AN ABSTRACT OF THE DISSERTATION OF

Adrienne J. McNamara for the degree of Doctor of Philosophy in Exercise and Sport Science presented on May 14, 2010.

Title: Translating the *Better Bones and Balance* Intervention Program into the Community Setting: Effects of Participation on Skeletal Health, Fall Risk Indicators, and Physical Activity among Older Women.

Abstract approved:

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Katherine B. Gunter

Better Bones and Balance (BBB) is a community-based exercise program to improve bone health and reduce fall risk among older adults. Prior research has shown that when the program is delivered by researchers under controlled conditions, participants improved strength and balance, and maintained bone mineral density (BMD) at the hip. Whether participants benefit from *BBB* delivered in the community setting is unknown. Purpose: The purpose of this study was 1) to evaluate the relationship between participation in *BBB* and skeletal health (hip, spine, whole body BMD; hip bone structure) and indicators of fall risk(strength, balance, balance confidence, fall worry, fall incidence) and 2) to quantify the dose of physical activity (min/week, ground reaction forces) from the *BBB* program. Methods: *BBB* participants (n=69) were recruited from *BBB* classes and compared to controls (n=46). Performance-based tests included the 30-second chair stand, “Up and Go”, tandem walk, tandem and one-leg stance. Self-reported indicators of fall risk were assessed by questionnaire. BMD and hip structure were measured using dual energy x-ray absorptiometry. To quantify the physical activity dose from BBB, 36 *BBB* participants were recruited from four *BBB* classes. Peak ground reaction forces (GRF) of the key exercises were measured using a force platform; duration and intensity of exercises were measured during class sessions using heart rate monitors and accelerometers. Results: *BBB* participants out-performed controls on all strength and balance tasks ($p<0.01$) except the tandem stance ($p=0.02$) and reported higher balance confidence ($p<0.01$). There were no group differences in fall worry, fall incidence, hip or spine BMD or bone structural outcomes. Both groups had higher than average hip t-scores compared to national norms ($p<0.05$). Mean one-leg GRFs associated with typical *BBB* exercises ranged from 1.3 to 2.4 x body weight and BBB participants performed 126 minutes per week of moderate to vigorous physical activity. Conclusions: *BBB* participation is associated with positive outcomes on performance and self-reported indicators of fall risk, and higher hip BMD compared to national norms. Additionally regular participation in *BBB* delivers an adequate dose of exercise to meet national guidelines for optimal health. *BBB* appears to be a safe and effective program for reducing fall risk indicators and enhancing general health among older women.

Translating The Better Bones and Balance Intervention Program Into the Community Setting: Effects of Participation on Skeletal Health, Fall Risk Indicators, and Physical Activity among Older Women

by
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I understand that my dissertation will become part of the permanent collection of the Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Adrienne J. McNamara

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CONTRIBUTION OF AUTHORS

Dr. Kathy Gunter assisted in the design, interpretation of data and editing of all three manuscripts. Dr. Mike Pavol assisted in the design of methods analysis of data related to use of the force plate system for the third manuscript.

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CHAPTER ONE: INTRODUCTION

BACKGROUND

One third of older adults fall each year and are at substantial risk for injury (CDC, 2006, Sattin, et al., 1990). For many older Americans, falls are a chronic condition requiring medical management. Among older individuals reporting a fall in the previous three to twelve months, 20%-25% report falling more than once and over 30% report an injury resulting in activity restriction or a visit to their physician (CDC, 2008; Gunter, White, Hayes, & Snow, 2000). The health and economic burden of falls in this population is large. In 2000, direct costs associated with fall injuries among those 65 and older was over $19 billion (Stevens, Corso, Finkelstein, & Miller, 2006). Among the most costly outcomes are fall-related hip fractures. More than 95% of hip fractures are attributable to a fall and hospital admissions for hip fractures continue to rise (CDC, 2008). In addition, the prevalence of osteoporosis is also increasing, affecting over 10 million Americans with 18 million more at risk due to low bone mass (NIH, 2001). The total number of annual fractures and costs associated with osteoporosis are predicted to rise 50% by the year 2025, reaching over 3 million fractures and 25 billion dollars (Burge, et al., 2007). Thus, the need persists to identify successful, evidence-based, comprehensive interventions to improve function and prevent falls and osteoporosis related injuries among community-dwelling older adults.

Role of exercise in improving bone mass in older adults

The factor of risk is a concept based on engineering principles that describes the likelihood of a bone sustaining a fracture. This concept is dependent on both the strength of the skeleton and the forces delivered to the skeleton, usually as a result of a fall. There are many effective pharmacological modalities that increase bone mass, however, to date, none of these prevent falls. Exercise is unique in that it has the capacity to enhance bone strength through improvements in bone mass and bone structure *and* reduce the risk of falling through improvements in muscle strength, coordination, balance and mobility.

Physical activity has been shown to enhance bone mass at various skeletal sites in numerous populations, provided that the exercise stimulus overloads the skeleton. In order for sufficient overload to be achieved, exercise must 1) specifically target the skeletal areas of interest, 2) be of sufficient intensity and duration and 3) provide a stimulus that is novel (Turner & Pavalko, 1998). Because bone loss and consequently, the risk of osteoporosis, increases with age, numerous studies have focused on finding the optimal exercise prescription to enhance bone mass and bone strength in older adults, although the ideal protocol for osteogenic exercise still remains unclear. Previous research has shown that both impact exercise and resistance exercise are effective in improving or maintaining bone mass in postmenopausal populations. However, it is likely that these two modes of exercise elicit their osteogenic responses through different mechanisms. For example, Kohrt, et al (1997) conducted an 11-month intervention examining the effects of different types of exercise versus no exercise on bone (Kohrt, Ehsani, & Birge, 1997). Postmenopausal, sedentary women (n=39, age 60-74), not taking hormone replacement therapy (HRT) were assigned to one of three groups: a) exercises involving predominately ground reaction forces (GRF) (such as running; walking, and stairs), b) exercises consisting of predominately joint reaction forces (JRF) (such as weight lifting and rowing) or c) a no exercise control group. Both exercise groups performed specific supervised exercises 3-5 days a week for nine months. Participants in the GRF group walked 30-45 minutes at 60-85% maximal heart rate (duration and intensity progressed through these ranges for the length of the study) and were encouraged to jog as much as possible. Stair climbing was added after the third month. Participants in the JRF program spent half of each session rowing (up to three 10 minutes bouts on a rowing ergometer at 80-85% maximal heart rate) and the remainder of the session weight training (2-3 sets of standing free weight exercise at an intensity resulting in fatigue after 8-12 repetitions). Bone mineral density (BMD) of the whole body, lumbar spine, proximal femur and distal forearm were assessed at baseline and then in 3 month intervals throughout the study. The change at the spine was 1.5 $\pm$ 0.7% and 1.8 $\pm$ 0.5% in the GRF and JRF groups respectively. Changes in whole body BMD were also similar between groups, while only the GRF group had an increase in femoral neck BMD (GRF, 3.5 $\pm$ 0.8 %; JRF, -0.2 $\pm$ 0.7%). Since resistance training stresses the bone by pulling on muscle attachments sites, the lack of change in femoral neck BMD in the JRF group is not surprising as this area is void of muscular attachments. These results emphasize the site specific nature of bone loading as well as the different mechanisms by which exercise may have osteogenic effects. Consequently, these results suggest that exercise programs that include multiple modes of exercise may be the most effective for the preservation of bone health among older adults.

Other authors have conducted multi-component exercise interventions to influence skeletal health in postmenopausal populations. Park et al (2008) conducted a 48 week randomized trial looking at the effects of a multi-component exercise program on BMD, bone remodeling, fall experience and fall risk factors among fifty elderly (age 65-70) community dwelling women (Park, Kim, Komatsu, Park, & Mutoh, 2008). The exercise program consisted of 3 sessions a week including weight training, "weight-bearing" exercise at 65-70% heart rate max (actual exercises not specified) and balance and posture training. Upon completion, the exercise group had a 5.6% and 4.1% increase in femoral neck and greater trochanter BMD, respectively, compared to non-significant losses in the control group. Furthermore, the exercise group had a significant decrease in deoxypyridinoline, indicating a reduction in bone resorption. Exercisers also realized significant improvements in 10-m walk time and one leg stance time, indicative of greater mobility and balance, findings important for fall reduction. A limitation of this study is that they did not report the actual exercises included in the intervention, nor did they report compliance to the program, which makes it difficult to assess the practicality of the program or to compare their program with that of others. Furthermore, they reported that the exercise intervention had no effect on actual incidence of falls, although their sample size was underpowered to detect differences in fall numbers. Lastly, the levels of baseline activity were very high as the exclusion criteria was participation in vigorous activity for more than 7 hours per week. Thus it is possible that these women were able to exercise at higher intensities from the onset of the study therby explaining the relatively large improvement in hip BMD. Consequently, due to the lack of reporting of actual exercises, it is unknown whether this program would be realistic or safe for a more sedentary population.

Likewise, Jessup et al (2003) found positive effects on bone from a multi-component exercise program (Jessup, Horne, Vishen, & Wheeler, 2003). Twenty three retirement home dwelling elderly women (age 69 $\pm$ 3.5 years) were randomly assigned to an exercise or control group. The exercise intervention consisted of three 60-90 minutes sessions per week where participants performed 8-10 reps of resistance exercise at 75% 1-RM as well as weight bearing exercises including walking, stair climbing and balance exercises while wearing weighted vests. After 32 weeks, the exercise group had a significant improvement in femoral neck BMD (0.7 g/cm^2) compared to losses in the control group (-0.04 g/cm^2). Additionally, exercisers had significant improvements in balance as well as reductions in body weight. Similar to Park et al (2008), these authors also failed to specify which resistance exercises were performed in the intervention making it difficult to compare their results to other programs. The very small sample size (n=9 each group) is also a limitation of this study, even though they did still see improvements in bone. These results agree with those of Englund et al (2005) who found increases in Ward's triangle BMD (+5.3 % vs -3.1% for exercisers and controls, respectively) as well as trochanter BMD (+6.9% vs +2.2% for exercise and controls respectively) in response to an exercise program consisting of strength training and aerobic exercise performed twice a week for 12 months (Englund, Littbrand, Sondell, Pettersson, & Bucht, 2005). Participants were elderly community dwelling women (mean age 73) who were randomly assigned to either the exercise or control group (n=21 and n=19, respectively). The exercise group also had significant improvements compared to baseline in one leg stance time, walk speed and grip strength (75.7%, 15.3% and 7.4% increase, respectively) indicating greater balance and strength from the program, thus reducing risk factors for falls. Although a positive bone effect was observed, it should be noted that Ward's triangle is not a clinically relevant site of the hip so the importance of these results should be interpreted cautiously. Furthermore, it is likely that the exercise stimulus was not adequate to elicit changes in femoral neck BMD in light of the fact that the femoral neck, due to its lack of muscular attachments, responds more favorably to impact than resistance exercise. However, it should be noted that preservation of the femoral neck in response to resistance exercise has been observed by others (Maddalozzo, et al., 2007). Nevertheless both of these interventions resulted in positive improvements in fall risk factors, findings ultimately important for fall prevention.

Going et al (2003) also examined the effects of a multi-component exercise program on bone health and strength (Going, et al., 2003). Three hundred and twenty early postmenopausal women (mean age 55) either taking or not taking HRT were randomized to an exercise or no exercise group. The exercise groups performed three sessions per week for 12 months with classes led by research staff and conducted in community facilities. The exercise protocol included 2 sets of 6-8 repetitions at 70-80% one repetition maximum (1-RM) of resistance training exercises utilizing free weights, machines, therabands and physioballs. Aerobic exercises including jogging, skipping/hopping and stair climbing wearing weighted vests (up to 300 stairs/session with 10-28 lbs in weighted vests) were also performed. The group with both HRT and exercise saw the greatest changes in BMD at the lumbar spine, femoral neck, greater trochanter and total body. The HRT only and exercise only group also had changes in lumbar spine, and femoral neck BMD. However, the women who exercised and did not use HRT also had significant improvements in greater trochanter BMD compared to no changes at this site for women who took HRT, but did not exercise. The group receiving neither HRT nor exercise lost bone. Both exercise groups had similar significant improvements in strength with no improvement in the HRT/no exercise group. These results suggest that although HRT can influence fracture risk through the improvement in bone, only exercise has the ability to reduce fall risk and consequently fracture risk through improvements in strength. Strengths of this study include the large sample size, the high compliance of the exercise program (79%) as well as the inclusion of calcium supplements for all participants. These results also highlight the importance of controlling for hormone status in exercise interventions, given the perceived additive effects of HRT and exercise on bone health in postmenopausal women. It should be noted that while each of these interventions were effective in improving bone and strength parameters, each protocol was conducted by research staff in a controlled setting. Therefore, the extent to which these exercise programs would translate into the community setting is unknown. In addition, the long-term sustainability (beyond 12 months) of these programs is also unclear.

The Erlagen Fitness Osteoporosis Prevention Study (EFOPS) examined the long term (3 year) effects of a multiple component exercise program on parameters of bone, muscle strength and general fitness in early postmenopausal osteopenic women (Kemmler, et al., 2002). One hundred thirty seven women with a DXA T-score between -1 and -2.5 SD self selected to either an exercise (n=86) or control (n=51) group. The exercise group was instructed to exercise four times a week, twice in a supervised setting and twice at home. The supervised training consisted of 65-70 minutes divided between warm-up and endurance, jumping, strength training and stretching. The endurance sequence consisted of 5 minutes of running, 5 min of games to promote unusual strain distributions and 10 minutes of low and high impact aerobic exercise at intensities ranging from 65-85% $HR_{max.}$ The jumping protocol was started 5 months into the intervention and consisted of rope skipping and multi-directional jumps (15 reps of each: closed leg jumps, jumping jack, diagonal jumps and lateral jumps with one-leg landing). The strength training protocol consisted of one day of resistance machines and one day of callisthenic/isometric and dumbbell exercise. For the first 7 months the resistance machine exercises consisted of horizontal leg press, leg curls, bench press, rowing, leg adduction and abduction, abdominal flexion, back extension, lat pulley, hyperextension, leg extension, shoulder raises and hip flexion. The intensity was gradually increased to achieve 2 sets of 15 reps at 60% 1-RM and 2 sets of 12 reps at 65% 1RM. After 7 months, this exercise session was rearranged to include a cycle of 12 week intervals of high-intensity training (2-4 sets per exercise at 70-90% 1-RM) followed by 4-6 weeks of regeneration (2 sets of 12-15 reps at 50-55% 1-RM). The first six months of the isometric exercise session included 2-3 sets of 6-10 second maximal intensity isometric exercises accompanied by three elastic band exercises (2-4 sets, 15-20 reps). After six months, bands were replaced by dumbbells and participants performed 4 exercises (wide-grip bench press, one-arm dumbbell rowing, squats/power cleans with weighted vests) at equivalent intensities to that of the machine based exercise. The two home sessions per week included isometric and elastic band exercises, along with rope skipping. Every 12 weeks, the intensity of the home exercises was increased.

After fourteen months, the women participating in the exercise program had significantly improved isometric strength of the trunk extensors, flexors and hip flexors (32%, 21% and 14%, respectively) as well as parameters of dynamic strength (increases in 1-RM: leg press, 43%; chest press, 45%; rowing, 16%; leg adduction, 22%). There were no significant strength changes among controls. Exercisers also had a significant increase in lumbar spine BMD compared to a significant decrease in spine BMD in controls (+1.3% vs. -1.2%, respectively). The control group lost bone at the total hip with no significant changes in hip bone mass among the exercisers. In addition, the exercise group also realized positive changes in aerobic capacity, insomnia and mood compared to negative or unchanged values in the control group.

After 26 months, fifty of the original 86 women in the exercise group and 33 of the original 51 women in the control group had data eligible for analysis (Kemmler, Lauber, et al., 2004). Similar to the one year data, the exercise group had positive strength changes compared to baseline data. However, at this time point, the control group had significant reductions in trunk and hip flexion as well as leg adduction strength. The control group also had a significant reduction in spine BMD compared to the initial increase followed by maintenance of BMD in the exercise group. The exercise group also had a significant increase in L1-L3 cortical bone area (as measured by quantitative computed tomography (QCT)) compared to baseline. Controls had a decrease in both trabecular and cortical bone resulting in significant differences between the treatment groups in both parameters. Additionally, both groups lost bone at the total hip, femoral neck and intertrochanter sites. However, the magnitude of change was much greater in the control group (-3 %) compared to the exercisers (-0.5%) resulting in significant differences between groups.

Results from the three-year follow up paralleled those of the two year time-point. (Engelke, et al., 2006). Seventy-nine percent of the original exercise group and 71% of the original control group completed the three-year follow up visit. Exercise compliance during the three years averaged 77% for group sessions and 61% for the home sessions. Three year changes in spine BMD were +0.8% for the exercise group compared to -3.3% for the control group ($p<0.5$). At the total hip, the exercise group maintained BMD compared to a significant reduction in the control group (-1.9%). Strengths of this study include the long duration of exercise training (3 years) and the utilization of QCT to assess bone changes allowing for an examination of patterns of bone loss that would otherwise be unavailable using DXA alone. However, QCT data was not collected at the 14-month time point and therefore short term changes in bone structure in response to this intervention remains unknown. Despite the relatively high compliance among the exercise group (average attendance of 2.4 sessions per week), the primary limitation of this study is the complexity of the exercise program which may be unrealistic for translation of the program to the community level. Furthermore, actual fall incidence was not measured so it is difficult to relate the true effect of the program on fall prevention.

