnover rates were also assessed. Bone formation was assessed via blood samples through osteocalcin and bone degradation was assessed via urine samples through deoxypyrodinoline cross-links.

Post-statistical analysis, three age tertiles emerged: youngest-old (53-58 years old), middle-old (59-64 years old), and oldest-old (65-83 years old). For exercise program attendance, 57% of the POWIR group participants averaged only1 class per week, 76% of participants attended 2 classes per week, and 23% adhered to the at home exercise, respectively. The FLEX group averaged 62, 72, and 44% attendance for their exercise programs. The oldest-old group of the FLEX group had significantly greater attendance than the attendance of the oldest-old in the

POWIR group ($p < 0.01$). BMD in the spine of the POWIR group was preserved over the training period, while the FLEX group showed a 2% reduction in BMD of the spine. This difference was significant ($p < 0.01$). However, there were no significant differences in BMD of any hip site, and there were also no significant differences between groups in terms of lean body mass and fat mass. Osteocalcin increased in the FLEX group, but changed little in the POWIR group, with this difference being significant ($p = 0.03$). Deoxypyrodinoline cross-link decreased more in the POWIR group than in the FLEX group; however, these changes were not significant. Overall, this study demonstrated that a structured resistance exercise training program can maintain lumbar spine BMD, which could potentially lead to a decrease in spinal fracture in breast cancer survivors. In contrast, the POWIR training program implemented in this study did not seem to be effective in altering the BMD of the hip, a common site of fracture in osteoporotic or osteopenic women.

After the findings of their previously mentioned study, Winters-Stone, Leo, and Schwartz (2012) reanalyzed the data to determine if age was a factor in altering hip BMD after either the POWIR or FLEX exercise programs. Post-statistical analysis, three age tertiles emerged: youngest-old (53-58 years old; n = 37), middle-old (59-64 years old; n = 35), and oldest-old (65-83 years old; n = 34). Results showed no significant differences between groups in relation to cancer stage diagnosis or treatment. BMD at the femoral neck was significantly greater in the youngest-old tertile in comparison to the oldest-old tertile ($p < 0.03$). BMD for the total hip and at the greater trochanter were not significantly different between the three age tertiles. In addition, no significant differences were found between the tertiles in relation to physical activity, energy intake, calcium consumption, or exercise class attendance.In regards to the exercise interventions, the resistance/impact training elicited significant improvements in total hip BMD in the youngest-old and middle-old (*p* = 0.02); however, this training program because less effective at stopping bone loss as age increased. There was a trend for significance in the youngest-old to have improved BMD over the older tertiles in the femoral neck (*p* = 0.07) No significant changes occurred in BMD as a result of the FLEX training program in any age tertile.

Bocalini, Serra, and dos Santos (2009) also evaluated the effects that resistance training can have on BMD, body composition, and muscular strength. For the design of their study, Bocalini, Serra, and dos Santos (2009) recruited 35 older women (ages 57-75) from São Paulo, Brazil. Participants were excluded from the study if they had any chronic cardiovascular, renal, or hepatic issues, metabolic disorders, cognitive impairment, any orthopedic problem that would impede resistance training, or the use of any medication that alters calcium or bone metabolism. Participants were then divided into a strength training group (TR; n = 23) or an untrained group (UN; n =12). Muscular strength was then evaluated at baseline and at the end of the 24 week strength training program in all participants via a 1RM for the chest press and the leg extension. The 1RM received at baseline was also used to determine exercise intensity of the TR group. A DEXA scan of the lumbar spine (L_1-L_4) and femoral neckdetermined BMD.The DEXA was also used to determine body composition. Those in the TR group resistance trained three times per week on non-consecutive days for approximately 1 hour per session over the period of 24 weeks. Participants would begin each training session by warming up at 50% of their heart rate maximum for 10 minutes. At the beginning of the training period participants began with only 1 set of 10 repetitions at 50% of their 1RM. This intensity gradually progressed over the training period to 3 sets of 10 repetitions at 85% of their 1RM.

At the end of the training period, 2 women in the UN group dropped out of the study, and 5 women the TR group did not attend at least 90% of the training sessions and therefore were excluded from analysis. This left a total of 10 women in the UN group and 15 in the TR group for analysis. No significant differences were identified between the groups prior to the training period. After the 24 weeks of resistance training, the TR group had significant reductions in body mass index (BMI) and body fat percentage in comparison to the UN group ($p < 0.05$). In relation to muscular strength, the TR group had a 39% improvement in lower body strength and a 46% improvement in upper body strength; these increases in strength were significant in comparison to baseline measures ($p < 0.001$). The UN group showed no changes in strength for the upper or lower limbs. BMD was significantly reduced over the 24 week training period for the UN group at both the lumbar spine and femoral neck ($p < 0.05$); however, there were no significant changes in BMD in the TR group post intervention. Overall, the results of the study demonstrate that 24 weeks of resistance training is able to prevent demineralization of bone in postmenopausal women and sustain BMD. In addition, the resistance training program in this study was sufficient to elicit positive changes in body composition and body weight.

A total of 55 women between the ages of 55 and 75 were recruited for a study by Bemben, Palmer, Bemben, and Knehans (2010). Participants were included in the study if they were at least 5 years postmenopausal, were not taking hormone replacement therapy (HRT) and had not been taking HRT for at least 1 year, had not participated in a resistance training program within the previous year, and had no cardiovascular, metabolic, or orthopedic restrictions to resistance training. Women were excluded from the study if they had been diagnosed as osteoporotic (> -2.5 SD from the mean BMD score) or were current smokers or had smoked in the previous 15 years. Participants were then randomly assigned to a resistance training only group (R; n = 22), a resistance training plus whole body vibration (WBV; n = 21) group, or a control group (n = 12) to participate in an 8 month training program. To assess muscular strength, a 1RM test was performed for the leg press, hip flexion/extension (right leg only), hip abduction/adduction (right leg only), overhead press, lat pulldown, and seated row. Both the R and WBV groups performed three sets of 10 repetitions at 80% of their 1RM for the each of the exercises that were tested for a 1RM. It should be noted that the hip extension/flexion and hip abduction/adduction were conducted on both legs for training. Dumbbell wrist curls and abdominal crunches were performed at a light to moderate intensity at a self-selected weight. WBV was high frequency vibration (30-40 Hz) that lasted 15-60s in three different positions between resistance exercises with at least 15s of rest between vibration periods. WBV training began as 1 set of 15s vibration periods at 30 Hz and progressed to 2 sets of 60s at 40 Hz. DEXA scans were used to determine BMD of the lumbar spine (L_1-L_4), the femur (femoral neck, greater trochanter, and total hip), and of the forearm (33% radius). Strength and BMD testing were conducted at baseline and at the end of the 8 month training program.

At baseline there were no significant differences between the two groups in relation to BMD. This trend continued after the 8 month training period. No significant differences existed between groups for BMD for the total body, lumbar spine, right trochanter, and left hip. However, BMD for the right total hip and right femoral neck both decreased significantly from baseline ($p< 0.05$) for both groups. Though not significant, over time the BMD of the radius increased in the control group and decreased in the WBV group. In relation to changes in strength, both the R and WBV groups showed significant increases in 1RM for all exercises from baseline ($p< 0.01$). The control group showed no significant changes in 1RM for any exercise. In general WBV in combination with resistance training was more effective at improving strength than resistance training alone. However, these changes were not significant over the 8 month training period. Overall, neither WBV and resistance training orresistance training by itself was not a significant stimulus to promote osteogenesis. In fact, the right hip actually showed significant decreases in BMD, while the left hip, lumbar, and radius showed little or no change in BMD.

Functional Fitness

One of the many components to successful aging in life is the ability to maintain functional fitness, or having the physical capacity to perform activities of daily living in a safe and independent manner without undue fatigue (American College of Sports Medicine, 2010). However, aging is frequently associated with declines in functional fitness and the ability of older adults to complete normal daily activities. In addition, the reduction in functional fitness reduces individual quality of life (QOL) and enhances the risk for falls. Rice and Keogh (2009) proposed a mechanism for the relationship between the loss in functional fitness and the increased incidence of falls and reduced QOL. The gradual decline in functional fitness with aging leads to a reduction in physical activity, the drop in physical activity leads to earlier onset of fatigue and sarcopenia (and associated loss of muscular strength and power).The reduction in physical activity and sarcopenia lead to reduced balance, all of which combine to increase the risk for falls and reduce QOL. Santos et al. (2012) states that sedentary behavior commonly associated with aging can enhance the declines in functional fitness, while regular participation in physical activity can act to buffer the effects of aging and help to maintain levels of functional fitness at an older age. For this reason, the following review will focus on resistance trainings' effects on the functional fitness of older adults.