In contrast to the complexity of the EFOPS program, Young et al (2007) conducted a trial evaluating the effects of a simple, yet novel, exercise program on strength, balance and bone (Young, Weeks, & Beck, 2007). Forty five postmenopausal sedentary women were randomized into three groups: line dancing, line dancing plus squats and line dancing and squats plus foot stamping. Each group met once per week for 12 months for a supervised class while the squats and squats plus stamping group performed the respective exercises five times per week at home. Following the intervention, there were no significant between or within group differences in DXA measured lumbar spine or hip BMD or in calcaneal broadband ultrasound attenuation (BUA). However, hip BMD was significantly correlated to stamping compliance (r=0.79), indicating the potential osteogenic influence of this particular exercise. A limitation of this study is the lack of a true control group as it is possible that between groups differences may have been observed when compared to a sedentary cohort. However, despite the lack of significant bone differences, significant improvements were observed in lower body strength (measured by squats endurance), and balance (measured via single leg stance and timed up and go scores) in all groups, findings beneficial for fall prevention.

The OSU Bone Research Laboratory has previously reported the beneficial effects of a lower extremity strength and balance exercise program involving weighted vests and jumping on hip bone mass and fall risk factors in older, postmenopausal women (Shaw & Snow, 1998). Eighteen postmenopausal women (age 66.2 ± 5.8) participated in an exercise class for one hour, three days a week for nine months. The exercise class consisted of 10 minutes of warm-up, 35 minutes of lower body resistance training and 10-15 minutes of cool down. The exercises performed included stepping, squats, chair raises, forward lunges, lateral lunges and toe raises. Resistance was achieved through the wearing of weighted vests and progressed from 5% of body weight initially up to 20% body weight added incrementally to the vests. After four months, jumping exercises were added and progressed from 1 jump per session to 28 jumps per session by the end of the intervention. Jumps were done without the vests. Twenty-two control participants were also recruited and maintained their current physical activity and dietary patterns. Bone mineral density was evaluated at baseline and at 9 months using DXA. In addition, muscular power, peak muscle strength and postural stability were also assessed. Results showed no change in hip BMD in either the exercise or control group after the 9 months. However, the exercise group had significant increases in physical performance. Specifically, hip abduction, knee extension and ankle plantar flexion strength all increased in the exercise group (30.3 ± 28.9%, 16.6 ± 16.5%, 22.2 ± 21.8%, respectively). The exercise group also exhibited positive changes in body composition with a decrease in leg fat mass and an increase in leg lean mass (3.5 ± 3.3%). Maximum power (measured by the Wingate anaerobic power test) also increased in exercisers compared to no change in controls. Finally, dynamic balance improved in the exercise group only. Similar to the results of Young et al (Young, et al., 2007) despite the lack of positive changes in bone mass, the exercise intervention was successful in reducing the risk factors associated with falling, although fall incidence in itself was not measured. These results are also in accordance with those of Villareal et al. (2003) who also failed to see changes in hip BMD among 28 frail elderly women in response to a 9-month exercise intervention that included balance exercises, high intensity resistance training (75-80% 1-RM) and endurance exercise (Villareal, et al., 2003). Similar to Shaw and Snow (1998), these women did realize positive changes in strength and body mass, despite the lack of change in bone at the hip. It should also be noted that a significant change in spine BMD was observed, a fact likely attributable to the fact that the spine seems to adapt quicker than the hip in response to exercise and that the majority of exercises performed were specific to the spine, rather than the hip. Spine BMD was not assessed by Shaw and Snow (1998), however, one would not expect to see an effect of this lower body exercise program on bone mass of the spine.

In a follow up study to that of Shaw and Snow (1998), Snow et al (2000) re-examined 18 of the original participants five years later (Snow, Shaw, Winters, & Witzke, 2000). Nine of the women had continued with the exercise program while the remaining nine were active, but not participating in weighted vest or jumping exercise. Interestingly, the women who continued with the exercise program had maintained or increased BMD at all measured hip sites (+ 1.54 ± 2.37%, -0.24 ± 1.02 %, -0/82% ± 1.04% for the femoral neck, trochanter and total hip, respectively) compared to loss of BMD in the control participants (-4.43 ± 0.93 %, -3.4 ± 1.09%, and -3.8 ± 1.02 %, respectively). These results indicate that although the exercise program was not effective at improving hip BMD after 9 months, long term participation (5 years) was effective at maintaining bone mass at the hip, implying that exercise interventions in older women may need to be of longer duration (> 9 months) if any bone changes are to be observed. However, at what point between 9 months and 5 years these effects are measurable is not known. Additionally, the high compliance of the exercisers even after five years, highlights the sustainability of this exercise intervention and its potential for community level translation although the limited sample size of this study limits the generalizability of the results. Furthermore, the researchers did not re-assess strength at the 5 year follow up, nor did they measure fall incidence. Consequently, the effectiveness of long term participation in this program on fall risk factors and fall incidence is still unknown.

While ample data exists to support the beneficial effects of controlled exercise trials on bone mass, there is limited research examining the effects of true community based exercise programs on skeletal health outcomes in older adults. Furthermore, the effect of long-term participation (> 3 years) in such programs is also unknown.

The effect of exercise on bone structure in older adults

To date, much of the literature on exercise and bone has focused on bone mass as the primary outcome variable used to assess bone strength. However, bone mass is only one component of bone strength and consequently is not 100% effective at predicting fractures. In fact, half of all incident fractures occur in women with BMD values above the diagnostic threshold for osteoporosis developed by the World Health Organization (WHO, osteoporosis defined by T score $\leq$ -2.5 standard deviations) (Boutroy, Bouxsein, Munoz, & Delmas, 2005). Therefore it is important to consider other outcome variables that may result in better prediction of fractures than BMD alone.

Bone geometry is another component of bone strength that may contribute to the likelihood of sustaining a fracture. Until recently, parameters of bone geometry and structure were difficult to measure, but with advances in technology, new methods have come available to estimate both structure and mass *in vivo*.

Hip Structure Analysis (HSA) is an application of DXA that allows measurements or estimates of parameters of bone strength. The software allows measurements of the bone mineralized cross sectional area (CSA), the cross sectional moment of inertia (CSMI, a measure of the distribution of mass about a neutral central axis), section modulus (Z, calculated from CSMI and inversely related to the maximum bending stress in a section), and buckling ratio (BR, a measure of cortical thinning). Hip Axis Length (HAL) which also can be derived from HSA analyses and is considered a marker for the ability of the femur to absorb the impact of a fall, has been found to be an independent predictor of hip fracture in older women, after adjusting for femoral BMD, age, height and weight (Faulkner, et al., 1993). Additionally, longer HAL was associated with lower femoral BMD in a population of postmenopausal women (Brownbill, Lindsey, Crncevic-Orlic, & Ilich, 2003; Kaptoge, et al., 2008) and therefore has the potential to aid in the prediction of fracture risk in conjunction with traditional measurements of bone mass. Kaptoge (2008) also found that neck shaft angle along with age to be the two strongest independent predictor of incident hip fractures (Kaptoge, et al., 2008). Femur Strength Index (FSI), a variable derived from GE Lunar HSA and a measure of the bone’s ability to withstand forces generated during a fall on the greater trochanter, was also found to be a significant predictor of hip fracture in postmenopausal women, independent of BMD and HAL (Faulkner, et al., 2006).

Exercise has the potential to alter bone structure. Adami et al (1999) examined the effect of resistance training on structural parameters of the wrist (measured via peripheral quantitative computed tomography, pQCT) in 234 sedentary postmenopausal women (mean age 65) (Adami, Gatti, Braga, Bianchini, & Rossini, 1999). Half of the women were randomly assigned to an exercise program consisting of two supervised 70-minute sessions each week where participants performed resistance exercises designed to target the wrist musculature. The remaining women were asked to maintain their current activity patterns. After six months there were no observable changes in hip, spine or radius BMC in response to the exercise intervention. However, there was a 2.8% increase in CSA in the exercise group as well as an increase in cortical area and cortical BMC of the ultradistal radius. This increase in cortical BMC is thought to result from a corticalization of trabecular bone, as trabecular BMC significantly decreased. This increase in cortical area and cortical BMC would theoretically serve to increase the bone's resistance to bending and therefore increase its resistance to fracture. A significant limitation of this study was the short duration (6 months) which was most likely insufficient to see DXA- evaluated bone changes. However, the positive changes in bone geometry suggest that exercise induced changes to bone structure may occur before any changes in bone mass can be seen. These results also emphasize the site specific nature of bone loading, as changes were seen only at the radius and not at the hip or spine in response to this wrist exercise protocol.

Lui-Ambrose et al (2004) also used pQCT to examine changes to bone geometry in response to exercise (Liu-Ambrose, Khan, Eng, Heinonen, & McKay, 2004). Ninety-eight osteopenic community-dwelling women (average age 79 $\pm$ 3 years) were randomly assigned to either a resistance training (2 sets, 6-8 reps at 75-80%1-RM, 9 exercises), agility (ball games, dance, obstacle courses) or stretching group (control group). Exercise sessions were 50 minutes in duration, conducted twice weekly for six months. Similar to Adami (1999), there were no DXA observed changes to bone in any group. However, the agility group increased cortical density of the 50% site of the tibia by 0.5% compared to losses of 0.4% in the stretching group. The resistance training group increased cortical density of the 30% site of the radius by 1.4% compared to a loss in the agility group of 0.4%. Also similar to Adami the duration of this intervention was likely too short to observe changes to bone mass (via DXA) at the hip or spine. Furthermore, the authors did not define the "9 key exercises" included in the resistance training intervention. Therefore it is possible that no exercises targeting the lower leg musculature were included, thus explaining the lack of change at the tibial site in this group. It should also be noted that pQCT only has the capacity to measure structural aspects of peripheral sites, (i.e. radius and tibia) and therefore cannot be used to evaluate the hip and spine, both of which are more meaningful in regards to osteoporotic fractures.

Unlike pQCT, HSA software does have the ability to evaluate the structural geometry of the hip in response to exercise. Using, HSA, Nikander et al (2005) compared BMD, CSA and Z in 233 competitive female athletes (age 20-28, sports include cross country skiing, weightlifting, cycling, orienteering, step aerobics, squash, speed skating, swimming, volleyball, soccer, and hurdling) to 30 nonathletic age-matched controls to evaluate the effects of varying loading modalities on bone parameters (Nikander, Sievanen, Heinonen, & Kannus, 2005). They found that women involved in all sports except for swimming and cycling had higher age-, body weight-, and height- adjusted BMD and CSA than non- athletic controls. In addition, section modulus was greater for athletes involved in all sports except for orienteering, weight lifting, cross-country skiing, swimming and cycling when compared to the non-athletes. Loading patterns between sports were stratified into five categories including high-impact, odd-impact, high-magnitude, low-impact, and non-impact loading. All loading types except for non-impact (such as swimming and cycling) had significant positive associations with BMD with the strongest association found for high-impact loads. Furthermore, high-impact and odd-impact loadings were more strongly associated with higher CSA than low-impact and non-impact loads. In regards to section modulus, high-impact and odd impact loads were associated with the greatest benefit, with moderate benefits for repetitive low impact loads and no difference between nonimpact high magnitude loads and controls. These results confirm the benefits of high impact exercises for bone strength at the hip in younger women via effects on bone mass and bone structure, both of which influence fracture risk.

Karinkanta, Heinonen, Sievanen, Usi-Rasi et al (2007) examined the effects of a multi-component exercise program on parameters of bone mass and structure in older women using both HSA and pQCT. (Karinkanta, et al., 2007). One hundred forty- nine home dwelling elderly women (age 70-79) were randomized into groups participating in either resistance training (STRENGTH), balance training (BAL), a combination of resistance, balance and jump training (COMB) or a control group. The resistance training protocol consisted of 3 sets of 8-10 repetitions at 75-80% of 1RM of large muscle group exercises (leg press, rowing, hip abduction, hip extension, calf raise and rising from a chair using a weighted vest). The balance/jump program consisted of aerobics or step aerobics routines including jumps as well as changes of direction exercises. The combination program consisted of alternating weeks with the resistance training and balance/jump programs. Each exercise group met for one hour, three times a week for 12 months. DXA was used to measure BMD and BMC of the femoral neck. HSA software was used to calculate section modulus and periosteal diameter. In addition, pQCT was used to assess the structure of the radius and tibial shaft. After twelve months all exercise groups had significantly greater gains in isometric leg extension force compared to the control group. The BAL and COMB groups had significant improvements in figure 8 run time (a measure of dynamic balance and mobility). The COMB group had improvements in physical function compared to the control group. There were no differences in femoral neck BMC between any groups. The STRENGTH group had favorable changes in femoral neck section modulus indicating greater resistance to bending. The COMB group was observed to have better tibial shaft structure (stronger) than the control group. Thus, both the COMB and STRENGTH groups had different but beneficial responses to their respective loading protocols. It should be noted that all participants were highly active outside of the intervention, with women in the control groups exercising an average of 7 hours per week. This high level of physical activity may confound the ability to see an effect from the exercise intervention alone. Another limitation of the study is the relatively low compliance to the exercise program (67%). Furthermore, although the exercise intervention was 12 months, it is still possible that this duration may not have been long enough to elicit changes in bone mass in this elderly population, although minor changes in bone structure were observed. Nonetheless, these results, along with those of Adami (1999) and Lui-Ambrose (2003), suggest that bone structure may adapt sooner than bone mass in response to exercise and that changes in structure can be independent of changes in mass.

Uusi-Rasi, Kannus, Cheng et al (2003) also examined the effects of exercise on bone structure using both HSA and pQCT (Uusi-Rasi, et al., 2003). In a randomly assigned placebo controlled double blind study, one hundred fifty two early postmenopausal women (mean age 53) received either 5mg/day of the bisphosphonate alendronate or a placebo. Participants were then randomly assigned to either an exercise or control group. The exercise program consisted of multidirectional jumps and calisthenic exercises performed in a supervised setting three times per week for 12 months. Alendronate treatment increased BMC of the femoral neck and lumbar spine compared to no changes as a result of the exercise intervention. There were no changes in femoral neck section modulus from either exercise or alendronate therapy. However, the exercise program did result in increases in section modulus and cortical area of the tibia (measured via pQCT) which was not observed from alendronate treatment. There were no additive or synergistic effects between exercise and alendronate. Furthermore, the exercise group had improvements in leg extensor power (measured via vertical jump test), dynamic balance (measured via figure 8 run time) and cardiorespiratory endurance (measured from 2km walk test). There were no physical performance changes as a result of alendronate treatment. These results indicate that both exercise and bisphosphonate treatment can influence bone, but they likely work through different mechanisms. These results also agree with those of others (Adami, et al., 1999; Karinkanta, et al., 2007; Liu-Ambrose, et al., 2004) that suggest changes in bone mass are independent of changes in bone structure. One limitation of this study is the low compliance associated with this exercise protocol. Specifically, the average attendance was 1.6 sessions per week with only 32 out of 82 participants attending more than 2 sessions per week. Therefore the overall exercise stimulus may not have been enough to elicit changes in bone mass. Furthermore, over 25% of exercise participants reported some adverse event/injury in association with the exercise program. In light of this, the palatability and long-term sustainability of this program is suspect.

Considering the relatively recent advancements in techonologies that assess bone structure, more work needs to be done to clarify the true effects of exercise programs on bone structural parameters. This is particularly true for older adults as this is a relatively understudied population in regards to bone structure.

Dose Response Relationship between exercise and bone health

While much research has focused on defining the appropriate type of exercise necessary to elicit bone adaptations, the amount of exercise necessary for bone health among postmenopausal populations is still unclear. Devine et al (2004) examined the relationship between varying levels of physical activity and calcium intake on DXA measured BMD in 1363 elderly (age 75$\pm$ 3) women (Devine, Dhaliwal, Dick, Bollerslev, &

Prince, 2004). Women were separated into tertiles of physical activity (<55kcal/day, 55-169 kcal/day, >169kcal/day) and calcium intakes (<792 mg/day, 792-1053 mg/day, >1053 mg/day) and BMD was compared between groups, controlling for age, weight, alcohol consumption and cigarette smoking. The highest tertile of physical activity had greater total hip, femoral neck and greater trochanter BMD compared to the moderate or low physical activity tertiles, after adjusting for calcium consumption. The two highest tertiles of calcium consumption had greater BMD at the trochanter (after adjusting for physical activity) compared to the lowest tertile, indicating an additive effect of calcium and physical activity at this site. It should be noted that the physical activity quantification was very general ("do you regularly participate in any sports or vigorous physical activity") and thus not stratified by type of activity or activities that might have differing osteogenic potentials (e.g. jumping versus swimming). Furthermore, this study only assessed current physical activity patterns; therefore a dose-response effect from historical physical activity could not be determined. Nevertheless this work suggests that participating in activity resulting in moderate (>169kcal/day) energy expenditure is positively related to hip bone density.