In 2009, Rice and Keogh analyzed 12 studies in a meta-analysis that aimed to determine the effects of power training on the functional fitness of older adults. Nine of the studies analyzed by Rice and Keogh also included strength training only groups and were included in the analysis for comparison. To find the studies to be used for analysis, Rice and Keogh searched PubMed, CINAHL, Sports Discus, Proquest 5000 International, and Google Scholar using the keywords “power training”, “older adult”, and “elder”. Derivatives of these three words/phrases were also included. Inclusion criteria for studies were: 1) a high-velocity power training group that trained for at least eight weeks, 2) involved healthy older adults over the age of 60, 3) had been published in peer reviewed journals, and 4) analyzed either gait or sit-to-stand activities. The overall results of the studies included in the analysis demonstrated that regardless of using strength or power training regimens, strength improved in the subject populations, 13-51% for power and 14-57% for strength, respectively. However, in terms of power, the power groups had much greater improvements (8-150%) than the strength training groups (4-45%). Finally, in relation to the measurements of functional fitness in the prospective studies, power training improved functional fitness in 10 of the 12 studies analyzed by 10-66%, while the strength training groups improved functional fitness in 4 of the 9 studies analyzed and only improved functional fitness 9-29%. Based on these results, it appears as though that power training may be the better option at improving functional fitnessin older adults than strength training programs.

Weight gain is commonly seen in individuals as they age, and this added weight can enhance and exacerbate the decline in functional fitness in older adults. Villareal et al. (2011) evaluated the effects that weight loss and exercise (combined and independently) can have on functional fitness in older adults. Participants were recruited via advertisements and were included in the study if they were relatively healthy (limited cardiovascular, metabolic, and musculoskeletal dysfunction), were 65 years of age or older, obese (as determined via BMI), had no changes in medication in the previous 6 months, were sedentary, and were mildly-moderately frail based on operational criteria. The operational criteria for frailty included: a low score on the

Physical Performance Test (PPT; below 18), a VO_{2peak} of 11-18 ml/kg/min, a difficulty of performing 2 or more instrumental activities of daily living (IADLS), or one ADL. All participants were tested on the PPT and their VO_{2peak} was determined on a graded exercise treadmill test. For the intervention, participants were randomly divided into one of four groups, a control group, a diet only (weight loss) group, an exercise only group, or a diet and exercise group. The intervention was 52-weeks in length. The control group received no dietary or exercise counseling and were asked to not participate in any weight loss programs for one year. The diet only group received dietary instruction and a dietary plan that created a 500-750 kcal deficit each day. Participants in the exercise only group exercised 3-days per week for approximately 90 minutes each session. All exercise bouts consisted of a combination of aerobic training (walking, stationary cycling, or stair climbing) at 65% of VO_{2peak}, gradually progressing to 70-85% of VO_{2peak}. Exercise sessions also included resistance training (1-2 sets of 8-12 repetitions) for the major muscle groups of the upper and lower body; in addition, balance and flexibility exercises were also included. Participants in the diet and exercise group followed both of the combined programs outlined above for the diet only and exercise only groups. Body composition and BMD of the lumbar spine and total hip were also assessed via a DEXA scan. Finally, balance and gait were assessed via the time taken to complete an obstacle course and the amount of time participants could stand on one leg.

A total of 93 of the original 107 participants completed the study, with no significant differences between groups prior to the intervention. Mean increases in PPT scores were significantly greater in the diet-exercise group than either the diet only or exercise only groups. VO_{2peak} improvements were also significantly greater in the diet-exercise group when compared to either the diet only or exercise only groups ($p < 0.001$). In relation to body weight and body composition, the diet only group showed the greatest decrease in body weight based on a 10% reduction, but this was not significantly greater than the diet-exercise group which showed decreases in body weight of 9%. No significant changes in weight were observed in either the exercise only or the control group. The diet-exercise group demonstrated smaller decreases in lean body mass (3%) than the diet only group (5%); both groups significantly improved from baseline ($p < 0.05$). Lean body mass in the exercise only group increased an average of 2% from baseline. Declines in fat mass were significantly greater in the diet-exercise group (16%) and the diet-only group (17%) than either the exercise (5%) or the control group ($p < 0.05$). BMD increased in the exercise only group in the total hip by 1.5% while it decreased by 1.1% in the diet-exercise group and by 2.6% in the diet only group ($p <0.05$). Time taken to complete the obstacle course improved by 12% in the diet-exercise group, 10% in the diet only group, and 13% in the exercise only group. All of these reductions were significant improvements from baseline and in comparison to the control group ($p < 0.05$). Gait speed increased by 23% in the diet-exercise group and by 13% in the exercise only group, both were significant improvements from baseline ($p < 0.05$). The results of this study appear to indicate that a combination of both proper diet to promote weight loss and exercise can enhance functional fitness and quality of life in obese older adults. However, it should be noted that interventions only altering diet or exercise were also effective at improving functional fitness and quality of life in older obese individuals. However, these improvements were to a lesser extent than the combined intervention.

As noted earlier, Santos et al. (2012) state the potential detrimental effects that sedentary lifestyles and physical activity can have on the functional fitness of older adults. To evaluate these correlations further, Santos et al. recruited 312 Portuguese men and women (117 males and 195 females) to participate in a research study. Participants were 65 or older and were included if they were deemed to be independent based on a 12-item Composite Physical Functioning Scale (CPFS). Height and weight were collected for anthropometry, and then physical activity (PA) levels were assessed. PA was assessed via accelerometry. Participants were given proper instruction on how to use the accelerometers and were asked to wear them near the iliac crest of the right hip. The accelerometer would take PA readings every 15 seconds and a day would be counted if the person had achieved 10 hours or more of monitor wear throughout the day. Participants were asked to wear the accelerometers a total of 4 days per week, including two week days and two weekend days. Accelerometer counts were categorized for PA levels based on the following readings: sedentary activity < 100 counts, light activity = 100-2019 counts, moderate activity = 2020-5998 counts, and vigorous activity = ≥ 5999 counts. The Senior Fitness Test was then used to evaluate functional fitness. The subset of tests within the Senior Fitness Test included: 30 second chair stand, arm curl, chair sit-and reach, back scratch, 8-foot-up-and-go, and the 6-minute walk test.

Significant differences existed between the two genders in regards to moderate-to-vigorous physical activity (MVPA), arm curl fitness, aerobic fitness as measured by the 6-minute walk test, and lower body flexibility. Even when adjusting for MVPA, gender, age, and accelerometer register time, sedentary behavior was negatively associated with functional fitness scoring. Conversely, MVPA was positively associated with Senior Fitness Test scoring independent of sedentary time, gender, age, and accelerometer register time. Overall, those participants that spent more time in performing MVPA in comparison to those with more sedentary time or even light PA had increased levels of functional fitness.

Electromyography

In 1998, Häkkinen, Kallinen et al. evaluated the effects of heavy strength and power training in middle-aged and older adults on measures of strength. In addition, if there were changes in strength with a training intervention, could these changes be explained all or in part by changes in the neuromuscular system or changes in muscle cross sectional area (CSA). Participants were 42 middle-aged and older men and women. Four groups were designated based upon age, a middle-aged male group (M40, *n* =10), an older male group (M70, *n* = 11), a middle-aged female group (W40, *n* = 11), and an older female group (W70, *n* = 10). Participants were healthy and all physically active prior to the study; however, none of the participants had followed any formal resistance training programs. Maximal force production and rate of force development for the hip, knee, and ankle extensors were determined on an electromechanical dynamometer. Each participants completed several warm-up repetitions before the 3 testing repetitions were counted. The greatest force production and rate of force production were utilized in analysis. A vertical squat jump from a force plate and a starting position of 90º of knee flexion was utilized to determine dynamic explosive force characteristics. The maximum height recorded was used for analysis and participants performed 3 trials with 1.5 minutes between trials. EMG was utilized to determine motor unit activation during the vertical squat jump for the vastus lateralis, vastus medialis, and biceps femoris of both right and left legs. The EMG was sampled at a rate of 1,000 Hz and was normalized for 1 second. The highest EMG value recorded was taken for further analysis. Rectus femoris and vastus intermedialis CSA were determined via a compound ultrasound on the right leg for all participants. Changes in body composition (body fat percentage) were determined via skinfolds. The training intervention consisted of a 6-month resistance training program in which the participants exercised twice per week performing the following exercises: chest press, lat pulldown, bilateral leg press, bilateral or unilateral leg extension, leg curl, sit-ups, trunk extension, and bilateral elbow flexion. 1RM was assessed every two months to determine changes in strength and progress the load of the intervention. Participants completed 3-4 sets of 10-15 repetitions at 50-70% of 1RM for the first 4 months of the training program. Resistance was then progressed during months 5-6 so that participants trained at 50-70% of month three 1RM for the third month and 70-80% of month four 1RM during the fourth month. The number of repetitions was lowered by 2-4 based up the percentage of 1RM the participants chose to exercise at during this period. Participants were asked to complete some of their leg press exercises at a load of 50-60% of 1RM and to perform the movement in an explosive manner to train for power.

No statistically significant changes were observed in either body mass or body fat percentage for any group. However, muscle CSA increased 4.9 ± 2.5% in the M40 group, 9.7 ± 2.5% in the W40 group, and 5.8 ± 2.0% for the W70 group. There were no significant changes in muscle CSA for the M70 group. All groups showed significant improvements (M40 = 36 ± 4%, M70 = 36 ± 3%, W40 = 66 ± 9%, and W70 = 57 ± 10%) in maximal force production. The change in female force production was significantly greater than either male group. In addition, rate of force production increased 41 ± 14% in M40, 40 ± 10% in M70, 31 ± 18% in W40, and 28 ± 10% in W70. EMG values of the vastus lateralis and vastus medialis improved for all groups after the training intervention (p <.05). Leg extension 1RM improved significantly for all groups, M40 = 22 ± 2%, M70 = 21 ± 3%, W40 = 34 ± 4%, and W70 = 30 ± 3%. Vertical squat jump height increased 11 ± 8% in the M40 group, 24 ± 8% in the M70 group, 14 ± 4% in the W40 group, and 18 ± 6% in the W70 group. This study illustrates the improvements in strength, muscle activation, and muscle CSA that can be obtained from a resistance training program with a power component. In addition, it appears that neuromuscular adaptations are a significant portion of the improvement in muscular strength and power based upon the changes in EMG activation.

In another study utilizing the same training protocol and participants, Häkkinen, Kraemer, Newton, and Alen (2000) evaluated the effects of a resistance training on the motor unit activation of the agonist and antagonist muscle groups, muscle fiber proportion and CSA, 1RM strength, and maximal and explosive isometric strength of the knee extensors. Isometric force-time curves and peak torque of the right knee extensors was determined using the David 200 dynamometer. Three trials were performed, with the maximum value being recorded for further analysis. Participants were encouraged to reach their peak force production within a period of 2.5-4 seconds. Maximal concentric knee force was determined on a David dynamometer by increasing the resistance by 2.5-5 kg. until the participant was unable to sufficiently complete one repetition. During the maximal concentric knee force test, surface EMG for the agonist vastus lateralis and vastus medialis, and antagonist biceps femoris were obtained at a sampling rate of 1000 Hz and time normalized to 1 second. As mentioned previously, the training protocol utilized was a 6-month heavy resistance training intervention (Häkkinen, Kallinen, et al., 1998). Muscle biopsies of the right vastus lateralis muscle were obtained pre- and post-training utilizing the Bergström technique. Participant characteristics and 1RM strength improvements were identical to those reported in a previous study (Häkkinen, Kallinen, et al., 1998). Maximal isometric torque values improved 28 ± 14% in the M40 group, 27 ±17% in the M70 group, 27 ± 19% in the W40 group, and 26 ± 14% in the W70 group. IEMG values were increased in the knee extensors for all groups during the isometric knee extension exercise (*p*-values between 0.01 and 0.05), but only decreased for the biceps femoris in the W70 group. Explosive strength improved in M40 by 21 ±41%,in M70 by 21 ± 24%, in W40 by 32 ± 45% and in W70 by 22 ± 28%. There were no significant changes in any intervention group in relation to fiber type distribution after training. However, significant increases occurred during the training period in the mean fiber areas of type I fibers in W70and of type II fibers along with a specific increase in Iia in both W40 and in W70, while the changes in the male groups were not statistically significant. Again, this study supports the idea that significant changes in neural responses to resistance training in older adults can be obtained, in addition to changes in muscular strength and muscle fiber CSA, particularly in women.

In 2001 Häkkinen, Pakarinen et al. completed a study in which they evaluated the effects of 21 weeks of resistance training on muscle CSA for the component parts of the quadriceps muscle group, as well as determine both acute and chronic changes to serum hormone and growth factor levels. Participants were 10 healthy older women with a mean age of 64 ± 3 years. EMG, 1RM, muscle biopsies, maximum isometric force development, and rate of force development for the knee extensors and biceps femoris were identical to the protocols previously described (Häkkinen, Kallinen, et al., 1998; Häkkinen, Kraemer, et al., 2000). Muscle CSA for the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedialis were determined with an MRI between the lengths of 3/12-12/15 along the femur. Serum concentrations of testosterone, cortisol, growth hormone (GH), and IGF-1 were obtained at the following time points: at a resting state, immediately prior to an exercise bout, immediately after an exercise bout, and at the end of the intervention. The training intervention consisted of resistance training twice per week on non-consecutive days for the leg press, leg extension, leg curl, chest press, lat pulldown, sit-ups, trunk extension, and elbow flexion. For the first 7 weeks of training, participants completed 3-4 sets of 10-20 repetitions at 40-70% of 1RM. The number of repetitions completed was based upon the intensity that the participant chose. During the middle 7 weeks participants completed 8-12 repetitions at 60-80% of 1RM, and during the final 7 weeks of the training session participants trained at 70-80% of 1RM , completing 4-5 sets of 5-12 repetitions. Participants would alternate between heavy resistance training at high-intensities and explosive resistance training at lower intensities. This model was designed to improve muscular strength as well as power. At the end of the intervention, maximal isometric force development had increased by 37%, while 1RM strength improved by 29%. Significant improvements in the EMG signal were observed for both the vastus lateralis and the vastus medialis during the isometric force development test. Muscle CSA increased throughout the length of the femur by 5-9%, with the increases in the vastus lateralis being between 7/15-12/15, at 3/15-8/15 for the vastus medialis, at 5/15-9/15 for the vastus intermedialis, and at 9/15 for the rectus femoris. Fiber CSA of type I, type Iia, and type Iib fibers increased by 22-36%, respectively. There were no basal level changes in any hormones, however GH levels remained elevated for 30 minutes after exercise at the end of the intervention. Levels of testosterone were positively correlated to the amount of change in muscle CSA. These findings again support the hypothesis that resistance training is able to positively affect muscular strength, muscle fiber size, and muscle fiber activation. However, it appears that hormones such as testosterone may be a limiting factor in the ability to increase muscle size.

In a more recent study, Wallerstein et al. (2012) evaluated the effects of either strength training or power training on neuromuscular adaptations in older adults. Participants were 59 healthy older adults that had only previously participated in light aerobic activities ≤ 2 days per week. Prior to training, participants were tested for leg press 1RM and quadriceps CSA and then divided into quartiles. Each quartile was randomly assigned to a strength training intervention, a power training intervention, or the control group. Participants that were not in the same quartile for both leg press 1RM and muscle CSA were evenly divided between the three groups. The chest press and leg press were both measured for 1RM to determine changes in muscular strength. Participants were then tested for two different types of isometric strength on an isokinetic dynamometer. The first form of isometric strength was ramp strength, in which the participant was instructed to gradually increase isometric strength over an initial two second period and then asked to hold the contraction for an additional two seconds. The second type of isometric contraction was a ballistic type contraction in which the participant was asked to generate maximal isometric force as quickly as possible and hold this contraction for two seconds. For the EMG, participants' skin was shaved, abraded, and cleaned to reduce impedance. Electrodes were placed over the vastus lateralis and vastus medialis, with the root mean square of the EMG being calculated over peak torque. Knee extensor torque and EMG data were synchronized at a sampling rate of 1,000 Hz. Electrical mechanical delay was determined via the EMG during the ballistic isometric contraction, taking the difference in time between the EMG and torque onset. Rate of torque development was determined again during the ballistic isometric contraction and was from the torque onset to 100ms.Quadriceps CSA was determined via a MRI and was determined by subtracting bone and subcutaneous fat mass from the scan. Both intervention groups exercised twice per week for 16 weeks and performed the following exercises: horizontal leg press, bilateral knee flexion, unilateral hip extension, plantar flexion in the horizontal leg press, lat pulldown, and upright row. Chest and leg press 1RM were reassessed every 4 weeks to correctly adjust training intensities. In order to accurately adjust the remaining intensities, participants were asked to work at the same rating of perceived exertion as during the chest and leg press exercises. The HIT group exercised at 70-90% of 1RM and the power group exercised at 30-50% of 1RM. No mention of sets, repetitions, or speed of movement was made.