Nurzenski, Briffa and Price (2007) found a similar relationship between physical activity and calcium on parameters of bone structure in 1008 elderly postmenopausal women (age 73 $\pm$ 4 years) (Nurzenski, et al., 2007). Similar to the methods in Devine et al, women were stratified into tertiles of physical activity (<65.6 kcal/d, 65.6-175.5 kcal/d, >175.6 kcal/day) and tertiles of calcium consumption (<780 mg/day, 781-1038 mg/day, >1039 mg/day). A dose response was observed between physical activity and

CSA of all three HSA regions of interest (ROI, narrow neck, intertrochanter, femoral shaft) in addition to section modulus and HSA derived BMD of the narrow neck and intertrochanter ROI. Specifically, physical activity levels greater than 65.6 kcal/day were considered most effective. Unlike the results of Devine et al, no dose response relationship was observed between calcium consumption and bone. However there was an additive effect of physical activity and calcium on HSA-derived BMD and CSA of all regions, and section modulus of the narrow neck and intertrochanter ROIs. These results agree with those of Ashe et al (2008) who found that minutes of moderate to vigorous physical activity (assessed via accelerometry) within the previous 7 days was positively associated with peak muscle power which in turn was associated with tibial bone strength in community dwelling elderly women (age 65-74) (Ashe, Liu-Ambrose, Cooper, Khan, & McKay, 2008). Similar to Devine et al, these two studies are also limited by the general (i.e. not bone specific) classification of physical activity and that only current levels of physical activity were considered.

Uusi-Rasi, Sievanen, Pasanen et al (2008) also examined the relationship between differing levels of physical activity and calcium on bone structure (Uusi-Rasi, Sievanen, Pasanen, Beck, & Kannus, 2008). Two hundred and nineteen women (92 premenopausal, 127 postmenopausal) with contrasting levels of physical activity and calcium consumption took part in a 10 year prospective observational study. Women were considered physically active if they “participated in vigorous activity causing enhanced breathing more than twice a week” and were considered to have high calcium if they consumed more than 1200 mg/day. Women were considered inactive if they participated in “light or minimal daily physical activity causing only a slight elevation in heart rate” and were considered to have low calcium if they consumed less than 800 mg/day. Postmenopausal women in the high activity groups had 6.9% and 5.5% greater femoral neck and trochanter BMC respectively, after the 10 year follow up. Additionally, high physical activity resulted in 6.8% and 9.6% greater CSA and section modulus of the narrow neck ROI, respectively. No effect was found for differing levels of calcium consumption. The fact that physical activity was not specified by type or amount other than a binary variable (heavy versus light) is a limitation of this study as one cannot decipher how much physical activity was needed to elicit the protective response. In addition, baseline data for the low physical activity group indicated that this group walked an average of 8000 steps per day and therefore cannot be considered sedentary. It is possible that greater differences would be seen among groups with larger differences in physical activity.

In contrast to Uusi-Rasi (2008) and Nurzinksi (2007), Kemmler (2004) found no relationship between habitual physical activity and BMD in a population of early postmenopausal osteopenic women participating in the EFOPS study (Kemmler, Weineck, Kalender, & Engelke, 2004). Physical activity patterns were assessed via questionnaire from which an activity intensity index (AII, habitual physical activity from housework, occupation or gardening), a weight bearing index (including all activities from the AII done in a standing position) and an osteogenic activity index (relating activities to their osteogenic potential) were derived. They found that the AII, muscle strength and cardiorespiratory endurance had little to no relationship with BMD, biomarkers of bone turnover, or broadband ultrasound attenuation (BUA) after adjusting for age and body weight. There was a minimaly significant relationship (r^2=0.27) between the osteogenic index and calcaneal BUA. While these results suggest no effect of regular exercise on bone health, it should be noted that these women were currently and historically inactive, seeing that women were excluded from study participation if they had been involved in athletic exercise within the previous 20 years. Furthermore, most physical activity that was reported was low impact in nature (swimming, cycling) and therefore carrying low osteogenic potential. Consequently, the lack of a relationship between this low level of physical activity and bone health is not surprising. These results do, however, give further strength to the notion that exercise must be specific to bone to produce an effect.

A common limitation to the aforementioned studies is the narrow focus on just current levels of physical activity. Kaptoge, Dalzell, Jakes et al (2003) attempted to address the dose response relationship of past physical activity on bone mass and structure in an elderly population of 423 men and 436 women (age 72 $\pm$ 3) (Kaptoge, et al., 2003). Historical physical activity after the age of 50 was quantified as a binary variable (heavy versus light). Classification of current physical activity included number of trips up stairs per day, hours per week spent in non high impact activities and hours per week spent in weight bearing activity. They found that, in this population, body weight and height were the strongest predictors of BMD, CSA and section modulus. Additionally, heavy physical activity after the age of 50 was associated with greater section modulus and CSA, especially at the narrow neck ROI, and this relationship was in a dose response manner as low physical activity had no effect. Higher lifetime physical activity (assessed on a standard deviation basis) was associated with larger sub-periosteal diameter at the intertrochanter and femoral shaft ROI. Interestingly, there was a stronger relationship between physical activity and section modulus compared to the relationship between physical activity and hip BMD. This supports the notion that exercise may improve bone strength through mechanisms independent of bone mass. Limitations of this study include the lack of a nutritional assessment as well as the general classification of physical activity (heavy versus light) which is not bone specific. However, this is one of the few studies to examine past activity in regards to the relationship between exercise and bone health.

While there appears to be a relationship between current levels of general physical activity and bone health among older adults, these studies have done little to address the relationship between past exercise participation and current skeletal health. In particular the effects of long-term participation in bone specific exercise on bone mass and structure is still unknown. Specifically, it is unclear whether there is an optimal duration for participating in bone loading exercise programs which is necessary to maximize skeletal benefits. More studies using objective measures of loading and activity dose are necessary to determine the optimal exercise prescription for skeletal health.

Exercise to improve function and reduce fall risk factors

As previously mentioned, the factor of risk pertains to the skeleton's ability to resist a fracture and is dependent on both the strength of the skeleton (i.e. bone mass and bone structure) but also on the forces applied to the bone. In most scenarios, forces transmitted to the skeleton that are high enough to elicit a fracture result from a fall. In fact, the magnitude of force generated from a fall has a larger influence on determining whether a bone breaks than does the strength of the skeleton. For example, a one standard deviation decrease in BMD will increase hip fracture risk two fold, whereas a fall in the sideways direction will increase the risk of hip fracture five to six fold (Jarvinen, Sievanen, Khan, Heinonen, & Kannus, 2008). In light of this, it has been suggested that falling and not osteoporosis is the strongest risk factor for fractures (Jarvinen, et al., 2008). Some risk factors for falls are extrinsic and easily reduced with simple environmental modifications, such as the removal of throw rugs and improved lighting. However, there are many other risk factors that are intrinsic to the individual such as poor strength, balance, and poor vision (Jarvinen et al, 2008). Exercise has the capacity to improve risk factors for falls such as strength and balance and therefore decrease fracture risk even in the absence of bone improvements. Furthermore, changes in strength that can improve fall risk can be realized relatively quickly, in contrast to the long period of time needed to elicit bone adaptations in older individuals. Therefore, exercise programs can be a viable alternative to other treatments, such as drug therapies, for reducing fractures.

Chang et al (2004) performed a meta-analysis evaluating the efficacy of multiple intervention modes for the prevention of falls in older adults (Chang, et al., 2004). Specifically, they compared randomized clinical trials employing programs involving multifactorial fall risk assessment and management, exercise, environmental modifications or education. From the forty studies included in the meta-analysis, results indicated that programs with multifactorial fall risk assessment and management had the greatest benefit in reducing both fall risk (OR 0.86) and monthly rate of falling (OR, 0.63). The most commonly assessed risks were medications, poor vision, environmental hazards and orthostatic blood pressure. Exercise also had a statistically significant benefit on fall risk (OR, 0.86), but with no significant benefit on the monthly rate of falling. There were no clear differences between different types of exercise programs. Education and environmental modifications were employed in the smallest number of studies and did not show any clear risk benefit. To better understand the relationship between exercise and falls in the absence of other treatments, another meta-analysis examined the effects of exercise-only interventions on fall risk (Sherrington, 2008). Evaluating 44 randomized controlled trials (RCT), the authors found a 17% reduction in risk of falling associated with the exercise interventions. In contrast to Chang et al (2004) who found no differences in varying modes of exercise for falls, multiple regression revealed that, of the varying components included in the different trials, high-challenge balance training, exercise dose greater than 50 hours (total exercise accumulated in interventions ranging from 3-20 months) and the absence of a walking as a primary training component of the program explained 65% of the inter-trial variability in fall reduction. Other exercise components such as strength, endurance or flexibility training had no significant effect on the risk of falling. These results confirm that exercise can be an important factor in reducing the risk of falls, provided that the stimulus is specific to target balance and that the dose of exercise is high. Therefore, exercise may have potential to decrease fracture risk through avenues beyond skeletal adaptation.

One limitation of many research studies involving exercise and falls and/or bone is that improvements seen under controlled laboratory conditions may not persist once the exercise program has been translated to the community level. Carter, Khan, McKay, Petit, Waterman, et al (2002) examined the effectiveness of the community based Osteofit class in improving risk factors for falls in older osteoporotic women (Carter, et al., 2002). Eighty women (average age 69) with diagnosed osteoporosis were randomized to either the Osteofit program or a control group. The exercise program, which was held at two community centers, consisted of 40 minutes of 6-16 strengthening and stretching exercises employing free weights and elastic bands. After 20 weeks of the intervention, the exercise group had significantly improved measures of knee extensor strength and dynamic balance (measured by figure-eight walking velocity), both of which are known risk factors for falls. There was a trend toward a significant decrease in measures of postural sway in the exercise group only. There were no differences in the actual rates of falling between groups (7 total falls in exercise group versus 8 falls in control group), although the duration of the intervention may have been inadequate to appropriately assess fall incidence. This program illustrates that positive effects from exercise programs can be obtained even in a non-laboratory community-based program. In addition, the exercise compliance was high (86%) among the participants and further supports the benefits of community-based exercise programs. However, measures of bone health were not evaluated in this population, so it is impossible to know if such a program could influence both bone strength and fall risk.

While the Osteofit program did not influence fall rates among participants, the Otago Program is a widespread exercise program proven to reduce fall incidence in elderly individuals (Robertson, Campbell, Gardner, & Devlin, 2002). This program, consisting of progressive muscle strengthening, balance training and walking, is home based, individually tailored to the participant and conducted by nurses and physical therapists. Participants are encouraged to perform the exercises three times a week and to walk an additional two times each week. Five home visits are usually conducted within the first 12 months and then every 6 months thereafter to monitor progress and provide support. Robertson et al (2002) performed a meta-analysis of four controlled trials (Campbell, Robertson, Gardner, Norton, & Buchner, 1999; Campbell, et al., 1997; Robertson, Devlin, Gardner, & Campbell, 2001; Robertson, Gardner, Devlin, McGee, & Campbell, 2001) that employed this protocol in 1016 community dwelling men and women (age 65-97) over a period of 1-2 years. Results indicated participants in the exercise groups had greater balance (measured via the four test balance scale) and greater lower body strength (measured by chair stands) after the interventions compared to no change in balance score and reduction in strength in the control groups. In addition, self-reported fear of falling increased among control participants, with maintenance of baseline levels for the exercise participants. Most notably however, was that the number of falls was 35% lower in the exercise group and the probability of falls was also lower among exercisers. Furthermore, the exercise groups reported fewer total injuries resulting from falls compared to the control groups. Subgroup analysis indicated the exercise participants over the age of 80 had fewer falls and significantly fewer injuries from falls compared to younger cohorts indicating the efficacy of this program, even among the oldest populations. Although this program is proven to be both popular and effective, the need for health care professionals to administer and individualize the protocol may be a limitation, as this may limit its accessibility. Furthermore, the home setting of the exercises, while convenient, also reduces the social interaction that can be a benefit of group exercise programs and may impact motivation to permanently sustain the exercise habit. Nevertheless, the primary strength of this study was its ability to prospectively monitor both fall risk and fall incidence and injuries as a result of a specific exercise program, a factor that many interventions are underpowered to do.

Barnett et al (2003) also examined fall risk factors, as well as fall incidence, in response to a 12- month community based exercise intervention (Barnett, Smith, Lord, Williams, & Baumand, 2003). One hundred sixty three people (aged over 65) who were identified by their physician as at risk of falling were randomized to either a control or exercise group. The exercise protocol consisted of one weekly session including aerobic (fast walking), balance (tai chi, stepping practice, change of direction exercises, dance steps, catching/throwing a ball) and strength exercises (sit to stand and wall press-ups, as well as resistance band upper and lower body exercises) performed in a group setting. Participants also performed similar exercises at home at least once a week. Fall risk was measured by knee extension and ankle dorisflexion strength, simple reaction time, sway, walking speed, leaning balance, step-up tests and sit-to-stand performance. At the end of the intervention, the exercise group performed significantly better than the controls in three measures of balance (postural sway on the floor with eyes open and closed and coordinated stability). There were no differences in strength, quality of life, fear of falling, reaction time or walking speeds. Like the results from the Otago program, the exercise group had sustained 40% fewer falls during the intervention than the control group, and of the falls sustained, fewer falls resulted in injury. Further, fewer subjects in the intervention group reported two or more falls, compared to the control group. These results are also in accordance with those of Madureira, Takayama, Gallinaro, Caparbo, Costa and Pereira (2007), who found that 12 months of balance training (one supervised and one home session a week) was effective at reducing fall incidence in elderly women with osteoporosis (Madureira, et al., 2007). Huang et al (2010) also found that Tai-Chi Chuang plus education about falls was an effective strategy to reduce fall incidence and functional fall indicators (functional reach, timed up and go, environmental modification) in elderly adults (age 71-72) after 5 months intervention and that the combination of the two methods was more effective than either Tai-Chi or education alone. After 12 months follow up, however, Tai-Chi alone, education alone, and Tai-Chi plus education all resulted in a significant decrease in fall incidence and risk of falling compared to a control group. (Huang, Liu, Y., & Kernohan, 2010). Together, these studies indicate the efficacy of exercise programs that target balance in improving both fall risk factors as well as fall incidence of at-risk individuals. These programs also highlight the popularity of community based exercise classes, as in all cases, exercise adherence and program enjoyment in older adults was high while yielding positive outcomes in regards to falls.

StrongWomen (SW) is another community-based exercise program designed to influence fracture risk through increasing strength, balance and bone in older women

(Nelson, 2006) and has enjoyed profound success in popular culture. The program includes training using hand and ankle free weights, vertical jumping (premenopausal participants only) and weight bearing aerobic exercise and is taught by community members specifically trained in the program. This program is based on laboratory interventions that have been shown to influence bone and the fall risk factors of strength and balance. Specifically, Nelson, Fiatarone, Morganti, Trice et al (1994) conducted a 12 month intervention with postmenopausal women (n=40) employing high intensity upper and lower body strength training using resistance machines (>80% 1-RM) and found that the exercise participants had maintained lumbar spine and hip BMD while non-exercising control participants lost bone (Nelson, et al., 1994). The exercise participants also experienced significant increases in muscle mass, muscle strength (1-RM) and balance (timed backwards tandem walk) compared to controls, who experienced decreases in these measures over the course of the intervention. However, fall incidence, fall history or fear of falling were not evaluated, so the direct effects of this program on falls are unknown. More recently, the SW program has been adapted to include upper and lower body exercise with resistance provided by dumbbells and ankle weights and incorporates weight bearing aerobic activity. Since 2003, SW has been widely disseminated, with active StrongWomen programs in 38 states with a total of over 6800 participants (Seguin, et al., 2008). Despite the popularity of the program, little data are available to determine the effectiveness of the SW protocol in its current form on parameters of strength, balance, fall incidence and bone as offered in the community setting. Therefore, it is difficult to compare SW to programs such as Otago, BBB and Osteofit, which have all been translated in the forms in which they were originally conducted. Nevertheless, the

SW program can serve as a model for effective widespread dissemination of exercise programs.

Exercise also has the capacity to maintain and/or improve physical function in older adults, thereby improving independence and quality of life. Dobek, White and Gunter (2007) found that an exercise program mimicking activities of daily living (ADL's) was effective at improving parameters of physical fitness (arm curl repetitions, chair stand repetitions and time in 6 min walk), as well as parameters of physical function (measured by the physical performance test and physical functional performance-10) with greater improvements seen in function in comparison to fitness (Dobek, White, & Gunter, 2007). de Vreede et al (2006) also found that an exercise program involving functional exercises had a greater impact on levels of physical function than a resistance training exercise program (de Vreede, Samson, van Meeteren, Duursma, & Verhaar, 2005), emphasizing the principle of specificity of training. Furthermore, Littbrand et al (2009) examined a functional weight bearing exercise program in 191 residential care facility residents with disability and found that the exercise program was associated with maintenance in ADLs in participants with dementia compared to loss in ADL function in controls, but these differences were not maintained 3 months after the supervised program ended. In addition, the program was associated with improvements in indoor mobility among all exercisers with and without dementia. This study was limited in terms of generalizability in that the program was individually tailored and the exercises were conducted via physical therapists and occupational therapists, which would hinder the translation of these results into the community. Nevertheless, these emphasize the importance of implementing exercise that can be sustained if long term benefits are to be achieved.

While performing specific functional tasks is ideal for functional improvement, traditional exercise has also been found to improve function. For example, in the bone and balance program designed by Karinkanta et al (2007) (program details explained above), the groups receiving the combination of resistance training and balance exercises had significant improvements in self reported physical function in comparison to the non-exercising control group (Karinkanta, et al., 2007). This suggests that by improving the physical domains associated with function, such as balance and strength, improvements in function can also occur. This is important because the loss of physical function is associated with declines in independence and increased risk/need for entering long term care such as nursing homes, thereby increasing the economic and social burden associated with aging. Therefore the potential for exercise to maintain function and therefore maintain independence further accentuates the benefit of exercise programs for older adults to influence not only bone and falls, but overall quality of life.   However, it should be noted that neither of these functional programs were conducted in a true community setting. Furthermore, the aforementioned community based fall prevention programs did not include exercises designed to target skeletal health. Therefore, the need exists to evaluate the potential for multi-component community based exercise programs to improve both bone and function *and* to reduce falls.

Quantification of Physical Activity Dose

As mentioned previously, it is essential for effective exercise trials to be translated out of the laboratory setting and into the community in order for exercise research to influence public health. However, it also crucial to understand the amount of physical activity associated with evidence based trials and community exercise classes so that these programs can be evaluated against public health activity recommendations. Unfortunately, a limitation of many exercise studies is the failure to *objectively* measure their associated exercise dose.

For bone loading protocols, the measurement of ground reaction forces (GRF) allows an objective assessment of bone loading forces associated with impact exercises. Bassey and Ramsdale (1995) measured the vertical GRF associated with a protocol of heel drops in postmenopausal women and found this exercise to be associated with loading forces ranging from 2.1-3.6 x body weight (BW) (Bassey & Ramsdale, 1995) and that compressive forces, as measured by femoral implant, were within 5% of the GRF. It should be noted that although 12 months of 50 heel drops per day failed to produce changes in hip BMD and therefore the forces from heel drops may be inadequate to stimulate skeletal adaptation. Bassey and Littwood (1997) also compared GRF to forces measured using a femoral implant and found that implant forces were 1.5-3 times higher than GRF during jumping and running. The larger discrepancy between implant and ground forces observed between jumps versus heel drops is likely attributed to forces generated by muscle pull on the femur during the higher intensity exercise, while less muscle activation would occur during heel drops. LIkewise, Young, Weeks and Beck

(2007) characterized the forces associated with an exercise intervention including foot stomping, where stomping compliance was positively correlated to hip BMD after 12 months (Young, et al., 2007). In comparison to heel drops, they found that stomping elicited approximately twice the GRF as heel drops (4.8x BW versus 2.3x BW) and may therefore have a greater osteogenic potential. In addition, Uusi-Rasi, Kannus Cheng, Seivenen et al (2003) reported GRF values of 2.1-5.6 x BW from an aerobic jumping (drop jumps off 10-25 cm foam fences) and aerobic stepping protocol, exercises that were associated with enhancement of tibial structure, but not BMD in postmenopausal women (Uusi-Rasi, et al., 2003). Winters and Snow (2000) also found GRF of 4-5xBW from a protocol of jumping and lower body resistance training that was effective at improving BMD in premenopausal women (Winters & Snow, 2000). The results of these studies suggest that GRF greater than 4x BW may have the greatest osteogenic impact. Such objective reporting of exercise dose allows for a clear comparison between various protocols and can aid in the understanding of appropriate exercise for skeletal health. Unfortunately, such clear reporting is not the norm among most bone studies.

Vainionpaa, Korpelainen Vihriala et al (2006) used a different approach to measure exercise intensity related to bone loading, by employing accelerometry to differentiate the effects of varying levels of exercise intensity on 12-month bone changes in premenopausal women (Vainionpaa, et al., 2006). One hundred and twenty women were randomized to either an exercise or control group and BMD was measured at baseline and 12 months. The exercise intervention consisted of step aerobics, stomping, jumping and running for 60 minutes, three times a week. All study participants wore a specialized accelerometer that measured accelerations in response to varying exercise patterns. The acceleration of gravity (1g) was subtracted from all scores so that standing was associated with accelerations of 0g. These measurements of accelerations were found to highly correlate with GRF forces (R=0.735). Accelerations were stratified into the following quintiles associated with specific activities: 0.3-1.0g, walking; 1.1-2.4 g, stepping; 2.5-3.8g, jogging; 3.9-5.3g, running and jumping; 5.4-9.2g, drop jumping. The accelerometers were programmed to capture the daily number of peak accelerations that occurred in each quintile. Results indicated participants in the exercise group had significantly higher number of total accelerations in the high intensity ranges compared to controls. Furthermore, the number of daily accelerations above 3.9 g was significantly related to 12-month BMD change at the femoral neck and greater trochanter regions of the proximal femur. Only accelerations above 5.4 g were associated with changes in L1 BMD. Additional analyses indicated that number of accelerations above 3.9 g was also a significant predictor of 12-month change in mid-femur cortical thickness and bone circumference, as measured by QCT , with total number and intensity of impact being the strongest predictors of changes in bone geometry, explaining approximately 36% of all variance (Vainionpaa, et al., 2007). These results objectively show that higher impact forces are associated with the greatest benefit to skeletal health in premenopausal women. However, whether this threshold for bone adaptation remains unchanged for older populations is yet unknown. Furthermore, although this technique was correlated with GRF, due to the measurement differences, direct comparisons between these osteogenic thresholds and the exercises employed by other protocols is also unclear. More work employing these newer techniques is warranted.

As with bone loading forces, the lack of objective measurement of physical activity dose associated with community programs is also lacking in regards to other disease states, such as cardiovascular disease. Despite the popularity of many community programs, it is unknown whether these programs provide the appropriate amount of physical activity to meet current national guidelines (DHHS, 2008; Nelson, et al., 2007). This is particularly true for older adults, as the use of objective devices, such as accelerometers, is scarce among this population. However, there are limited studies assessing physical activity patterns through accelerometry among the elderly. For example, Ayabe, Yahiro Yoshioko et al (2009) evaluated the free living physical activity patterns of 507 adults aged 19-69 over 7 days (Ayabe, et al., 2009) using the Lifecorder uni-axial accelerometer. They found that the time spent in either moderate (3-6 METS) or vigorous (>6 METS) physical activity was significantly lower in the oldest age group in comparison to the younger groups. They also found that the time spent in moderate to vigorous physical activity (MVPA) was negatively correlated with age for both men and women. Further, they found that time spent in MVPA per total number of daily steps significantly decreased with age, indicating a shift toward lighter intensity physical activity. A limitation of this study is that they did not include individuals over the age of 70 and therefore the relationship between exercise amount and intensity in the later decades is still unknown. Further, a limitation of all accelerometers is that they assess absolute rather than relative exercise intensity and they do not measure upper body movement. Therefore it is possible to perform an activity that elicits a cardiovascular response, such as in upper body movement, without concomitant recording by the accelerometers. This could also be the case for an older adult with low relative fitness, where an activity classified as light (<3 METS) by the accelerometer may be adequate to produce sufficient elevation in heart rate for achievement of health benefits. However, Aoyagi, Park, Watanabe, Park et al (2007) found that spending between just 15-20 minutes a day above 3 METs (measured via accelerometers) was significantly correlated with measures of functional health in older Japanese adults and that the relationship was strongest among adults between 75-89 (Aoyagi, Park, Watanabe, Park, & Shephard, 2009). Although this duration does not meet the current national guidelines for physical activity (Nelson, et al., 2007), positive health outcomes in regards to strength and balance, factors important for functional fitness were still realized. This emphasizes the importance of even small levels of physical activity for the elderly. It is possible if a different cutoff for moderate intensity was used (i.e. <3 METS), greater levels of PA may have been observed.

Addressing the intensity discrepancy for older adults, Copeland and Esliger (2009) established modified cut points for activity counts based on the average counts associated with walking on the treadmill at 3.2 km/hr, a workload associated with a measured oxygen consumption of 13 ml/kg/min, or 3.7 METs (Copeland & Esliger, 2009). This workload resulted in a mean of 1,041 counts/min, which was well below the threshold cutpoint of 1,952 that is typically used to delineate moderate intensity (3 METS) for young adults. Using this modified cutpoint, they evaluated the general activity patterns in 38 free-living older adults (age 69.7 $\pm$ 3.5 yr) and found that participants accrued 68 $\pm$ 32 minutes per day of physical activity above the threshold. This value was significantly higher than what was recorded using the traditional cut-point for younger adults (29 ± 22 min/day), emphasizing the potential for accelerometers to underestimate physical activity in older populations. Results also indicated that of the MVPA recorded, 66% of time accrued was sporadic lasting less than 10 minutes, and therefore participants' activity level was not consistent with current physical activity guidelines that recommend aerobic activity should be accrued in bouts ≥ 10 minutes in duration in order to maximize health benefits ((DHHS, 2008; Nelson, et al., 2007). A strength of this study was the high compliance with more than 90% of participants wearing the accelerometer for the entire 7 days, indicating that these devices are non-invasive and well tolerated by older adults.

Pruitt, Glynn, King, Guralnki et al (2008) also established modified cutpoints to utilize accelerometry for older adults (Pruitt, et al., 2008). Average activity counts were evaluated during a 400 m walk and used to create individual thresholds ($Thresh_{IND}$) to delineate "meaningful activity" in 106 elderly participants (age 70-86) at risk for mobility disability. Participants were randomized to engage in structured home-based and supervised physical activity classes or to participate in a non-exercise "successful aging" program for 12 months. Participants wore the accelerometers (Actigraph) for 7 days at the 6 month and 12 month time period of the intervention and data from both time points were combined. There was a trend toward increased time spent above the $Thresh_{IND}$ in the exercise group compared to the non-exercise groups (18.5 ± 27.2 min/day versus 11.0 ± 11.4, min/day, p=0.08). There were also significantly more activity bouts lasting longer than 10 minutes in the exercise group compared to the non-exercise class, indicating the ability of the structured exercise program to positively influence the physical activity patterns of these older adults. While both the aforementioned studies (Pruitt et al 2008; Copeland et al 2009) addressed the potential for underestimating physical activity among older adults using accelerometers, it should be noted that their methods for doing so varied widely. To date, there is no standard in the literature for how to consistently address this issue across elderly populations or across accelerometer devices. Furthermore, establishing individualized thresholds, particularly those based on directly measured oxygen consumption, may not be realistic for evaluation of community based exercise programs as the process would be both costly and time consuming for large populations. Therefore more work, either comparing accelerometry to relative measures of intensity such as heart rates, or by establishing an industry wide modified threshold to use for research on older adults is necessary. In addition, it is also necessary to utilize these objective measures of physical activity quantification to evaluate the exercise accrued in response to specific community exercise programs, rather than just free living activity patterns, in order to understand the influence of such programs on overall health. To date, such research, particularly among older adults, is scarce.

Rationale

The research involving exercise and bone clearly suggests that exercise has the capacity to influence skeletal strength and therefore decrease fracture risk through improvements in both bone strength (mass and structure) and fall risk factors. However most published research studies showing this association have evaluated laboratory-based or researcher-led exercise programs, some of which were very complicated in design (Kemmler et al 2004), had poor compliance with high rates of injuries (Uusi-Rasi et al 2003), or had poor reporting/descriptions of the actual exercise programs. In addition, few exercise interventions last longer than 12-18 months, although there are exceptions to this (Engelke et al 2006; Robertson, 2002). In order to promote exercise for the prevention of osteoporosis, the exercise program must be able to successfully translate out of the laboratory and into the community so that it is available for those individuals at risk for falls and fractures. For this to happen, the exercise must be safe, enjoyable and sustainable in order to keep individuals participating. This is particularly important as gains in bone are lost once the exercise stimulus has ceased (Englund, Littbrand, Sondell, Bucht, & Pettersson, 2009). Therefore, the need exists to design and evaluate true community based (i.e. real world) exercise programs for the prevention of both falls and fractures. Although there have been studies examining community based fall prevention programs, to date, very few studies have focused on *bone specifi*c community-based exercise with the intent of both improved bone and reduced fall risk factors.

Furthermore, it is well known that the majority of older adults do not accumulate the recommended amount of physical activity to maintain general health (Nelson, et al., 2007) . What is also unknown is the precise amount of physical activity that older adults accrue during community based exercise programs as objective measures of exercise amount and intensity are often unevaluated and/or unreported. Consequently a need exists to perform objective evaluations to determine the amount and intensity of physical activity associated with community based exercise programs for older adults in order to evaluate these programs against the guidelines for physical activity for Americans.

PURPOSE

The purpose of this study was to evaluate *Better Bones and Balance,* a bone- and falls - specific community exercise program based on research from the Bone Research Laboratory at Oregon State University (Shaw and Snow 1998, Snow et al 2000). This program has shown successful translation (in terms of enjoyment and sustainability) out of the laboratory and into the community. From the original 18 exercise participants (Shaw and Snow, 2000), this exercise class has grown to include an enrollment of over 300 participants in just Linn and Benton counties, with more throughout the states of Oregon, Washington and California. The program has proved to be both enjoyable and sustainable as there are participants who have been regularly attending classes for over 14 years. Owing to the popularity and success of the program, we had the opportunity to examine the relationship between participation in a true community-based bone loading and fall prevention program and parameters of bone health (hip, spine and whole body bone mass and hip structure), strength, balance, and self reported indicators of fall risk (balance confidence, fall worry, fall incidence). Furthermore, due to the consistent long term participation of many program participants involved in the class, we also had the opportunity to examine the dose-response relationship between duration of participation in this targeted program and outcomes related to bone mass and structure. To date, most of the literature regarding the dose response of exercise for bone focuses on current physical activity or previous non-bone specific (e.g. general) physical activity. This study sought to inform our understanding of bone's adaptive response to continued long term participation in a specific, bone loading, osteoporosis risk reduction program in older postmenopausal women.

Our secondary purpose was to evaluate the amount of physical activity occurring in the *BBB* class sessions in regards to bone loading forces and the amount of time spent at or above moderate intensity activity. This will allow us to better compare and contrast our program tothose programs already represented in the literature and will inform individuals, clinicians, and researchers of the specific loads associated with the *BBB* program. In addition, this information will allow us to evaluate the ability of BBB to meet the recommended guidelines of physical activity for adults for the optimizing cardiovascular as well as skeletal benefits.

RESEARCH QUESTIONS AND HYPOTHESES

Specific Aim 1: We sought to examine the relationship between participation in BBB and bone health and fall risk factors. Specifically, we asked the following research questions:

***Research Question 1*:**

What is the relationship between community BBB participation and bone mass (BMD) at the hip, spine and whole body, and hip structure (section modulus Z; cross sectional area, CSA; cross sectional moment of inertia, CSMI) among older estrogen deplete postmenopausal women who have been participating in BBB for at least one year?

***Hypothesis 1*:** Women participating in BBB will exhibit enhanced BMD and hip structural parameters compared to non-participating age- matched controls.

Research Question 2

Is there a dose-response relationship between duration of participation in BBB and bone mass at the hip, spine and whole body, and hip structure?

Hypothesis 2: There will be a positive relationship between duration of BBB participation and hip BMD and hip structural parameters.

Research Question 3:

What is the relationship between community-based participation in *BBB* and both performance based (strength and balance) and self-reported (fall worry, balance confidence, fall incidence) indicators of fall risk among older postmenopausal women who have been participating in BBB for at least one year?

Hypothesis 3: Women participating in *BBB* will report fewer falls, less fall worry and higher balance confidence and outperform controls on tests of balance and strength.

Specific Aim 2: We sought to quantify the amount and intensity of physical activity associated with the BBB program. Specifically we asked the following research questions:

Research Question 4:

What are the ground reaction forces associated with the key BBB exercises (jumps, heel drops, stepping and stomping)?

Research Question 5:

How much physical activity (minute of moderate to vigorous physical activity, MVPA) and time spent above 55% age predicted HR max) is accrued during a typical BBB class and over a typical week (3 class sessions) of class participation?

COMMENTS

For the success of this study we assumed that all participants answered truthfully on all questionnaires. In addition, we assumed that all participants gave their maximum effort on the fitness, strength and balance tests. Due to the cross sectional nature of this data, causal inferences examining the relationship between long-term *Better Bones and Balance* participation were not made. Furthermore, we did not have the ability to logistically blind the researchers to the exercise status (*BBB* participant versus control) of our participants. However, conscious effort was made to eliminate bias in the strength and bone testing. Finally, the specific age and gender restrictions of our population (estrogen deplete postmenopausal women) is a delimitation of the study, in that results cannot be generalized to younger age groups, or to men.

CHAPTER TWO

TRANSLATION OF *BETTER BONES AND BALANCE*, A COMMUNITY-BASED FALL AND FRACTURE RISK REDUCTION EXERCISE PROGRAM FOR OLDER ADULTS: INFLUENCE OF PARTICIPATION ON SKELETAL HEALTH.