At the end of the end of the training period, both the HIT group and the power training groups significantly improved in the leg press (42.7% and 33.8%) and the chest press (31.0% and 25.4%), respectively. Peak torque in the ramp isometric contraction significantly improved 22.3% in the HIT group and 17.1% in the power group, with no significant differences between groups. There was a main time effect for both the ballistic isometric contraction and the rate of torque development for each intervention group. A main time effect was also observed for the vastus lateralis muscle in each group for both the ballistic and ramp isometric contractions, as measured on an EMG. There were no significant changes in vastus medialis activation. Electrical mechanical delay did not change in the vastus medialis muscle post-training; however, there was a significant decrease in electrical mechanical delay for the vastus lateralis. Finally, there was only an increase in quadriceps CSA for both training groups in the left leg. Based on the results of this study, it appears that both HIT programs and power training programs are effective in improving components of muscular fitness. Both groups showed improvements in muscular strength, likely due to a combination of neuromuscular adaptations and muscle CSA.

Previous research involving the SW® is very limited; however, Glenn, Cook, DiBrezzo, Gray, and Vincenzo (2012) utilized the SW® in a study involving EMG. The participants for their study included 25 healthy male and female college-aged students. Glenn et al. (2012) evaluated the amount of EMG activity for the pectoralis major (PM), biceps brachii (BB), triceps brachii (TB), anterior deltoid (AD), rectus abdominus (RA), and middle trapezius (TR) during the chest (CS), bicep (BS), and triceps shakes (TS) using both the SW® and a dumbbell of equal mass. The EMG protocol used was identical to the protocol in this study, except for the mass of the SW®

and dumbbell used in the testing for this study. The results of Glenn et al. showed that the BB activity during the CS was significantly greater while utilizing the dumbbell than while using the SW®. This was the only significant difference in muscle activity between the two shaking exercises. The results of this study indicate that no inherent property of the SW® can cause an increase in muscle activation over shaking a traditional dumbbell.

CHAPTER III: METHODOLOGY

Participants

Participants were 17 postmenopausal women that were recruited from the University of Arkansas campus (Fayetteville, AR). Prior to testing, informed consent was obtained and the study was approved via the university institutional review board. Participants were screened prior to participation and were excluded from the study if they had any orthopedic, metabolic, pulmonary, or cardiovascular contraindications to exercise. After evaluation, participants were numbered, and then randomly divided into two groups via a number generator. The first group being the SW® group (N = 9), and the second being the HIT group (N = 8).

Instrumentation

EMG signals were collected using HeartTrace Electrodes (Cardiology Shop, Berlin, MA) and data were processed with the Trigno Wireless EMG System from Delsys (Natick, MA 01760). The 2.5lb female SW® (Fitness IQ, LLC, Neenah, WI) was used for both training and EMG testing of the participants. A DEXA scan determined changes in fat mass, fat-free mass, body fat percentage, and BMD. Height and weight were measured on a calibrated scale that contained a separate attachment for height measurement. Measurements of handgrip strength wereconducted on a handgrip dynamometer, and estimated 1RM testing and training took place on Hammer Strength (Life Fitness, Schiller Park, IL 60176) resistance training machines.

Anthropometrics & Body Composition

Upon arrival for both pre- and post-testing, participants' height and weight were measured on a calibrated scale with a separate attachment for height. Body composition and BMD were measured immediately after height and weight measurement. The DEXA scan emits two X-ray beams of different energy levels (one low-energy and one high) to provide a description of participants' lean body mass, fat mass, body fat percentage, and bone density; all of which were collected for this study. Haarbo, Gotfredsen, Hassager, and Christiansen (1991) state that DEXA is a validated and accurate measure of body composition.

EMG Testing

Participants werefittedwith EMG electrodes. Electrodes were placed over the muscle belly running parallel to the muscle fibers on the right side of all participants for the following muscles: PM, RA, AD, BB, TB, and the middle portion of TR. After electrode placement, each subject underwent manual muscle testing to determine the MVIC for each muscle.

Manual muscle testing was performed on the right side in the following order for each participant: BB, AD, RA, TR, TB, and PM. Each manual muscle test lasted 5 seconds, with the largest reading being recorded as the MVIC for each muscle. For the manual muscle test of the BB, the participant sat comfortably with their right arm fully adducted to their side and their elbowflexed at 90°. From this position the participant was asked to pull their wrist towards their shoulder as hard as possible only using their BB. During this time frame, a tester provided a manual resistance to the participant. Manual muscle testing of the AD consisted of the participant sitting with their arm flexed to 90° at the shoulder and the elbow fully extended. Participants were then asked to resist their arm being pushed down (reducing flexion) at the shoulder against the manual resistance of the tester. Next, participants were asked to lie supine on a table for testing of the RA. Their arms were at their sides and their legs were flexed or extended in a manner the participants felt comfortable. Participants performed a crunch keeping their head and shoulders in alignment against the resistance of the tester being applied to their shoulders. To test the TR, participants began in a prone position with their right arm hanging loosely from the table. Again, participants abducted their shoulder and flexed their elbow to 90° so that their fist pointed towards the floor. Participants were instructed to pull their arm towards the ceiling in a straight line, being sure not to try and pull their arm towards the side of their body. This ensured the TR was recorded and not the latissimus dorsi. For the manual muscle test of the TB, the participant started in the same position as the manual muscle test for the BB. The participant then tried to fully extend their arm against the resistance of the tester instead of flexing. Returning to the supine position, participantsmoved to the right edge of the table so that their right arm hung loosely off the table. To test MVIC of the PM participants abducted their shoulder to 90° and flexed their elbow to 90° so that their fist pointed towards the ceiling. Resistance was applied to the fist and bicep by the tester and the participant horizontally adducted at the shoulder to bring their arm across their chest.

After the manual muscle testing period, participants were given the appropriate SW® or DB and instructed on how to perform each shaking exercise. A 5.0lb SW® and 5.0lb DB was utilized for EMG testing. Participants performed the 3 different shaking exercises, the chest CS, BS, and TS, in that order. Participants were randomly selected to start with either the DB or the SW® for the testing period. Participants stood erect with their feet shoulder width apart and feet facing forward for all three shaking exercises.

During the CS, participants were instructed to hold the SW® or DB with both hands at a 45° angle so that the top portion of the SW® or DB pointed toward their chin and the bottom pointed toward the floor. During this shake, participants' shoulders were flexed at approximately 45° and elbows at 90°. From there, the SW® or DB was shaken as forcefully and quickly as possible with very little or no joint movement at the shoulder or elbow. The shaking period lasted 5 seconds, with the 1st and 5th seconds being discarded and the 2nd-4th seconds being recorded for analysis. Eliminating the 1st and 5th seconds accounted for any discrepancy between the starting of the timer and the participant beginning the protocol.

For the BS, participants externally rotated their shoulders, abducted at the shoulder to 90°, and flexed 90° at the elbow so that the right fist pointed towards the ceiling. Then with only their right arm, participants shook the exercise equipment as hard and fast as possible only moving at the elbow in flexion and extension so that the end of the equipment moved closer and further away from their ear.

The TS consisted of the participants holding the exercise equipment behind their heads with both hands so that the shoulders were just short of full extension and the elbows were flexed to 90°. Participants shook the device as hard and fast as possible up and down for 5 seconds so that very minimal flexion and extension of the elbow occurred.

After completing the first two trials to test SW® efficacy, participants performed the same exercises with a 5 lb. SW® to evaluate if the SW® exercises could generate larger muscle activation with larger loads. The protocol with the 5 lb. DB was identical as previously described for the SW®. Participants were tested for changes in motor unit recruitment at baseline and at the end of the 10-week training program.

Muscular Strength

For muscular strength, several different tests wereutilized. The first test was handgrip strength as measured via a handgrip dynamometer. Each participant repeated this test three times on both their right and left hands. This test began by adjusting the length of the lever arm of the dynamometer so that the middle phalanx of the participants' middle finger created a 90º angle across the lever arm. Participants then placed the dynamometer to their side while standing with thehand to be tested fully flexed and adducted to their side. All fingers gripped the dynamometer across the lever arm with the thumb on the outside of the dynamometer handle. Participants then squeezed the dynamometer as hard as possible for 3 seconds. Right and left hands were alternated between trials, and three total trials were used for each hand.