Adrienne J. McNamara and Katherine B. Gunter

ABSTRACT (formatted for Osteoporosis International)

Prior research has shown that participation in *Better Bones and Balance (BBB)* under controlled laboratory conditions, reduced bone loss at the hip in older women. Whether bone benefits are derived from *BBB* when delivered in the community setting is unknown. **Purpose:** To evaluate the relationship between *BBB* participation and parameters of skeletal health in postmenopausal women. **Methods:** *BBB* participants (n=69) were recruited from *BBB* classes and compared to sedentary controls (n=46); total sample aged 69 ± 7.7 years. Women were excluded if they were <5 years postmenopausal or reported use of bone altering medications. Bone mineral density (BMD) of the hip, spine and whole body was measured using Dual energy x-ray absorptiometry; hip bone structure [cross sectional area, cross sectional moment of inertia] at the narrow neck and intertrochanter were derived using hip structural analysis software. Diet, physical activity, and health history were assessed by questionnaires. Group differences in bone outcomes were determined using ANCOVA controlling for age, lean mass and BMI. **Results:** There were no differences between groups in hip or spine BMD or bone structural outcomes (P>0.05).Controls exhibited higher whole body BMD (p<0.05). Both groups had higher than average t-scores when compared to NHANES data (p<0.05), despite *BBB* participants reporting more frequent prior diagnoses of, or risk factors for, osteoporosis, compared to controls. **Conclusions:** Participation in BBB was not associated with better skeletal outcomes compared when compared to a sample of sedentary controls. However both groups had higher than expected hip BMD. More work is needed evaluate the effects of *BBB* on bone outcomes in postmenopausal women.

INTRODUCTION

Osteoporosis is a disease characterized by alterations in bone mass and bone architecture leading to skeletal fragility and subsequently, bone fractures (NIH, 2001). Hip fractures are the most costly as they contribute to 72% of the estimated 20 billion dollar annual cost associated with all osteoporotic fractures (Burge, et al 2007). These costs are only expected to rise in the coming decades as incidence of osteoporosis is expected to double by the year 2050 (Burge, et al., 2007). Consequently strategies to attenuate bone loss and prevent osteoporosis among older adults will prove essential in reducing the public health impact associated with the aging profile of America.

Many factors influence skeletal health and consequently one's risk of osteoporosis. Some factors are outside the locus of one's control, such as age and genetics, still others are modifiable lifestyle factors that can slow or prevent disease onset. Exercise is an elective lifestyle option that has the potential to increase and/or maintain bone density of the hip and contribute to favorable alterations in the structural properties of bone, thereby reducing the risk of hip fracture. While exercise interventions of varying modalities have been successful in attenuating bone loss among older adults (Engelke, et al., 2006; Going, et al., 2003; Karinkanta, et al., 2007; Kohrt, et al., 1997; Liu-Ambrose, et al., 2004; Maddalozzo & Snow, 2000; Maddalozzo, et al., 2007), the public health impact from such programs is not realized unless a program can be successfully translated from the research setting into the community. This is especially important as the beneficial effects of exercise on bone mineral density (BMD) are lost once the exercise has been terminated (Englund, et al., 2009; Winters & Snow, 2000). Therefore, it is crucial to offer exercise programs that are palatable, convenient and can be sustained for many years. *Better Bones and Balance (BBB)* is a community based exercise program designed for older adults to reduce the risk of hip fractures through the enhancement of bone health and reduction of fall risk factors. The *BBB* program incorporates lower body resistance training with weighted vests, impact and balance exercises and is delivered as three 50-minute sessions per week and taught by community fitness instructors. Specifically, the program emphasizes five "key" weight-bearing exercises: stepping onto benches, forward and side lunges, squats, heel drops and/or jumps (without weighted vests). Recently stomping has been included in the protocol based on evidence that this exercise may have osteogenic potential (Young, et al., 2007). A minimum of 30 repetitions of each exercise are performed during each class session. Prior evidence suggests that the *BBB* program is associated with improved strength, power and balance after 9 months of participation under controlled laboratory conditions, and maintenance in hip BMD after 5 years of participation (Shaw & Snow, 1998; Snow, et al., 2000). Since the last published report (Snow, et al., 2000) *BBB* has grown in size and popularity with over 300 exercisers in Western Oregon and more classes emerging each year throughout the west coast. While the program has been disseminated widely throughout Oregon, the effectiveness of the program in its current community setting remains unknown. A unique characteristic of this program is the long-term compliance of BBB participants. Many of the original research participants are still engaging in the class 15 years post -intervention. This level of dedication offers the unique opportunity to consider the implication of long-term participation in a single bone loading exercise program on parameters of skeletal health. This is important considering the appropriate dose of exercise for optimizing bone benefits is not yet fully understood. Therefore, the purpose of this study was twofold: 1) to evaluate the relationship between participation in *BBB* as delivered in the community setting and hip, spine and whole body BMD and hip structural parameters among postmenopausal women and 2) to evaluate the relationship between duration of *BBB* participation and hip BMD and hip structure. We hypothesized that 1) *BBB* participation would be associated with higher hip BMD and more favorable hip structure compared to controls and 2) There would be a positive relationship between length of participation and skeletal health.

METHODS

Participants

Postmenopausal women (n=69) participating in a *BBB* program for at least one year were recruited from all *BBB* classes offered in Oregon's Willamette Valley and invited to participate in this study. Control participants (n=46), matched by age to the BBB sample, were recruited via fliers in the Corvallis and Albany community, and from the Oregon State University (OSU) Center for Healthy Aging LIFE registry, a database of older adults who have expressed interest in research participation. Groups were age-matched by recruiting equal proportions of *BBB* and control participants from each of the following age categories: <59, 60-80, 80+.

Prior to enrollment in the study, all participants completed a screening questionnaire via phone interview or in person. Participants were eligible for the study if they were at least 5 years postmenopausal, had no history of hormone replacement therapy within the previous 5 years or bone altering medications within the previous 10 years. Participants also needed to demonstrate sufficient functional ability to perform tasks of daily living and no significant cognitive impairment. Cognitive impairment was defined as scoring less than 24 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975; Schultz-Larsen, Lomholt, & Kreiner, 2007) while "sufficient functional ability" was defined as scoring less than 16 out of 24 on the composite physical function (CPF) scale (Rose, 2003). In addition, control participants had to be sedentary; defined as performing less than 60 minutes a week of moderate to vigorous physical activity and no resistance training for the previous 12 months (Bennett, Winters-Stone, Nail, & Scherer, 2006). Walking and stretching were not included in these weekly totals, due to the minimal impact of these exercises on bone.

This study was approved by the OSU Institutional Review Board and all participants gave written informed consent before participating in this study. All measurements were performed at the OSU Bone Research Laboratory.

Procedures

Demographic information: A health history questionnaire was used to collect demographic information such as age, menopause status, medication use and health co-morbidities. Participants were also asked about prior diagnosis of osteoporosis, and risk factors for osteoporosis. Height (cm) and body mass (kg) were measured directly using a fixed, wall mounted stadiometer and digital scale, respectively; values were used to calculate body mass index (BMI; kg/m^2). Additionally we administered the two minute step test, a measure of cardiorespiratory endurance, to characterize differences in fitness between groups. Participants were asked to march in place for two minutes (raising their knee to a height that corresponds to the mid-point between the iliac crest and the superior portion of the patella); the score is recorded as the number of times the right knee rises to the corresponding height.

Physical Activity: In order to control for the influence of physical activity outside of *BBB,* participants filled out the Aerobics Center Longitudinal Physical Activity Questionnaire (ACLPAQ)(Kohl, Blair, Paffenbarger, Macera, & Kronenfeld, 1988). This instrument quantifies individuals' regular levels of moderate to vigorous physical activity (MET *hours/week) during the previous 3 months. The Compendium of Physical Activities (Ainsworth, et al., 1993) was used to assign the respective MET values for all reported physical activities (Pereira, et al., 1997). This questionnaire has been shown to be both valid and reliable for adult populations, ages 20-80. In order to evaluate whether physical activity outside of BBB participation was similar between groups, time spent in *BBB* was omitted from the calculation of MET*hrs/week. In addition, the Bone Specific Physical Activity Questionnaire (BPAQ) was used to determine past and current physical activity patterns that may specifically influence the skeleton (Weeks & Beck, 2008). Scores on the BPAQ are derived using algorithms that weight activities associated with larger skeletal loads higher than activities eliciting lower skeletal loads. Time spent in *BBB* was also omitted from this calculation. This instrument was found to be more effective at predicting indices of skeletal strength than other instruments assessing general activity patterns (Weeks & Beck, 2008). Finally, *BBB* participants also completed a *BBB* participation history questionnaire assessing their duration of involvement in *BBB* as well as their current (previous 12 months) level of participation and fidelity to the program (avg. days per week, performance of key components such as jumps, use of weighted vest, etc.).

Nutrient Intake: Several nutrients are known to have a substantial influence on bone metabolism, most notably calcium and vitamin D. The 2005 Block Full-length Food Frequency Questionnaire (NutritionQuest, Berkeley CA) was used to assess typical nutrient intake over the previous 12 months. Nutrients evaluated included total energy (kcals), protein (g/kg body weight), calcium (mg) and vitamin D (IU) from food and supplemental sources. This instrument is a self-report questionnaire and has been validated against multiple diet record methods (Block, Woods, Potosky, & Clifford, 1990).

Bone Mineral Density and Hip Structure: Bone Mineral Density (BMD, g/cm^2) of the proximal femur (total hip, femoral neck and greater trochanter), anterior posterior (AP) lumbar spine and whole body were assessed using dual energy x-ray absorptiometry (DXA) (QDR-4500A Elite, Waltham, MA). Measurements were taken of the left hip unless a participant indicated a left hip replacement. In this case the right hip was scanned. Information on body composition including whole body lean mass and body fat percentage was collected from the whole body scans. Hip structural analysis (HSA) was performed on hip DXA scans to evaluate cross sectional area (CSA, cm^2), cross sectional moment of inertia (CSMI, cm^4) and section modulus (Z,cm^3) at the intertrochanteric (IT) and narrow neck (NN) regions of the proximal femur. The HSA program utilizes two-dimensional data from DXA scans to estimate three -dimensional structural outcomes and can provide additional information about skeletal strength beyond that given by measurements of mass alone. In-house operator precision (CV) (Baim, et al., 2005) for hip and spine BMD was calculated at 0.7% and 0.9% respectively while precision for hip structure parameters ranged from 1.9 % (NN CSA) to 4.6% (NN CSMI) within this current sample of older adults.

Data analysis

All data were analyzed using PASW version 17 (SPSS inc, Chicago, IL). Group differences on descriptive variables were calculated by independent t-tests. Pearson product moments were calculated to assess the correlations between bone and potential covariates (e.g. age, body weight, lean body mass, BPAQ scores, calcium, vitamin D, BMI). Analysis of Covariance (ANCOVA) was used to determine bone difference between groups adjusting for age, lean body mass and BMI. One sample t-tests were used to compare group hip and spine t-scores to NHANES reference values. Forward multiple regression analysis was used to assess the influence of *BBB* participation *duration* (in years) (among BBB participants only) on parameters of skeletal health above and beyond the variability predicted in a model including only age, lean mass and BMI. Significance for all analyses was set at an alpha level of 0.05.

RESULTS

Participants: Invitations to participate in the study were extended to all current *BBB* participants in Linn and Benton counties (approximately 300) via informational sessions held during scheduled class sessions or through announcements made by class instructors. Participants were asked to sign up or contact the researcher only if they felt they met the specified inclusion criteria. Consequently, 110 participants had screening interviews conducted and of those, sixty five percent (n=72) were eligible to participate and had appointments scheduled. Of those scheduled, two women were excluded due to hormone use within the previous five years which was not disclosed in their screening interviews. One additional participant was excluded after she failed to complete the questionnaires. Complete data were available on sixty nine *BBB* participants. The average duration of BBB participation was 5.7 $\pm$ 4.3 years with 91.3% of participants attending greater than 10 out of a possible 12 classes a month, and 95.7% attending classes year round. The proportion of participants reporting regular use of their weighted vests is presented in Figure 2.1. Only 18.8% of participants report faithfully wearing their vests, while 40.6% of participants report never wearing their vests.

Approximately 250 potential control participants were contacted directly from the research database and invited to participate; others contacted us as a result of fliers or word of mouth. Of those, forty seven participants were interested and met our inclusion criteria and were consequently tested. One participant failed to complete her questionnaires and was therefore excluded, leaving 46 control participants who completed the study.

Nutrient intakes and descriptive characteristics of the two groups are presented in Table 2.1 and Table 2.2, respectively. There were no differences between groups in calcium or vitamin D from dietary sources although *BBB* participants reported significantly higher intakes of *supplemental* calcium and vitamin D leading to significantly higher total nutrient intakes. *BBB* participants also reported higher protein intakes when expressed relative to total body weight. BBB participants also had significantly higher scores on the “current” subscale of the BPAQ indicating greater levels of bone loading physical activity, outside of *BBB*, within the previous 12 months. There were no differences in past or lifetime total BPAQ scores between groups after removing the influence of *BBB* participation. There were also no differences in general physical activity performed outside of *BBB* between groups. While our control participants were defined as sedentary (no moderate to vigorous physical activity), both groups reported regular walking , housework and gardening. Additionally, the *BBB* participants had higher cardiorespiratory fitness, lower percent body fat, lower body weight and higher proportion of lean body mass than controls.

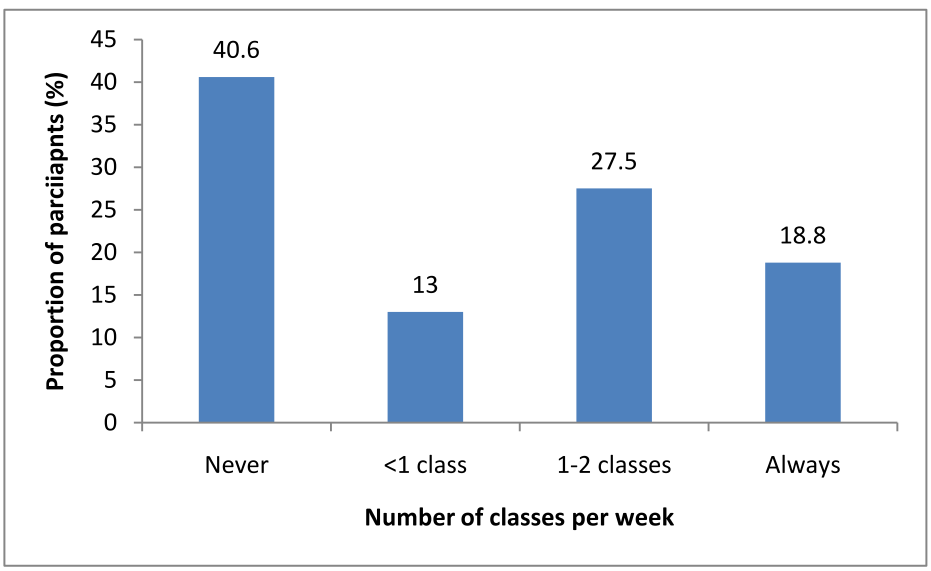

Figure 2.1 Proportion of BBB participants reporting use of weighted vests. Data represent the frequency (classes per week) with which participants regularly wear a weighted vest during BBB class sessions.

Table 2.1: Energy and Nutrient intakes, means (SD). Vales unadjusted for under-reporting

Variable	BBB (n=69)	Control (n=46)	p-value
Dietary energy intake (kcal/day)	1467 (501)	1422 (443)	ns
Dietary protein intake (g/kg bodyweight)	0.91 (0.34)	0.76 (0.31)	<0.05
Total vitamin D from diet and supplements (IU/day)	613 (234)	504 (266)	<0.05
Vitamin D from diet only (IU/day)	149 (104)	132 (101)	ns
Vitamin D from supplements only (IU/day)	464 (214)	372 (246)	<0.05
Total Calcium from diet and supplements (mg/day	1693 (568)	1355 (630)	<0.01
Calcium from diet only (mg/day)	786 (352)	727 (326)	ns
Calcium from supplements only(mg/day)	907 (440)	629 (521)	<0.01

Table 2.2: Descriptive Variables; means (SD)

Variable	BBB (n=69)	Control (n=46)	p-value
Age	70.1(7.8)	68.1 (7.6)	ns
Years post menopause	18.9 (8.8)	17.4 (9.9)	ns
Height (cm)	161.7 (7.2)	162.9 (5.6)	ns
Body Mass (kg)	68.1 (10.9)	75.0 (16.3)	<0.01
BMI (kg/m^2)	26.1 (4.3)	28.2 (5.7)	<0.05
Body fat (%)	34.7 (5.8)	37.8 (6.4)	<0.01
Fat mass index (kg/m^2)	9.3 (2.8)	11.1 (3.1)	<0.01
Whole body lean mass (kg)	42.6 (5.2)	44.3 (6.8)	ns
Lean body mass (%)	62.9 (5.6)	59.9 (6.0)	<0.01
Physical Fitness (steps in 2 minutes)	111.5 (21.8)	96.5 (24.9)	<0.001
*General physical activity (MET*hrs/week)*	46.7 (53.2)	33.0 (26.6)	ns
BPAQ current	2.35 (4.7)	0.65 (.95)	<0.05
BPAQ past	39.0 (36.7)	37.7 (40.6)	ns
BPAQ total	20.6 (24.5)	19.2 (20.4)	ns

BPAQ= Bone-specific Physical Activity Questionnaire
All physical activity measures were calculated excluding the influence of *BBB*.