The second test for muscular strength was an estimation of HIT participants’ 1RM on thechest press, leg press, lat pulldown, and seated row. Participants were instructed to breathe out during the concentric phase of movement and to breathe in during the eccentric phase of the movement, with both concentric and eccentric phases lasting approximately 2-seconds. Prior to testing participants warmed up at a self selected weight for approximately 8-12 repetitions, followed by another warm-up set at a self-selected weight for 6-8 repetitions. To estimate 1RM, participants performed an 8-repetition maximum (8RM). Repetitions were not counted if participants did not move each repetition throughout the entire range of motion, altered their form, performed the repetitions too quickly or too slowly, or if there was a change in their breathing patterns. If participants failed to meet the previously mentioned lifting criteria on the first self-selected weight, then the current weight was reduced, a 1-minute rest period was given, and participants attempted another 8RM. Upon completion of an 8RM, participants were given a 1-minute resting period and then the opportunity to increase the current weight and try a second (or third if necessary) 8RM if they had not failed previously.

The final test used to determine changes in muscular fitness was a modified YMCA bench press test. The typical YMCA bench press test requires a weight of 35lbs. for women; this study utilized a weight of 20lbs. The reason being, 35lbs. may have been a difficult weight for some of the participants to lift successfully. To begin the test, participants laid supine on a standard bench press with their feet flat on the floor. Participants then gripped the 20lb. straight bar approximately shoulder width apart. The test began in the “down” position in which the shoulders were slightly abducted from the side, the elbows flexed slightly below 90° and the bar being approximately 2 inches from the chest. A metronome was set to 60 beats per minute so that with each beat the participants either raised or lowered the bar for a total of 30 repetitions per minute. Participants performed as many repetitions as possible. The test was concluded when participants broke proper form or were no longer able to keep up with the pace of the metronome. Handgrip strength, 8RM, and YMCA bench press scores were assessed at baseline, after five weeks, and at the end of the training intervention.

Training Protocol

Both training programs were 10-weeks in length, and both training groups were required to warm-up and cool-down for at least 5-minutes at a low to moderate aerobic intensity on a treadmill, stationary/recumbent bike, or elliptical. The training program for the SW® group was the same exercises, intensities, and duration as prescribed by the SW® DVD. These exercises were the same as those used for EMG testing, and a 2.5lb.SW® was used, rather than the 5lb. SW® used for testing. The duration of the video is 6-minutes and participants trained two days per week on non-consecutive days. Training for the HIT was also two days per week with at least 48 hours between training sessions. For this group, the following exercises were utilized: chest press, leg press, lat pulldown, and seated row. All exercises were performed on isotonic resistance machines. For the first four weeks of the training program participants performed 3 sets of 8 repetitions at 80% of their original estimated 1RM. At the end of the first five weeks, participants were reassessed for estimated 1RM strength. So, for weeks 5-10, participants performed 3 sets of 8 repetitions at of their newly estimated 1RM for all exercises so that participants were working at the correct percentage of their maximum.

Statistical Analysis

Independent *t*-tests were utilized to determine baseline differences between groups in terms of FFM, body fat percentage, BMD, height, weight, and age. A repeated measures analysis of variance (ANOVA) measured the effect of time on YMCA bench press, handgrip, and estimated 1RM (for the HIT group only) for within-group comparison. An ANOVA was also utilized to measure pre-post between-group differences for the effect of time from the beginning of the intervention to the end in the following variables: weight, body fat percentage, FFM, BMD, YMCA bench press repetitions, and handgrip strength for the right and left hands. A Bonferonni correction was utilized to determine where significant changes occurred. The software chosen to run the analysis was SPSS 19 for Windows (IBM Corporation, Armonk, NY 10504).

CHAPTER IV: RESULTS

Baseline Characteristics

Each intervention group had eight participants, for a total of 16 participants (one participant of the SW® group did not meet the minimum requirement of the 80% compliance rate to qualify for statistical analysis). Participants of the HIT group had a mean age of 55.88 ± 5.64 years, while those of the SW® group had a mean age of 56.75 ± 5.97 years. Mean weights for the HIT and SW® groups were 80.57 ± 11.39 kg and 67.33 ± 9.05 kg, respectively. There was a significant difference in participant mass at baseline (*p* = .02). No significant differences were observed between-groups in relation to height, body fat percentage, or BMD. However, there was a significant baseline between-group difference in relation to FFM (*p* = .008). The HIT group had a mean FFM of 44.81 ± 4.26 kg and the SW® group had a mean FFM of 39.60 ± 2.21 kg (Table 1).

Anthropometric Data

No significant differences were observed for either group at the end of the intervention period for mass or BMD. In addition, no significant changes in FFM for the HIT group occurred at the end of the intervention (44.81 ± 4.26 kg to 44.96 ± 3.97 kg). In contrast, the SW® group showed a significant decrease in FFM from 39.60 ± 2.21 kg to 39.09 ± 2.48 kg from week one to week ten (*p* = .033; Figure 1). When comparing the pre-to-post change for the SW® and HIT groups from the interventions, no significant differences between the percent change in mass, body fat percentage, and BMD were observed. However, there was a significant difference in the change in body fat percentage from the beginning to the end of the intervention between groups (*p* = .021) HIT body fat percentage declined from 44.65 ± 5.27% to 44.00 ± 5.11% over the course of the intervention, while the SW® group body fat percentage increased from 41.14 ± 7.62% to 42.05 ± 7.63% over the course of the intervention.

Muscular Strength and Endurance

In relation to muscular strength and endurance, the YMCA bench press improved significantly for the HIT group only (*p* = .013). This improvement was observed between the first and the tenth weeks. Mean HIT group YMCA scores improved from 54.63 ± 32.92 repetitions to 77.13 ± 47.67 repetitions between week 1 and week 10 (Figure 2). YMCA bench press scores did not change significantly over the intervention period for the SW® group. However, a trend for significance was apparent between week 1 and week 10 for the SW® group; mean YMCA scores improved from 32.75 ± 11.70 repetitions to 45.88 ± 22.98 repetitions (*p* = .083). No significant effect of time was observed for the handgrip strength of either hand for either group. While the SW® group was not evaluated on estimated 1RM strength for any variable, the HIT group was evaluated for estimated 1RM of the chest press, leg press, lat pulldown, and seated row. There was a significant effect of time for the leg press. Scores improved significantly between weeks 1-10 (*p* = .006) and weeks 6-10 (*p* = .001). From the beginning of the intervention to the end, leg press values improved 29.92 ± 20.50%. While leg press values improved 10.83 ± 5.95% between weeks 6 and 10. Similarly to the change in leg press values, Lat pulldown values also improved significantly between weeks 1-10 (*p* = .002) and weeks 6-10 (*p* = .006). Lat pulldown values increased an average of 31.41 ± 21.47% between weeks 1-10 and 13.40 ± 9.77% between weeks 6-10. Finally, seated row values improved significantly from the beginning of the intervention to the end (*p* = .001) and between weeks 6-10 (*p* = .000). All changes in estimated 1RM strength are shown in Figure 3. When comparing the change in YMCA bench press scores and handgrip strength over the course of the intervention between the HIT and SW®, no significant differences were apparent.

EMG

The comparison of percent MVIC activity within-group via the repeated measures ANOVA identified no significant increases in percent MVIC for any muscle group during any exercise for either intervention group. There was no trend for significance within-group. However, there was a slight trend for significance (p = .098) of the BB activity of the HIT group to be greater than SW® group BB activity during the chest shake with either the dumbbell or SW®, during the triceps shake when using the dumbbell, and during the biceps shake when using the SW® (Table 2).

CHAPTER V: DISCUSSION

The results of this study indicate that the SW® device is not an effective resistance training device at improving various components of muscular fitness in post-menopausal women when compared to traditional HIT programs. The SW® was ineffective at increasing muscular strength as measured by handgrip strength, was ineffective at improving muscular endurance as measured by the YMCA bench press test, and was not effective at altering motor unit activation as measured via an EMG. In addition, those in the SW® group demonstrated a significant decrease in FFM during the 10-week length of this study. In contrast, the HIT group showed improvements in muscular strength, as measured on estimated 1RM for the leg press, lat pulldown, and seated row, and muscular endurance as measured via improved YMCA bench press repetitions. Neither intervention appeared to alter measures BMD or body mass for either group. In summary, when compared to a traditional resistance training program in post-menopausal women, interventions involving the SW® were not an effective method to improve muscular fitness.

Weight and Body Composition

Neither intervention elicited significant alterations in participants' weight. This is not surprising based on previous research findings. Resistance training is not typically thought of as a sufficient stimulus alone to burn enough calories to generate weight loss. However, resistance exercise has been known to elicit changes in body composition. This is particularly due to its ability to stimulate muscular hypertrophy and increase FFM (Rabelo, et al., 2011). In the present study, FFM did not increase in either group. In fact, FFM declined in the SW® group. These findings are contrary to those previously found by Rabelo et al. The SW® had a significantly lower FFM in comparison to the HIT group prior to the intervention, which leads to the possibility of enhanced sarcopenia in the participants of the SW® group. The SW® device may not have caused the decrease in FFM, but perhaps was not a sufficient stimulus to prevent further declines in participant FFM over 10-weeks. The decline in FFM and the initial difference in FFM between the two intervention groups, likely explain the significantly lower FFM in the SW® group in comparison to the HIT group post-intervention. The declines in FFM for the SW® group are in opposition to one of the null hypothesis for this study, and therefore mean that the hypothesis that neither HIT nor SW® interventions would have a significant impact on FFM must be rejected.

There were also significant changes in body fat % over the course of the intervention. The change in body fat percentage was positive for the HIT intervention, in that body fat decreased, and was negative for the SW® intervention, in that body fat increased. These results are also not surprising. Though not significant, HIT FFM increased very slightly with no change in mass, this would cause the ratio of FFM of body fat to change. If FFM increases with no change in mass, then body fat must decrease. Conversely, FFM declined significantly in the SW® group with no change in mass. This would mean that body fat must increase to maintain the same mass. Thus, body fat in terms of fat mass may not have actually increased in the SW® group, but the decline in FFM caused an increase in body fat percentage, while the slight increase in FFM for the HIT group may not indicate losses in fat mass, but simply a change in body fat percentage.

Muscular Strength and Endurance

The handgrip strength test is a common measure of muscular strength in older adults. The participants of this study did not obtain significant improvement in handgrip strength over the course of the intervention. Although the muscles involved in handgrip strength were stimulated by both training interventions, neither intervention specifically targeted these muscle groups, thus preventing an improvement in handgrip strength. In addition, changes in muscle mass were not observed in either intervention, so an increase in muscle mass would not have contributed to increased handgrip strength. Finally, improvements in muscle activity were limited in the HIT group, and not apparent in the SW® group, likely preventing improvements in handgrip strength. Since no changes in handgrip strength were determined in either group, the null hypothesis stating no significant differences in muscular strength between the two groups should be supported.

The YMCA bench press test is a validated measured of muscular endurance for the upper body (American College of Sports Medicine, 2010). The HIT group showed significant improvements in muscular endurance at the end of the 10-week intervention period; however, the SW® group did not improve significantly over the course of the intervention. It should be noted that there were improvements in YMCA bench press scores for the SW® group, but these scores did not reach statistically significant levels, possibly indicating a learning effect from the completion of three separate YMCA bench press trials. These results reject the hypothesis that no significant differences in muscular endurance would occur at the end of the two training interventions.

Other common measures of muscular strength are the 1RM, or the estimated 1RM, as used in the present study. Participants of the HIT group showed significant improvements in estimated 1RM strength for the leg press, lat pulldown, and seated row five and ten weeks, these results reject the null hypothesis that no significant improvements in muscular strength would occur as a result of high-intensity resistance training. Peterson et al. (2010) reported in their meta-analysis improvements for the chest press, leg press, and lat pull to be 24%, 29%, and 25%, respectively. The improvements of the HIT participants in this study were similar to the reported findings of Peterson et al. (2010). Similar improvements in muscular strength were reported by Bocalini, Serra, and dos Santos (2009) for the upper and lower body (39% for the leg extension and 46% for the chest press). Both, Peterson et al. and Bocalini, Serra, and dos Santos reported training intensities between 70-85% of 1RM, performing 2-3 sets of 8-10 repetitions. The training intensities and work load of the participants in the present study were similar to those previously reported (3 sets of 8 repetitions at 80% estimated 1RM).

The SW® group did not show statistically significant improvements in muscular strength or endurance. Possible mechanisms for the lack in improvement in muscular strength likely involve the SW®'s ability to work at a high percentage of 1RM. Though not specifically measured in the SW® group, the percent of 1RM at which the SW® group exercised might have been lower than the 80% of 1RM utilized for the HIT group. Working at a low percentage of 1RM would have limited the stimulus available to initiate muscular hypertrophy or change motor unit recruitment.

Other possible mechanisms for the discrepancy in muscle strength and endurance between the two groups were FFM. Prior to the beginning of the intervention, significant group differences were apparent in FFM, with the HIT group having significantly higher FFM than the SW® group. This discrepancy in FFM could have indicated a prior muscular fitness for the HIT group that caused the participants of that group to be more accustomed to the strains of high-intensity resistance training, allowing them to work closer to their true maximum. However, if the reduced FFM of the SW® group did indicate a lower initial muscular fitness, then a 10-week intervention should have induced larger relative gains in the individuals with lower levels of fitness. The HIT group also had a significantly higher total mass in comparison to the SW®

group. The higher initial mass may explain the significantly higher FFM in the HIT group prior to the intervention and may have no relation on initial group muscular fitness levels.

FFM decreased in the SW® group post-intervention. The reduction in FFM after a resistance training intervention is uncommon, and therefore, hard to explain. The SW® may not have provided a sufficient stimulus to prevent further age-related losses in muscle mass. Another possibility may lie in the nature of the SW® exercises themselves. Only the upper body was targeted by the SW®, thus reductions in FFM may have come exclusively from the lower body. The loss in lower body FFM would not have occurred in the HIT group as they performed the leg press twice per week. Unfortunately, since specific areas of FFM were not measured, this study was not able to determine where losses in FFM may have occurred. Further research is needed to identify this problem. The decreases in SW® FFM may also describe why the HIT group improved in different areas of muscular fitness post-intervention and the SW® group did not.

Bone Mineral Density

No changes in BMD were observed for either group at the end of the intervention, which fully supports the null hypothesis for this study. These findings are both in alignment and in contrast to previous literature involving high-intensity resistance training and changes in BMD. In an earlier study by Kerr et al. (1996), high-intensity resistance training improved BMD of the greater trochanter, intertrochanteric hip, and Ward’s triangle in comparison to control after a 12-month intervention. Thus, the findings of the present study do not show improvements in BMD and are not in alignment with Kerr et al. Maddalozo and Snow (2000) conducted a study in which 36-weeks of resistance training did not improve BMD, but did preserve BMD. Winters-Stone, Leo, and Schwartz (2011) also demonstrated the ability of resistance training to preserve BMD after a resistance training intervention for 1-year. Previous research indicates that resistance training is capable of preserving and potentially improving BMD. The findings of the present study support this hypothesis. It is worth mentioning that the length of the intervention of this study was much shorter (10-weeks) than the three studies mentioned (36-weeks and 12 months, respectively). This duration may not have been sufficient to fully determine the capacities of the SW® to preserve or improve BMD in post-menopausal women. Future research involving longer training interventions with the SW® are necessary to determine if BMD is truly preserved, or if the 10-weeks in the present study was an insufficient length of time to detect changes in BMD, either positively or negatively.

EMG

Muscle activation in the present study was not significantly different from the beginning of the interventions to the end for all conditions. These findings were independent of shaking either the SW® or the DB. Although no intervention was utilized in the Glenn et al. (2012) study, the general results found here agree with those of Glenn et al. The SW® did not show a definitive pattern of generating greater muscle activation than the DB while utilizing the SW® exercises. Pocari (2011) evaluated the impact of the SW® on muscle action potentials in comparison to traditional DB exercises of identical weight. Their results indicated that the percent of MVIC utilized was greater while shaking the SW® rather than during dynamic bicep curls of an equal weight to the SW®. MAPs were not compared during dynamic exercise and during the SW® exercises in this study. Thus, it appears that based on previous findings and the results of this study that inherently, the SW® device and exercises are capable of producing greater muscle activation than traditional dynamic exercises of an equal load. The SW® device itself has no property over a DB that provides it the ability to generate greater muscle activation, only the SW® exercises themselves seem to have this ability to increase muscle activation. This result may seem likely, because the somewhat isometric nature of the SW® exercises allows participants to work at a greater percentage of their MVIC than dynamic exercises of the same load. Future research should focus on determining if a SW® intervention would be more effective than a dynamic intervention of equal weight.

The participants of the HIT group also did not show significant improvements in muscle activation during any measure, and there were no significant differences in muscle activation between groups, which are in contrast to the results of the study by Wallerstein et al. (2012). In their study, Wallerstein et al. determined that a 16-week high-intensity resistance training program was sufficient to improve vastus lateralis activation as recorded on an EMG. This may have occurred for a couple of reasons. First, the length of training intervention in the present study was several weeks shorter than that of Wallerstein et at. The length of the intervention may not have been sufficient for neuromuscular adaptations to become statistically in the present study. Secondly, one (the chest press) or two (seated row and lat pulldown) exercises were used for the muscle groups of the upper body. Thus, even though the intensities of the present study and that of Wallerstein et al. were comparable, the amount of total work done for each muscle may not have been sufficient for neuromuscular adaptation to occur. This same explanation likely could also be applied to the lack of neuromuscular change seen for the SW® group. The amount of work completed, as well as the intensity, was likely insufficient to stimulate neuromuscular change.