Group Differences in Bone Mass and Structure. Correlation analysis indicated that body mass index (BMI), age and lean mass (kg) were significantly correlated with all bone variables and were chosen as covariates for all analyses. Total calcium intake (mg/day) was also significantly correlated with whole body, total hip and AP lumbar spine BMD, but was not correlated with any structural parameter. There were no significant correlations between total Vitamin D intake (IU/day) and any bone variables. To evaluate a potential bias in nutrient values due to possible under-recording of food intake, reported energy intake was evaluated against estimated basal metabolic rate using the Mifflin equation (Mifflin, et al., 1990). Individuals whose energy intake to BMR ratio was less than 1.30 were considered to be under-reporters (Goldberg, et al., 1991). Sixty-one percent of our participants reported energy intakes below this threshold, while 29.5% of the participants reported energy intakes below their estimated BMR. The proportion of under-reporters was similar between groups. It is possible that such prevalent underreporting may have influenced our calcium and vitamin D results. Even with under-reporting, both groups reported total calcium intakes above the Recommended Daily Allowance of 1200 mg/day, and therefore likely have adequate calcium intakes. In light of this, and that including calcium in the model did not significantly alter our results, calcium was not included as a covariate for the final analyses of skeletal outcomes.

The adjusted group means for BMD are presented in Figure 2.2. There were no differences between groups in total spine, total hip, greater trochanter, or femoral neck BMD although control participants had higher adjusted whole body BMD. There were no group differences in any of the adjusted hip structural parameters between groups (Table 2.3).

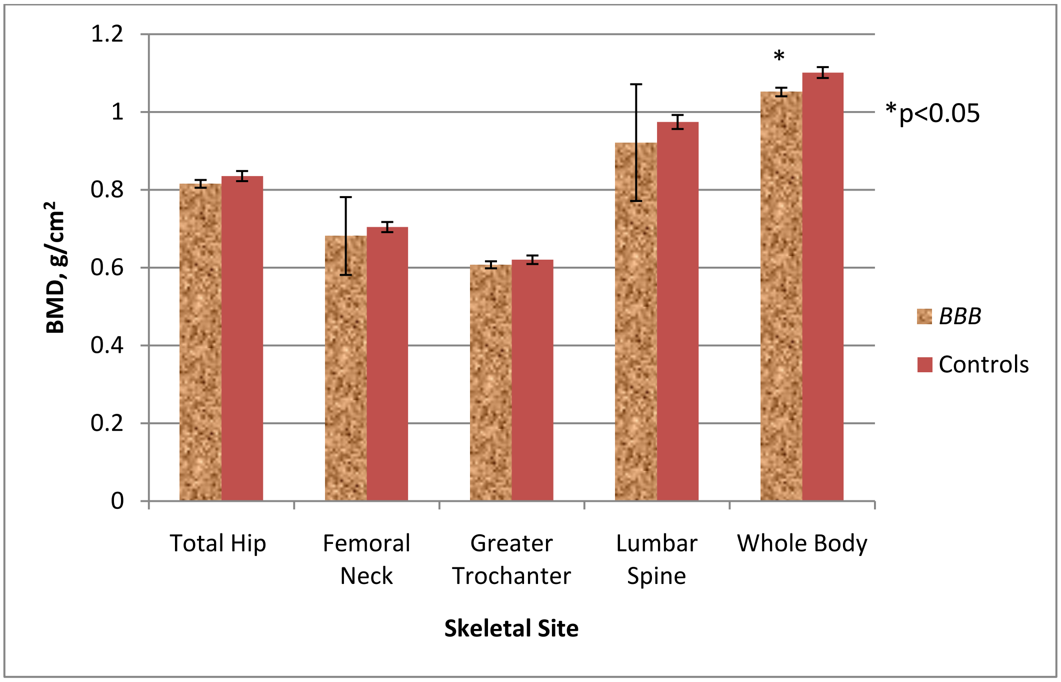

Figure2.2: Bone Mineral Density differences between BBB participants and controls. Data presented as means and standard errors. Values adjusted for age, lean body mass and BMI. * denotes controls exhibiting higher whole body BMD than controls, ($p<0.05$).

Table 2.3: Age, lean mass and Body Mass Index Adjusted Hip Structural Parameters; means (SE)

Variable	***BBB*** **(n=69)**	**Control (n=46)**	**p-value**
Narrow neck CSA (cm^2)	2.683 (0.038)	2.673 (0.46)	0.561
Narrow neck CSMI (cm^4)	2.629 (0.074)	2.604 (0.090)	0.836
Narrow neck Z (cm^3)	1.36 (0.03)	1.36 (0.04)	0.864
Intertrochanteric CSA (cm^2)	3.932 (0.065)	4.128 (0.080)	0.063
Intertrochanteric CSMI (cm^4)	9.606 (0.206)	9.992 (0.252)	0.245
Intertrochanteric Z (cm^3)	3.20 (0.07)	3.27 (0.81)	0.527

Abbreviations: NN: narrow neck; IT: intertrochanteric; CSA: cross sectional area; CSMI: Cross sectional moment of inertia; Z: section modulus

DXA results can also be expressed in t-scores, a unit that is the World Health Organization’s criterion for diagnosis of osteoporosis (t score <-2.5) and that compares an individual’s bone health to a reference of a young healthy adult (NIH, 2001). Thus in order to gain a better understanding of how well our sample of older women represented older women in general, we compared t-scores from the *BBB* and controls participants to NHANES data (Looker, et al., 1998; Ott, 2010). Although there were no differences between groups in hip BMD or total hip t-score (-1.055± 0.086 vs. -0.862 ± 0.105 for *BBB* versus controls, respectively, $p>0.05$), *BBB* and control participants between the ages of 60-80 had higher (more positive) hip t-scores when compared to normative data (Figure 2.3). In fact, only two participants (both *BBB*) from our entire sample were classified as osteoporotic at the hip. At the spine, controls had significantly higher lumbar spine t-scores compared to *BBB* participants(-0.591 ±1.3, vs. -1.2 ± 1.2 respectively, $p<0.05$) and compared to national reference values (-1.3, $p<0.05$)(Kanis & Gluer, 2000). There were no differences between *BBB* participants’ spine t-scores and those from the NHANES reference group ($p>0.05$). Two control participants and 8 *BBB* participants were classified as osteoporotic at the lumbar spine.

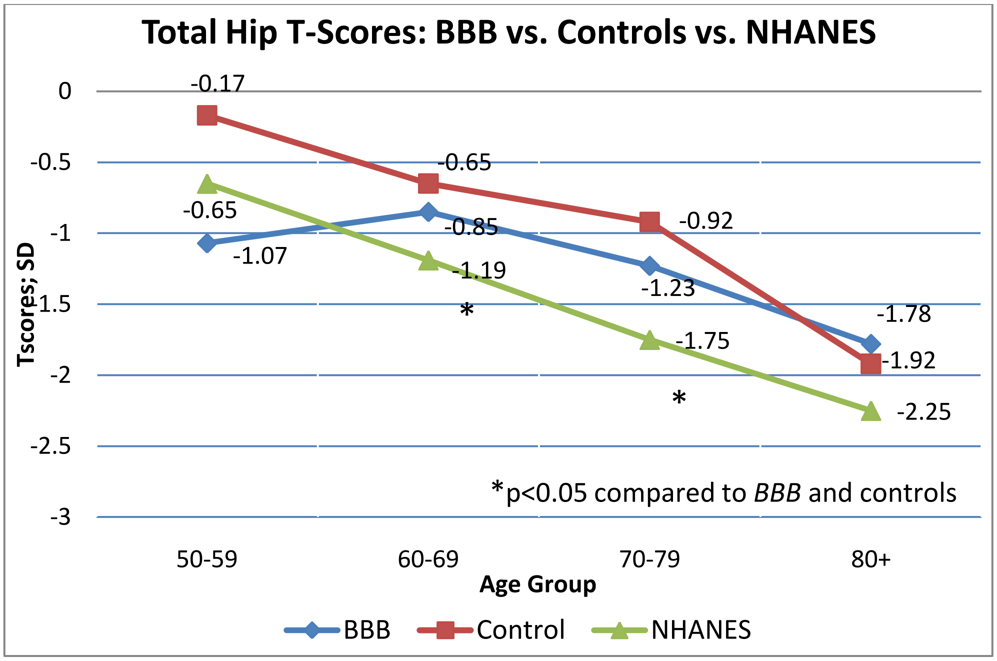

Figure 2.3 Comparison of BBB and control group hip T-scores to NHANES reference values. * denotes both BBB and control groups exhibiting higher T-scores compared to NHANES values for ages 60-79.

Effects of Long-term Participation in BBB on Bone Mass and Structure. Multiple regression analysis indicated that age, lean body mass and BMI were the strongest predictors of total hip BMD explaining 38.3% of total variance among *BBB* participants only ($p<0.001$)(Table 1.3). When duration of *BBB* participation was added to the model, years spent in *BBB* failed to offer any additional predictive power above and beyond that of age, lean mass and BMI in any bone parameter (Table 2.4). Of the examined predictors, lean body mass alone was most strongly related to each bone variable explaining 14-29% of the total variance.

Table2.4: Correlations between bone parameters, length of *BBB* participation, and lean mass among *BBB* participants only

Variable	Full Model including Age, BMI and Lean Mass							Additional influence of Duration	
	Total#	Age (years)		BMI (kg/m^2)		Lean mass (kg)			
	R^2	R^2	β	R^2	B	R^2	β	$R^2\Delta$	β
Total hip BMD	0.383^{+}	0.099	-0.165	0.268*	0.320	0.276*	0.283	0.008	-0.096
AP spine BMD	0.292^{+}	0.008*	0.234	0.182	0.209	0.205*	0.397	0.001	-0.029
FN BMD	0.209^{+}	0.053	-0.119	0.089	0.077	0.191*	0.357	0.000	-0.022
GT BMD	0.352^{+}	0.057	-0.120	0.28*	0.408	0.189*	0.453	0.008	-0.096
NN CSA	0.299^{+}	0.038	-0.195	0.060	-0.112	0.290*	0.587	0.007	-0.091
NN CSMI	0.192^{+}	0.053	0.112	0.001	-0.261	0.144*	0.555	0.002	-0.053
NNZ	0.218^{+}	0.015	0.034	0.009	-0.239	0.184*	0.566	0.004	-0.071
IT CSA	0.254^{+}	0.037	-0.019	0.114	0.061	0.245*	0.435	0.015	-0.135
IT CSMI	0.289^{+}	0.011	0.094	0.067	-0.098	0.284*	0.596	0.013	-0.125
IT Z	0.244^{+}	0.015	0.061	0.141	0.121	0.228*	0.401	0.002	-0.164

Full model evaluating total variability in skeletal parameters explained by age, BMI and lean mass
+ $p<0.001$ * $p<0.05$

R^2: variance explained from each variable included in the model

Total# R^2: variance predicted by the inclusion of age, BMI, lean mass without the influence of duration.

$R^2\Delta$: Additional variability attributed to duration (years of participation) *above* that predicted from the full model (Total# R^2).

Abbreviations: BMD: Bone Mineral Density; FN: femoral neck; GT: greater trochanter; NN: narrow neck; IT: intertrochanteric; CSA: cross sectional area; CSMI: Cross sectional moment of inertia; Z: section modulus

DISCUSSION

This study found that older women participating in *Better Bones and Balance*, a community-based fall and fracture prevention program had similar bone mass at the hip and spine and similar bone structure of the hip compared to sedentary age-matched controls. Thus we found no specific benefit from participation in *Better Bones and Balance* to skeletal health when comparing our BBB sample to controls. When compared to national reference data, both *BBB* and control participants had better than average hip t-scores indicating positive skeletal health. Therefore, it is possible that the *BBB* program may serve as an effective strategy to attenuate bone loss *at the hip* for older women. When comparing t-scores at the spine to national norms, only control participants exhibited higher than expected t-scores at the spine. As the *BBB* protocol emphasizes lower body resistance training and impact exercise, without exercises specifically targeting the lower back, the lower spine t-scores of the *BBB* participants are not surprising. Therefore, it is possible that participation in *BBB* may contribute to this discrepancy between hip and spine BMD among *BBB* participants, and that the *BBB* program may serve as an effective strategy to attenuate bone loss *at the hip* for older women. Previous reports indicate that *BBB*, when delivered as a laboratory intervention with stringent progression criteria over 9 months, stimulated increases in strength, balance and power in postmenopausal women. This duration was insufficient to stimulate any measureable differences in bone mass between exercisers and controls (Shaw & Snow, 1998). However a follow-up study revealed that after 5 years of continuous participation, exercisers had maintained hip BMD while controls lost bone

(Snow, et al., 2000). The results of the current study show no differences in hip bone outcomes between controls and exercisers. However both groups had higher than average bone mass.

Our second interest was in determining whether years of participation in the program influenced skeletal outcomes. We were unable to identify an association between *duration* of BBB participation and parameters of bone health in this population of older women.

Studies investigating the effects of physical activity on skeletal outcomes in older women have shown mixed results. For example, many studies have documented improvements or maintenance of hip BMD in response to multi-component exercise programs (Engelke, et al., 2006; Going, et al., 2003; Jessup, et al., 2003; Kemmler, et al., 2002; Kemmler, Lauber, et al., 2004; Park, et al., 2008; Snow, et al., 2000). Similarities between these effective studies include duration of at least 48 weeks, exercise frequency of at least three times a week, and multiple modes of training including both impact and resistance exercises. However, others have failed to see group differences in hip BMD in response to similar exercise protocols. For example, Villareal (2003) found no change in hip BMD in response to 9 months of resistance, balance and aerobic training in elderly women taking HRT (Villareal, et al., 2003). Likewise Uusi-Rasi et al (2003) saw no change in DXA measured bone outcomes in response to 12 months of jumping and callisthenic exercise in older women(Uusi-Rasi, et al., 2003). This is also the case for Liu-Ambrose et al (2004) who found no changes in bone mass after 6 months resistance and agility training in community dwelling osteopenic women(Liu-Ambrose, et al., 2004). Like the original report on *BBB* (Shaw & Snow, 1998) where differences in bone were not observed after 9 months, it is possible that these studies may have been too short in duration to elicit changes in bone mass. It is also possible that the frequency of training of twice a week employed by each of these studies (with the exception of Shaw and Snow, (1998)) may have been inadequate to provide appropriate skeletal overload. However, both Liu-Ambrose et al (2003) and Uusi-Rasi et al (2003) did observe favorable changes in bone structure of the tibia and/or radius, as measured by peripheral Quantitative Computed Tomography (pQCT)(Liu-Ambrose, et al., 2004; Uusi-Rasi, et al., 2003). Although pQCT does not measure the clinically relevant hip site, altered geometric parameters of the tibia have been associated with prior hip fracture and appear to predict fracture risk independent of BMD (Sornay-Rendu, Boutroy, Munoz, & Delmas, 2007; Vico, et al., 2008). Therefore it is possible that exercise has the capacity to alter the distribution of bone without concomitant changes in bone mass, and that structural changes may occur in response to exercise prior to changes in mass thereby influencing fracture risk.

While *BBB* shares many characteristics of the effective interventions mentioned above (long duration, three exercise sessions/week, multiple modes of exercise), we found no differences in hip structure or mass between *BBB* participants and controls in this cross sectional study. However, as depicted in Figure 2.3, both control and *BBB* participants have healthier than typical bone mass when compared to national age-matched norms. It is likely that our stringent inclusion criteria may have resulted in a healthy cohort selection bias so that our sample of controls was not representative of the general population. Our data corroborate this, as only 24% of controls reported prior diagnosis of, or risk factors for, osteoporosis whereas 46% of *BBB* participants indicated enhanced osteoporosis risk, (assessed via bone scans , n=18) or other known risk factors (n=5). Therefore, it is encouraging that *BBB* participants, over 40% of whom entered the program due to concern over their bone health also had better than average hip bone mass when compared to NHANES data (Looker, et al., 1998; Ott, 2010). Thus, it is possible that participation in *BBB may* contributing to this higher than expected bone mass among a cohort of women, who generally speaking, were at risk of or suffering from osteoporosis when they began participating in *BBB* classes. A randomized controlled trial, prospectively evaluating *BBB* is needed to reduce any such source of recruitment bias.

A key difference between *BBB* and most reported programs designed to reduce fracture risk, is that *BBB* is delivered in a community setting. Further, though instructors are trained by researchers in annual workshops, delivery is left to the community-based instructors. This is another potential contributor to the lack of observable differences in bone between exercisers and controls. The strict protocol typically adhered to in the laboratory setting likely differs from how programs are delivered when translated to the community setting. Shaw et al., (1998) reported that in the laboratory setting, *BBB* participants began wearing vests during month 4 of the nine month intervention and wore them consistently to the end; systematically increasing vest weight over time. As observed in Figure1, only 18.8% of current participants faithfully use their weighted vests every class period while 40.6% of participants report never wearing a weighted vest during class. Further, our observations of instructional sessions suggest that some participants modify the exercises in ways that may decrease skeletal loads. For example, we observed exercisers doing "lunges" where they simply shifted their weight onto the front foot without significantly lowering their hips toward the ground. Additionally, approximately 30% of the *BBB* participants in this study report that they never perform the jumps; rather they substitute alternative activities such as heel drops, or avoid the impact all together. We recently examined the vertical ground reaction forces (GRF) associated with the key *BBB* exercises and found the mean GRF for the heel drops to be the lowest followed by steps and stomps, with jumps eliciting the highest GRFs (2.14 ± 0.28 BW, one leg values). Therefore, it is possible that without the added resistance supplied by the vests, and the improper execution of certain exercises, participants may not be achieving adequate overload to stimulate skeletal adaptation, thus accounting for the lack of skeletal differences between groups. In light of our findings, future training of *BBB* instructors emphasizing program fidelity and proper technique may lead to more favorable bone results associated with this program.

Among fall and fracture prevention programs that have been translated to community-based programs, *BBB* is probably most comparable to the Strong Women program (Nelson, 2006). Strong Women is based in part on the research of Nelson et al (1994) who found maintenance of hip BMD and improvements in strength and balance in response to 12 months of high intensity resistance training (Nelson, et al., 1994). The Strong Women program was subsequently adapted from this research to include upper and lower body resistance training using hand held and ankle weights and weight bearing aerobic activity. However, the influence of these program changes on fall and fracture outcomes has not been reported.

There are notable differences between *BBB* and Strong Women. For example, while Strong Women does include similar exercises to *BBB* such as squats, lunges and stepping, the program does not encourage jumping for postmenopausal women. Rather, considerable emphasis is placed on upper body resistance training using hand held weights. It is possible that such upper body exercise may be beneficial for spine BMD, a benefit that has not been observed in response to *BBB*. However, no evidence on the influence of the community-based Strong Women program on hip or spine bone health has been reported. Therefore, one significant benefit of *BBB* over Strong Women is that we have detailed the consistency of the program from its original format and have worked through annual workshops to impress upon instructors what is required to see the effects observed in the original study. Furthermore, *BBB* allows variety in class structure while incorporating the key program exercises in every class (lunges, squats, steps, stomps and jumps). This variety may contribute to the long term sustainability and enjoyment observed by the *BBB* participants. In fact among the 69 *BBB* participants in our sample, 33 had been participating for at least 5 years continually and of those, 14 had been participating for at least 10 years, many of whom indicated that they intend to continue participating in *BBB* as long as they are able. Though Strong Women has been offered as a community-based program since 2003, with 6800 participants engaging in programs throughout 38 states (Seguin et al, 2008), information regarding program effectiveness or long-term adherence among participants is lacking.

Given that many *BBB* participants attended classes faithfully for many years, we sought to determine whether long-term participation was associated with increased bone mass or enhanced bone structure within our sample of *BBB* participants. Specifically, we evaluated the relationship between years of participation in *BBB,* on bone mass and bone structural outcomes and found no correlation between bone health and years of *BBB* participation after accounting for age, lean mass and BMI. Given that earlier, prospective studies found that participation in the class over five years (Snow et al, 2000) preserved bone mass among older women, we expected to see that adherence to the program over many years was positively associated with bone outcomes. It is possible that after a yet unknown duration of time, participants may enter a maintenance phase of training whereby the habitual activities performed in class no longer supply a novel overload to the skeleton to stimulate further adaptation. This appears to be the case when examining results from the Erlagen Fitness and Osteoporosis Study (EFOPS), a complex exercise program emphasizing jumping, resistance training and use of weighted vests for early postmenopausal osteopenic women (Engelke, et al., 2006; Kemmler, et al., 2002; Kemmler, Lauber, et al., 2004). Specifically, increases in spine and trochanteric BMD were observed after two years of participation while no further increases were observed at the three year time point. However, as this population was considerably younger (mean age 55) and the program was not community based, whether a similar time curve would be observed for our older *BBB* participants is unknown. Another potential explanation for the lack of an observed relationship between length of *BBB* participation and bone is the possibility that fidelity to the program may decrease as participation duration increases, thereby reducing the impact of the program. Our cross-sectional design is likely inadequate to properly evaluate this question as it is probable that most long term participants included in this study would already be in such a maintenance phase. Long-term prospective monitoring of new *BBB* participants would allow us to better examine the relationship between long term participation in this program and to elucidate if and at what time point benefits to bone may plateau.

There were observable positive differences between *BBB* participants and controls. *BBB* participants exhibited more favorable body composition compared to controls. Specifically, the *BBB* participants had lower BMI, lower percent body fat and higher percentage of lean mass, although the total lean mass did not differ between groups. That our *BBB* participants were lighter and leaner, but did not have lower hip bone mass than controls, may also indicate the potential positive influence of *BBB* on bone health as higher body weight is typically associated with greater BMD (Ensrud, et al., 2003). In addition, Fat Mass Index (FMI) scores were significantly lower in *BBB* participants compared to controls. FMI; a measure of weight attributed to body fat normalized to body height (kg fat/m^2)) is a gender specific measure of fat that is not confounded by lean tissue and therefore has a higher correlation with cardiovascular disease risk than does BMI (Kelly, Wilson, & Heymsfield, 2009). Therefore, *BBB* participation may be associated with reduction in risk for cardiovascular disease. This is supported by the superior cardiorepiratory fitness of the *BBB* participants compared to controls, as measured by the 2-min step test (Table 2.2). Furthermore, this sample of *BBB* participants was found to have enhanced strength, balance and balance confidence compared to controls (McNamara and Gunter, 2010), factors associated with reduction in fall risk. This is important as over 95% of all hip fractures occur as a result of a fall and therefore it has been suggested that falling and not osteoporosis is the strongest risk factor for fracture (Jarvinen, et al., 2008). Therefore, participation in *BBB* is associated with reduction in cardiovascular disease risk and fall risk factors, despite no differences between groups in bone parameters.

There are several limitations that must be considered when interpreting our findings. Due to an attempt to control for multiple confounding factors, our stringent exclusion criteria may have resulted in selection bias so that we were comparing our *BBB* participants to a control group with better than average skeletal health. On a similar note, the cross-sectional design of this study did not allow us to evaluate the influence of duration of *BBB* on *individual* changes in bone mass, nor does the design allow us to make causal inferences about the program.

There are several strengths to this study as well. Few reports exist that have evaluated true community based programs specifically designed to influence fracture risk by targeting skeletal health, as well as fall risk factors associated with strength and balance. If a program cannot be disseminated and sustained without researcher involvement, the benefits will not be broad enough to impact the public health. An additional strength of this study, and the *BBB* program was the long-term involvement in the program by *BBB* participants. This allowed us to examine the potential influence of long-term participation in a single exercise protocol on skeletal health. Long-term sustainability of exercise is not the norm among U.S. adults and older adults are the least active subset of the U.S. population (Nelson, et al., 2007). Many *BBB* participants have been faithfully and actively engaging in this exercise program for up to 15 years. We believe this highlights the unique and highly palatable nature of the *BBB* program. This is particularly important as benefits to bone and muscle that are achieved through exercise are lost once exercise has ceased (Englund, et al., 2009; Winters & Snow, 2000). Therefore a program that fosters continued participation will likely be paramount in maintaining health among older adults. Finally, we evaluated bone structure in addition to bone mass in this study. As exercise may have the ability to influence structure without changing bone mass it is critical to assess bone structure to fully understand the potential influence of bone loading protocols on bone's overall strength (Adami, et al., 1999; Liu-Ambrose, et al., 2004; Uusi-Rasi, et al., 2003).

In conclusion, *BBB* participants did not exhibit differences in bone mass or structure compared to age matched sedentary controls, and duration of participation in the *BBB* program was not associated with skeletal outcomes. However, both *BBB* and controls had significantly better hip t-scores, the metric used to diagnose osteoporosis, compared to national normative values. Further, *BBB* participants had favorable differences in body composition and enhanced cardiorespiratory endurance compared to controls; unanticipated outcomes that suggest *BBB* may have beneficial health effects that extend beyond improving fall and fracture risk. A randomized long term prospective study is warranted to examine the relationship between bone health and *BBB* participation and to evaluate the appropriate duration of participation needed to optimize skeletal health.

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CHAPTER THREE

SUCCESSFUL TRANSLATION OF *BETTER BONES AND BALANCE*: A COMMUNITY-BASED FALL AND FRACTURE RISK REDUCTION EXERCISE PROGRAM FOR OLDER ADULTS

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ABSTRACT (formatted for the *Journal of Aging and Health*)

Objective: Few studies have examined whether evidence-based exercise programs to mediate fall risk among older individuals are effective when translated to the community setting. This study examined the relationship between community-based participation in *Better Bones and Balance (BBB)* and performance on functional and self-reported fall risk indicators among older postmenopausal women compared to controls. **Methods:** One hundred fifteen women, aged 69 $\pm$ 7.7 years, completed the study. BBB participants (n=69) and sedentary controls (n=46) were tested on functional and self-reported indicators of fall risk. **Results:** *BBB* participants performed better than controls on all strength and balance tasks (p<0.01) except the tandem stance (p=0.02). BBB participants reported higher balance confidence; there were no differences in fall worry or fall incidence between groups. **Discussion:** In conclusion, *BBB* participation is associated with enhanced physical function and better balance confidence indicating successful translation of this program out of the laboratory and into the community.

Key Words: Older women, fall risk, balance, strength

INTRODUCTION

The prevalence of osteoporosis is on the rise in U.S. society and consequently fracture incidence is also increasing. Recent data suggests that osteoporotic fractures carry an economic burden of over 17 billion dollars with hip fractures accounting for approximately 72% of all fracture related costs(Burge, et al., 2007). These numbers are expected to double by 2025. Although the etiology of fractures is complex and encompasses the many factors related to skeletal health, one's risk of hip fracture is also inexorably linked to one's risk of falling. In fact, over 95% of all hip fractures occur as a result of a fall and therefore it has been suggested that falling and not osteoporosis is the strongest risk factor for fracture (Jarvinen, et al., 2008). This is significant as over one third of Americans fall each year (CDC, 2008; Sattin, et al., 1990) and of those reporting a fall in the previous three to twelve months, 20%-25% report falling more than once and over 30% report an injury resulting in activity restriction or a visit to their physician (CDC, 2008; Gunter, et al., 2000). Additionally falls are associated with other non-fracture morbidities such as loss of independence, chronic pain and muscular injury (CDC, 2006). Some risk factors for falls are extrinsic and easily reduced with simple environmental modifications such as the removal of throw rugs and improved lighting. However, there are many other risk factors that are intrinsic to the individual such as poor strength and balance, and poor vision. Exercise has the capacity to improve risk factors for falls such as strength and balance and therefore decrease fracture risk even in the absence of bone improvements. As such, exercise programs can be a viable alternative to other treatments, such as drug therapies, for reducing fracture risk.

It is well documented that exercise may reduce the risk of falls by modulating risk factors associated with strength and balance (Carter, et al., 2002; Chang, et al., 2004; Hourigan, et al., 2008; Madureira, et al., 2007; Sherrington, et al., 2008). Exercise has also been shown to reduce fall incidence among older adults (Barnett, et al., 2003; Huang, et al., 2010; Robertson, et al., 2002) and data suggests that multi-factorial fall interventions that incorporate exercise are more effective in reducing falls than those that do not include an exercise component (Chang 2004). Robertson et al (2002) found that an individually tailored home based exercise program has been associated with a 35% reduction in fall number and fall-related injuries in elderly adults (Robertson, et al., 2002) while others have found improvement in strength and/or balance and reductions in the number of falls experienced by older group exercise participants (Barnett, et al., 2003; Huang, et al., 2010; Madureira, et al., 2007). To achieve widespread impact and reduce the public health burden associated with falls it is essential for such interventions to translate to the community setting. To date, studies examining the effectiveness of exercise programs to mediate fall risk that have translated from the laboratory to the community are limited (Campbell, et al., 1999; Carter, et al., 2002; Seguin, et al., 2008). *Better Bones and Balance (BBB)* is an evidence-based fall and fracture prevention program that has been widely translated into a community setting and has been ongoing for 15 years boasting high enjoyment and sustainability among its older adult participants. The *BBB* program incorporates lower body resistance training, impact and balance exercises and is typically delivered as three 50 minute sessions per week and taught by community fitness instructors. Specifically, the program emphasizes five “key” weight-bearing exercises: stepping onto benches, forward and side lunges, squats, heel drops and/or jumps (without weighted vests). A minimum of 30 repetitions of each exercise are performed during each class session. Each class also includes balance training. Participants engage in activities that challenge dynamic and static balance with balance activities often integrated into strength activities. Prior evidence suggests that this program is efficacious in improving strength, balance and power when delivered under controlled laboratory conditions (Shaw & Snow, 1998); however the effectiveness of the program in its current community setting remains unknown. Therefore the purpose of this study was to evaluate the relationship between community-based participation in *BBB* and both performance based (strength and balance) and self-reported (fall worry, balance confidence, fall incidence) fall risk indicators among older postmenopausal women. Specifically, we compared women participating in *BBB* for at least one year to age matched controls on tests of functional performance and self-reported falls and fall risk indicators. We hypothesized that women participating in *BBB* would report less fall worry, higher balance confidence and fewer falls and outperform controls on tests of balance and strength.

METHODS

Participants

Postmenopausal women participating in a *BBB* program for at least one year were recruited from all *BBB* classes offered in Oregon's Willamette Valley and invited to participate in this study. Sedentary control participants were recruited via fliers in the Corvallis and Albany communities, and from the Oregon State University (OSU) Center for Healthy Aging LIFE registry, a database of older adults who have expressed interest in research participation. Groups were age-matched by recruiting equal proportions of *BBB* and control participants from the following age categories: 50-60, 60-70, 70-80, 80+.

Prior to enrollment in the study, all participants completed a screening questionnaire via phone interview or in person. Participants were eligible for the study if they were at least 5 years postmenopausal, had no history of hormone replacement therapy within the previous 5 years. As this sample was concurrently used to evaluate bone outcomes, participants were ineligible for the study if bone altering medications had been used within the previous 10 years. Participants also needed to demonstrate sufficient functional ability to perform tasks of daily living and no significant cognitive impairment. Functional and cognitive sufficiency was confirmed during the first visit using the Mini-Mental State Examination (MMSE) and the Composite Physical Function (CPF) scale (Folstein, et al., 1975; Schultz-Larsen, et al., 2007) Cognitive impairment was defined as scoring less than 24 on the MMSE and having "sufficient functional ability" was defined as scoring greater than 16 out of 24 on the CPF scale (Folstein, et al., 1975; Schultz-Larsen, et al., 2007). In addition, control participants had to be sedentary--defined as performing less than 60 minutes a week of moderate to vigorous physical activity and no resistance training for the previous 12 months (Bennett, et al., 2006). Controls were still eligible to participate if they reported regular walking, stretching or household activities (chores, gardening, etc).

This study was approved by the OSU Institutional Review Board and all participants gave written informed consent before participating. All measurements were performed at the OSU Bone Research Laboratory.

Procedures

Demographic information: A health history questionnaire was used to collect demographic information such as age, menopause status, medication use, health co-morbidities, fear of falling, and number of falls in the previous year. Information regarding medication use was also used to validate study eligibility conducted at initial screening.

Physical Activity: The Aerobics Center Longitudinal Physical Activity Questionnaire (ACLPAQ)(Kohl, et al., 1988) was used to assess regular levels of moderate to vigorous physical activity (MET *hours/week) during the previous 3 months and was also used to validate eligibility for control participants. Scores were calculated excluding time spent in *BBB.* The Compendium of Physical Activities (Ainsworth, et al., 1993) was used to assign the respective MET values for all reported physical activities. This questionnaire has been shown to be both valid and reliable for adult populations, ages 20-80 (Pereira, et al., 1997). *BBB* participants also completed a questionnaire assessing their past and current involvement in *BBB* as well as their current level of participation and fidelity to the program (avg. days per week, performance of key components such as jumps, use of weighted vest, etc.).

Balance: Static balance was assessed using the one-leg stance and tandem stance components of the FICSIT4 (Buchner, et al., 1993; Rossiter-Fornoff, Wolf, Wolfson, & Buchner, 1995). Participants were asked to stand on their dominant leg for as long as possible up to 30 seconds; and stand in a tandem position for as long as they could or up to 60 seconds. The ceiling for the tandem stance was doubled from 30 seconds to 60 seconds as this is an activity commonly practiced in *BBB* and to increase variability. Two trials of each exercise were performed and the longest trial of each was used in analysis. Dynamic balance was assessed using the tandem walk. Participants were asked to walk heel-to-toe on a straight line for 10 feet; time to complete the task (seconds) was recorded. Two trials were performed and the fastest score was used for analysis. Each participant was allowed 3 attempts to complete the task successfully. Participants unable to complete the task without committing more than two errors (e.g. missing heel-toe contact, losing balance and correcting with a step, or deviating from the line) were assigned a threshold score equal to the lowest sample score plus 5 seconds. Difficulty completing the tandem walk has been found to be predictive of fall related hip fractures among older adults (Dargent-Molina et al, 1996).

Self Reported Fall Risk Measures: The Balance Efficacy Scale (BES), an 18 item self-report questionnaire, was used to asses participants' confidence in performing various activities of daily living that require balance(Rose, 2003). Scores range from 0 to 100 indicating the level of confidence in one's ability to perform specified tasks without losing their balance. The BES was previously found to be both reliable and valid in a population of active older adults (Gunter, et al., 2003). Fall worry was assessed using a single question and was scored on a 6 point Likert scale with responses ranging from "not worried" to "extremely worried" about falling (Rose, 2003). Finally, participants were asked to report the number of falls they experienced in the previous 12-months. A fall was defined as "unintentionally coming to rest at a lower level, on an object, the floor, or the ground, other than as a consequence of a sudden onset of paralysis, epileptic seizure, or overwhelming external force" (Tinetti, et al., 1997).