A final important point worth mentioning is the value of EMG in this particular research study. Many of the values obtained through the YMCA bench press test and estimated 1RM tests were very scattered because of the variations in the fitness levels of this population. Some of the participants were rather fit and had few, if any signs of losses in muscle mass, muscular strength, or muscular endurance, while other participants seemed to be very much affected by the aging process. These variations made statistical analysis difficult, as standard deviations were often high, preventing potentially significant values to be rendered not significant. In contrast, EMG values are normalized through the MVICs obtained during manual muscle testing. Thus, all percent MVIC values are relative and therefore create more closely knit values that may indicate more representative significant values. In addition, resistance training programs in postmenopausal women may not always initiate changes in muscle mass, as sarcopenia fights against improvements in muscle mass. EMG however, can detect changes in neuromuscular activation and therefore may be able to indicate improvements in muscular coordination and strength that may not be evident on conventional strength or endurance measurements such as 1RM testing or the YMCA bench press.

Study Limitations

An apparent limitation of this study that developed after the randomization of the participants was the difference in FFM at baseline. HIT participants had significantly greater FFM at baseline than did participants in the SW® group. This difference was also apparent during baseline testing for the YMCA bench press and handgrip strength. Though not significantly different, an observable difference appeared between the two groups on these two variables of muscular fitness existed. This discrepancy could skew the results of this study and cause the HIT group to show greater improvements than the SW® group.

A second limitation of this study is the differences in the training programs of each group. The SW® group completed the same exercises with the same resistance for the duration of the intervention. In contrast, the HIT group had an increase in resistance to adjust for any improvements in strength after the first 5 weeks of the study as to maintain a constant percentage of 1RM. This may have allowed the HIT group to continually improve in YMCA endurance and strength as measured by 8RM. However, the SW® group did not improve after 5 or 10 weeks of the intervention. If the SW® were to be effective at improving muscular fitness, it likely would have been in the first 5 weeks of the study when the SW® would have been a "new" stimulus.

Lastly, a limitation of the study that needs to be mentioned is the small sample size utilized. Though sufficient for statistical analysis, a greater number of participants would be necessary to draw larger conclusions of the SW® and apply them to postmenopausal women. In addition, a larger sample size would likely limit some of the variations in the statistical analysis and lead to more concrete findings in relation to changes in muscular strength, muscular endurance, body composition, BMD, and neuromuscular adaptations.

Conclusions

The SW® as a device does not appear to be an effective exercise tool in post-menopausal women in regards to muscular fitness, body composition and BMD. More specifically, the SW® group did not significantly improve in muscular strength, muscular endurance, muscle mass, body fat percentage, BMD, or motor unit recruitment as measured on an EMG. In contrast, high-intensity resistance training was effective at improving muscular endurance, preserving muscle mass, muscular strength as measured by estimated 1RM, and lowering participants' percent body fat. Future research with the SW® should focus on long-term changes in muscle mass and body composition, as well as BMD. In addition, the SW®'s exercise technique MVIC advantage should be compared to dynamic exercise interventions when the loads between the two exercises are equal.

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Table 1

Group Baseline Characteristics						
Group	Mass	Height	Age	Body Fat %	FFM	BMD
SW	67.33 (kg)	1.60 (m)	56.75 (yr)	41.14%	39.6 (kg)	1.13 (g/cm^2)
HIT	80.57 (kg)	1.62 (m)	55.88 (yr)	44.65%	44.81 (kg)*	1.17 (g/cm^2)

* Denotes significant difference at baseline ($p < .05$).

Table 1: Group baseline anthropometric data. Description of mass, height, age, body fat percentage, fat free mass, and bone mineral density at baseline.

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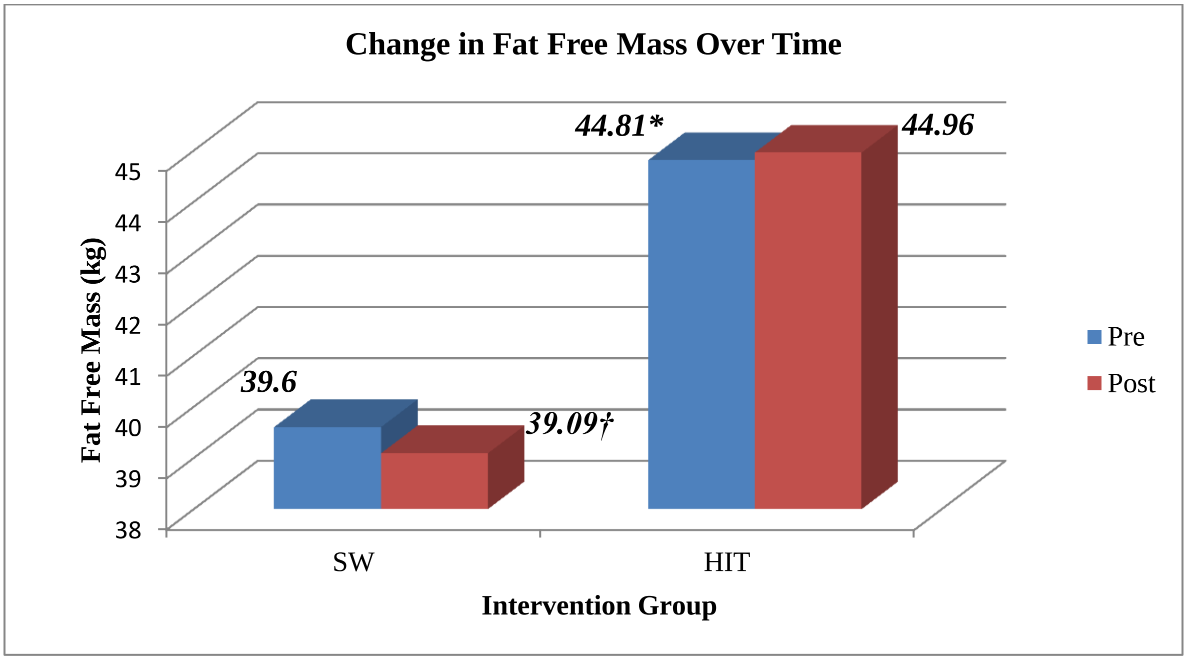
Figure 1

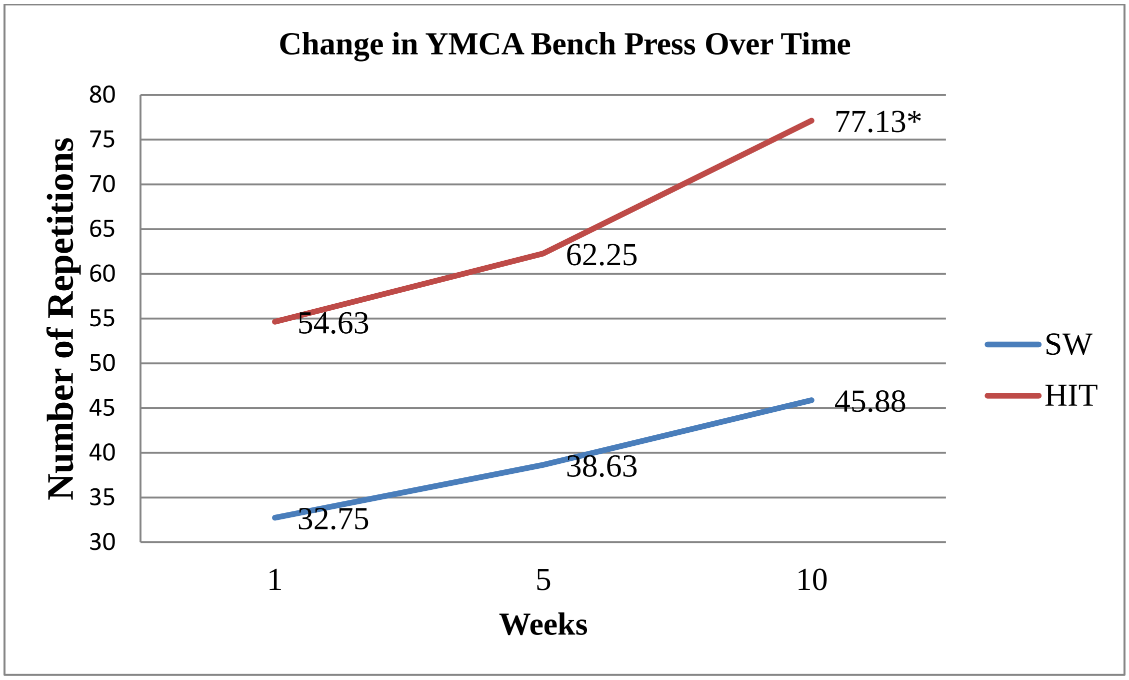


* Denotes significant difference between groups at baseline (*p* < .05).

† Denotes significant difference for SW group from the beginning to the end of the intervention (*p* <.05).

Figure 1: The change in fat free mass over time. Fat free mass changes from week 1 to week 10.

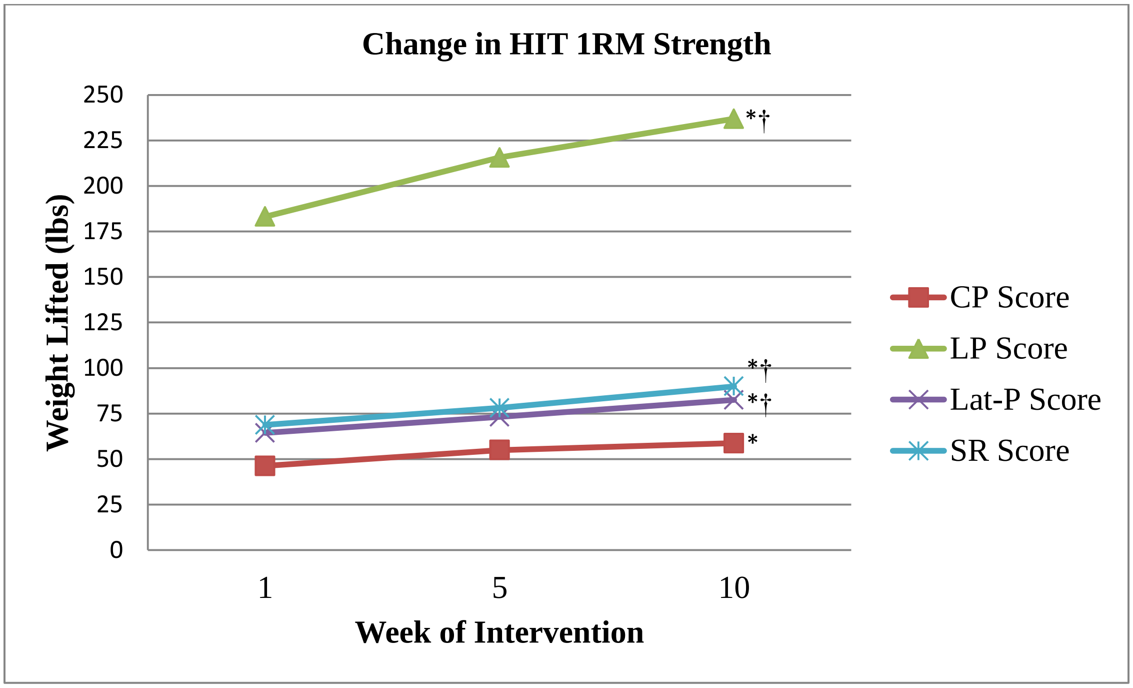
Figure 2



* Denotes significant difference from week 1 to week 10 (*p* < .05).

Figure 2: The change in YMCA bench press repetitions over time. YMCA bench press change from beginning to the end of the intervention.

Figure 3



* Denotes significant difference from baseline (*p*< .05).

† Denotes significant difference between weeks 5-10 (*p*< .05).

Figure 3: The change in HIT estimated 1RM strength. Improvements in HIT 1RM strength over the 10-week intervention.

Table 2

HIT				
Chest Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	41.97 ± 18.07	51.28 ± 20.47	51.37 ± 27.23	56.05 ± 23.37
Biceps	40.23 ± 30.85	62.01 ± 22.40	44.06 ± 26.04	76.33 ± 27.86
Ant. Delt.	19.64 ± 6.37	33.74 ± 18.78	28.58 ± 11.03	34.18 ± 16.03
Rect. Ab.	25.59 ± 20.59	39.14 ± 36.94	29.05 ± 36.38	33.43 ± 26.20
Trapezius	43.73 ± 27.0	51.08 ± 42.93	49.76 ± 24.37	51.22 ± 41.34
Triceps	46.77 ± 22.07	47.46 ± 22.83	52.88 ± 14.98	49.58 ± 19.34
Biceps Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	30.20 ± 16.58	31.23 ± 21.14	31.87 ± 17.99	35.27 ± 24.02
Biceps	42.01 ± 34. 14	64.44 ± 20.74	49.22 ± 35.39	75.08 ± 29.95
Ant. Delt.	36.80 ± 9.25	46.32 ± 13.66	43.67 ± 16.16	51.95 ± 16.94
Rect. Ab.	26.07 ± 27.84	26.64 ± 24.10	25.79 ± 26.78	27.34 ± 23.47
Trapezius	58.69 ± 38.35	59.17 ± 37.82	61.16 ± 33.47	61.44 ± 34.06
Triceps	48.01 ± 33.36	59.90 ± 31.13	54.09 ± 23.75	63.61 ± 31.00
Triceps Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	22.37 ± 18.94	27.46 ± 8.55	35.16 ± 25.63	32.56 ± 24.16
Biceps	42.46 ± 27.89	85.87 ± 23. 82	48.43 ± 36.46	66.37 ± 14.97
Ant. Delt.	48.63 ± 21.49	44.51 ± 8.82	41.29 ± 14.14	46.08 ± 17.31
Rect. Ab.	26.77 ± 25.93	30.14 ± 25.00	19.09 ± 9.16	29.28 ± 22.52
Trapezius	60.45 ± 36.06	66.12 ± 34.66	77.06 ± 36.83	69.31 ± 31.30
Triceps	70.40 ± 31.17	67.31 ± 28.72	72.60 ± 26.75	62.67 ± 34.86
SW				
Chest Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	42.71 ± 21.09	36.34 ± 31.24	34.21 ± 11.40	44.61 ± 38.82
Biceps	40.81 ± 21.23	37.67 ± 16.10	43.26 ± 28.10	39.34 ± 22.05
Ant. Delt.	19.75 ± 11.96	23.50 ± 13.05	21.45 ± 14.70	27.62 ± 16.48
Rect. Ab.	21.54 ± 13.09	36.01 ± 15.09	21.05 ± 13.09	20.45 ± 7.37
Trapezius	20.42 ± 5.82	29.49 ± 8.70	20.35 ± 6.92	34.60 ± 15.17
Triceps	44.36 ± 21.36	41.16 ± 12.01	51.20 ± 25.26	41.31 ± 9.78
Biceps Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	12.3 ± 3.37	18.13 ± 16.08	13.33 ± 5.27	17.21 ± 9.74
Biceps	44.37 ± 25.62	50.52 ± 35.04	45.68 ± 25.76	48.67 ± 30.88
Ant. Delt.	32.9 ± 17.07	41.52 ± 15.06	33.11 ± 16.45	40.16 ± 15.83
Rect. Ab.	18.92 ± 12.68	21.76 ± 7.51	21.86 ± 17.70	24.71 ± 11.22
Trapezius	26.85 ± 10.21	49.21 ± 18.20	29.08 ± 14.82	55.22 ± 27.23
Triceps	56.29 ± 29.65	55.00 ± 29.36	60.21 ± 24.82	56.36 ± 21.13

Triceps Shake				
Muscle	**DB Pre**	**DB Post**	**SW Pre**	**SW Post**
Pect. Major	10.97 ± 4.99	20.83 ± 17.83	28.04 ± 23.42	20.38 ± 11.70
Biceps	52.66 ± 37.89	56.07 ± 27.79	50.30 ± 38.40	66.47 ± 32.32
Ant. Delt.	29.18 ± 13.64	43.50 ± 16.07	37.82 ± 20.99	48.12 ± 19.36
Rect. Ab.	19.31 ± 14.06	23.28 ± 9.37	22.17 ± 16.22	26.79 ± 11.25
Trapezius	39.64 ± 35.10	42.68 ± 22.78	29.40 ± 11.09	57.20 ± 33.24
Triceps	67.32 ± 32.54	68.44 ± 28.50	72.14 ± 30.89	87.69 ± 49.25

Table 2: Change in mean percent MVIC from pre- to post-intervention. The chart denotes the change in percent MVIC for each muscle, during each exercise, with both the dumbbell and the SW® for both resistance training groups.

March 14, 2013

MEMORANDUM

TO:	Isaac Cook Ro DiBrezzo
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	13-01-402
Protocol Title:	*Evaluation of Shake Weight Protocol in Senior Populations*
Review Type:	☐ EXEMPT ☐ EXPEDITED ☒ FULL IRB
Approved Project Period:	Start Date: 03/13/2013 Expiration Date: 03/10/2014

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 50 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.