Performance-based fall risk indicators: Components of the Senior Fitness Test (SFT) were used to assess underlying physical parameters associated with functional fitness. The SFT has been validated in a population of over 7,000 older adults and can provide data to indicate whether an older adult may be at risk for loss of function and increased risk of falls (Rikli & Jones, 2001). Functional mobility was measured using the 8 foot timed up and go (TUG) where the time it takes the participant to rise from a chair, walk 8 feet, turn 180 degrees and return to the chair and sit down is measured in seconds. Two trials were performed and the fastest score was reported. Scores greater than 11 seconds have been shown to be predictive of falling among older adults (Trueblood, Hodson-Chenault, et al, 2001). Lower body strength/endurance was measured using the 30-second chair stand where participants are asked to stand up from a chair (height of 19 inches) as many times as possible in 30 seconds without using their arms for assistance. The 30-second chair stand has been shown to be a valid indicator of lower body strength when compared to maximal leg press scores among older adults (Jones, Rikli and Beam, 1999).

Data analysis

All data were analyzed using PASW version 17 (SPSS inc, Chicago, IL). Group differences on descriptive variables were calculated by independent t-tests. Pearson product moments were calculated to assess the relationship between strength and balance scores and demographic variables and to identify covariates. Multivariate analysis of covariance (MANCOVA) was used to evaluate differences between groups in the functional fitness parameters related to fall risk; these included tandem stance, tandem walk, one-leg stance, timed up and go and 30 second chair stands. To control for the influence of physical activity done outside of the *Better Bones and Balance* classes on strength and balance, ACLPAQ score (excluding time spent in *BBB* classes) was included as a covariate along with age, and lean mass. In the case of multivariate significance, follow-up ANCOVA analyses were run to determine which variables contributed to the multivariate findings. Multivariate significance was set at an alpha level of 0.05. Bonferroni adjustments were applied to the interpretation of follow-up analyses; with adjusted alphas of 0.01.

Due to the potential bias associated with assigning a threshold score for the tandem walk, we compared group differences in the proportion of participants who were unable to complete the task and subsequently received a threshold score compared to the proportion that were able to complete the task.

In regards to the self reported fall measures, analysis of covariance was used to evaluate differences in BES, adjusting for age. The Mann-Whitney U test was used to evaluate differences in fall worry. A two way contingency table analysis was conducted to evaluate if the number of participants who had experienced a fall and the number of participants who experienced multiple falls differed between groups. Alpha was set at 0.05.

RESULTS

Participants: Invitations to participate in the study were extended to all current *BBB* participants in Linn and Benton counties (approximately 300) via informational sessions held during scheduled class sessions or through announcements made by class instructors. Interested individuals were asked to sign up or contact the researcher only if they felt they met the specified inclusion criteria. Consequently, 110 participants had screening interviews conducted and of those, 65% (n=72) were eligible to participate and had appointments scheduled.   Of those scheduled, two women were excluded due to hormone use within the previous five years which was not disclosed in their screening interview. One additional participant was excluded after she failed to complete the questionnaires. Complete data were available on 69 *BBB* participants among whom the average duration of *BBB* participation was 5.7 $\pm$ 4.3 years. Approximately 250 potential control participants were directly contacted from the research database and invited to participate. Others contacted us as a result of seeing fliers or hearing about the study through word of mouth. Of those, 47 met our inclusion criteria and were invited to participate. One control failed to complete her questionnaires and was therefore excluded, leaving 46 control participants who completed the study.

Descriptive variables are reported in table 3.1. There were significant differences in body size between *BBB* and control participants. There were no differences between groups in levels of physical activity performed outside of *BBB* classes. While our controls were considered sedentary (no vigorous, structured activity), regular participation in walking, gardening and household chores were common in both groups.

Table 3.1: Descriptive variables; means (SD)

Descriptive Measures	***BBB (n=69)***	**Control (n=46)**	**p-value**
Age	70.1(7.8)	68.1 (7.6)	ns
Years post menopause	18.9 (8.8)	17.4 (9.9)	ns
Physical function (CPF score)	23.5 (1.1)	22.3 (2.9)	<0.01
Height (cm)	161.7 (7.2)	162.9 (5.6)	ns
Weight (kg)	68.1 (10.9)	75.0 (16.3)	<0.01
Body fat (%)	34.7 (5.8)	37.8 (6.4)	<0.01
Body mass index (kg/m^2)	26.1 (4.3)	28.2 (5.7)	<0.05
*General physical activity (MET*hrs/week)*	46.7 (53.2)	33.0 (26.6)	ns

BBB Adherence and Compliance. To gauge differences between the laboratory-based *BBB* intervention and the community-based *BBB* program, we asked participants to report fidelity related to program adherence and compliance. We found that 91.3 % of participants reported attending at least 10 out of a possible 12 classes a month and 95.7% of participants attend classes year round. In regards to compliance with program components, only 18.8% of participants reported faithful use of their weighted vest while 40.6% of participants indicated that they never wear their vests. During classes, participants are given the choice of performing either heel drops or full counter movement jumps. We found that 69.6% of participants reported that they regularly perform full jumps, 29% reported regularly performing heel drops, while 1.4% reported they did not perform any of the impact exercises.

Correlational analyses supported the relationships among strength and balance functional variables and provided evidence that multi-collinearity and redundancy among these variables did not pose a concern for multivariate analyses. Scores from the BES as well as fall worry were both significantly correlated with all strength and balance variables (r ranged from 0.38-0.72 for BES and from (-)0.24 – (-)0.30 for fall worry) . The number of falls in the previous 12 months correlated with fall worry only (r=0.23).

Results from the MANCOVA indicated a significant multivariate effect after adjusting for age, lean body mass and physical activity (p<0.001). Follow up analyses indicated that *BBB* participants performed better than the control participants on all tests of functional fitness, with the exception of tandem stance. (Figure 3.1 and 3.2; p=0.02 for tandem stance, all others p<0.01). We also found that there was a significantly higher proportion of controls who could not perform the tandem walk task (15.2% of controls vs. 4.3% of *BBB*; p<0.05). When those who could not complete the task were excluded, there was no difference in tandem walk scores between groups (p>0.05).

In regards to the self reported fall risk measures, the *BBB* participants reported better balance confidence than the controls (p<0.01), but no difference in level of worry about falling compared to controls. There were also no differences between *BBB* and controls in the proportion of individuals reporting a single fall or multiple falls in the previous 12 months (Table 3.2).

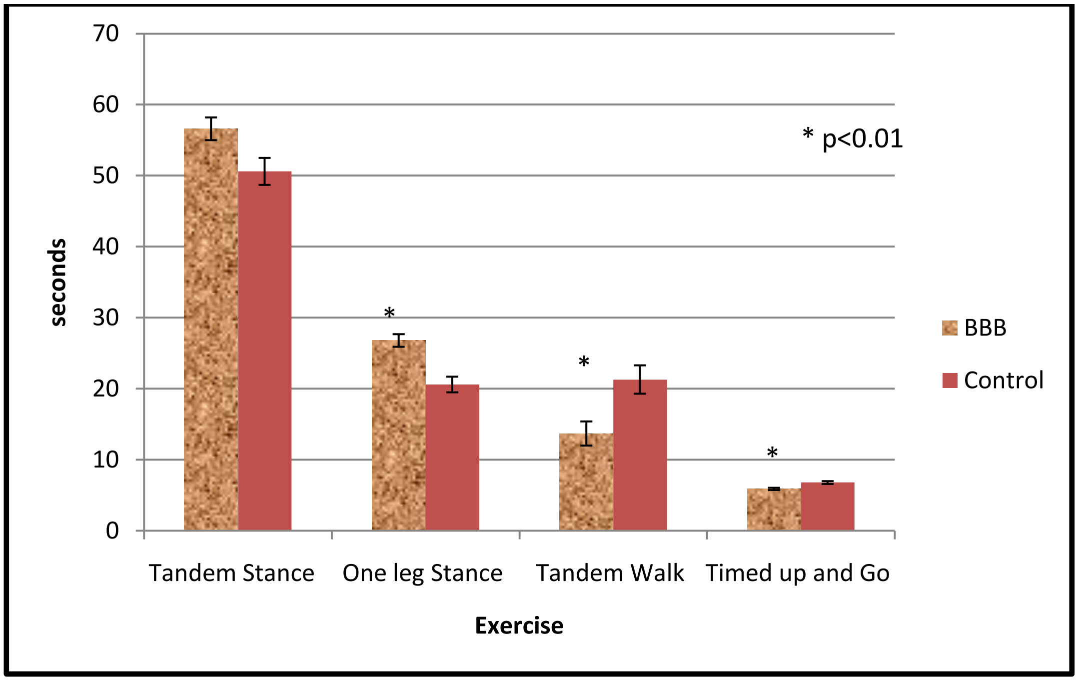

Figure 3.1: Age, lean Mass and Physical Activity Adjusted Balance and Mobility Scores. Data presented as means and standard errors. BBB participants outperformed controls on all tasks (p<0.01) with the exception of tandem stance (p=0.02). Higher scores on the tandem stance and one leg stance indicate better performance whereas lower scores on the tandem walk and timed up and go indicate better performance.

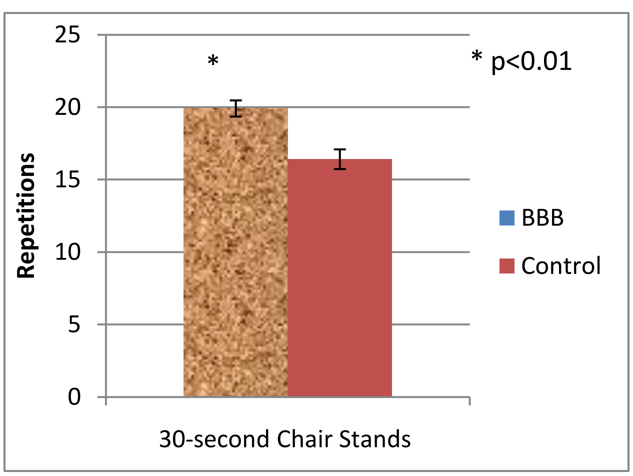

Figure 3.2: 30 second chair stand scores. Data adjusted for age, lean mass and physical activity and expressed as mean and standard error. BBB participants scored higher than controls (p<0.01)

Table 3.2: Self-Reported Fall Risk Measures; means (SD)

Fall Risk Measures	***BBB***	**Control**	**p value**
Balance Efficacy Scale	95.0 (6.69)	90.2 (11.8)	p<0.01
Fall worry	1.9 (1.3)	2.3 (1.5)	ns
At least one fall (%) in previous 12 months	42.0	37.0	ns
Multiple falls (%)in previous 12 months	21.7	17.4	ns

DISCUSSION

This study found that older women participating in *BBB*, a community-based fall and fracture prevention exercise program displayed better functional fitness as measured by strength, balance and mobility, and report better balance confidence compared to sedentary age-matched controls. Previous reports show that when the program was delivered in a laboratory environment with stringent progression protocols, participants improved balance, strength and lower extremity power after 9-months (Shaw & Snow, 1998). Our results support these original findings and indicate that in a community-setting, where program fidelity (as it relates to progression and intensity) varies, *BBB* participants have better strength, balance and mobility compared to controls. There were no differences between groups in the number of falls over the previous 12-months, nor were there differences in self reported fall worry. However, *BBB* participants did report better balance confidence than controls. Overall, these results suggest a successful translation of the *Better Bones and Balance* program from its original lab setting to its current model as a community based exercise class.

While many laboratory based programs have found exercise to be effective in reducing risk factors for falls and/or fall incidence (Banez, et al., 2008; Barnett, et al., 2003; Hourigan, et al., 2008; Madureira, et al., 2007) few programs, however, emerge from the lab environment to the community setting. One that has is Osteofit, a falls prevention program of education, lifestyle management and exercise that has 2 levels of participation- *Osteofit Level 1* an introduction to exercise: and *Osteofit for Life (level 2(Carter, et al., 2002))*. This program was designed to influence bone density and risk factors for falls among older osteopenic and osteoporotic women. This program is widely available to the public, and delivered in a community setting. Evaluation of this program which consisted of twice weekly exercise classes including resistance training using free weights and therabands, found that 20 weeks of participation increased dynamic and static balance and knee extensor strength. Like *BBB*, where cross sectional data indicate no differences between *BBB* participants and controls in the number of falls reported over the 12-months preceding the study, there were no observed differences between Osteofit and control participants in fall incidence over the intervention period. However, it is likely the duration of the intervention (20 weeks) was too short to adequately assess falls. Nevertheless both *BBB* and Osteofit have the potential to influence fall risk through improvements in strength and balance. *BBB* can also be compared to the Strong Women, Strong Bones program (Nelson, 2006), a nationally disseminated community based exercise program designed to decrease fracture risk through improvements in bone and reduction of fall risk factors for older women. Strong Women employs upper and lower body resistance training using handheld free weights and ankle weights, and is in part based on the work of Nelson et al (1994) who found maintenance of hip BMD and improvements in strength and balance in response to 12 months of high intensity resistance exercise in postmenopausal women (Nelson, et al., 1994). Although Strong Women has boasted national success with over 6800 participants engaging in the program throughout 38 states (Seguin, et al., 2008), the efficacy of the program in its current community setting in regards to fall incidence, strength and balance, and balance confidence has not been evaluated. Furthermore, as dissemination of Strong Women began as recently as 2003, the relationship between long term participation in Strong Women and risk factors for falls is also unknown. Conversely, *BBB* has documented enhanced strength, balance and balance confidence in *BBB* participants engaged in the program as offered in the community setting when compared to controls. Additionally, *BBB* participants have been faithfully engaging in the classes for up to 15 years and boast high enjoyment and desire to continue participation. Among the 69 BBB participants in our sample, 33 had been participating for at least 5 years continually and of those 14 had been participating for at least 10 years. As one 80 year old participant of 4 years indicated: “I intend to continue participating in BBB for another 20 years.” Yet another participant indicated she intended to continue with BBB “till death do us part”. These comments from participants speak to the value of this program beyond its influence on balance, strength and mobility.

Despite the cross-sectional nature of our study which limits the impact of our findings, the fact that the *BBB* program emerged from the lab into the community and has been engaging seniors since 1994 makes it novel and significant. With the exception of Osteofit and Strong Women, few other programs have been conducted in a true community-based setting. However, unlike *BBB,* the long term sustainability of such programs is still unknown. Regardless of setting, any exercise associated with the maintenance of functional fitness may also be associated with the maintenance of independence and consequently a potential reduction in risk of institutionalization in long term care facilities. The current annual cost of living in a nursing home is approximately $78,000/year (AARP, 2010), therefore any program that might delay the need for long term care through the maintenance of functional independence through fitness improvements and/or prevention of injurious falls would have widespread economic as well as public health impact.

Of interest in evaluating fall reduction programs is determining what factors among programs prove the most effective for reducing the risk of falls. A recent meta-analysis (Sherrington, et al., 2008)examining the role of exercise in fall prevention interventions, found a variety of factors included in different interventions contributed to a reduction in fall risk. Components of programs identified as having the greatest impact in reducing fall risk included; greater than 50 hours/intervention of exercise (delivered between 3 and 20 months), inclusion of high challenge balance training, and the *absence* of walking as a primary program component. *BBB* contains all three of these factors and, therefore, has the potential to be a powerful program for the reduction of falls, particularly considering its longevity. Chang et al (2004) showed that multi-factorial programs (such as education and environmental modification) that also include exercise proved the most effective for reducing falls (Chang, et al., 2004). Education about fall reduction strategies (prevention, recovering from loss of balance, getting off the floor) is included in the *BBB* curriculum and consequently may further influence fall risk.

Previous published work related to *BBB* did not measure fall incidence. Similarly, we found no differences in fall incidence between *BBB* and controls in this cross sectional study. However, we did not measure falls prospectively and relied on a self-report measure requiring participants to recall all falls they experienced in the 12-months preceding the study. Several researchers question the validity of a 12-month fall recall among older adults due to issues regarding memory (Ganz, Higashi, & Rubenstein, 2005). Consequently, this method may have limited our findings.

This study has several other limitations that must be considered when interpreting our findings. First, as noted, the cross-sectional design does not permit prospective measurement of fall incidence. Thus the true relationship between *BBB* participation and fall incidence may not have been captured using these methods. The cross-sectional design also prohibits inferences of causation; we can only infer that *BBB* is associated with enhanced functional fitness compared to controls. However previous lab-based, prospective studies of *BBB* (Shaw and Snow, 1998; Snow et al, 2000) lend support to the program's likely contribution to the better strength, balance and mobility observed among *BBB* participants in our study.

This study has several strengths. To the best of our knowledge, limited studies have previously examined the relationship between functional fitness and fall risk factors in a *community-based program* to reduce fracture risk through exercises designed to improve skeletal health directly (Snow, et al., 2000), and reduce the likelihood of a fall through balance and strength exercises. An additional strength of this study was the long-term involvement in the class among *BBB* participants. Long-term sustainability of exercise is not the norm among U.S. adults and older adults are the least active subset of the U.S. population (Nelson, et al., 2007). Many *BBB* participants have been faithfully and actively engaging in this exercise program for over 10 years. We believe this highlights the unique and highly acceptable nature of the *BBB* program. Finally, we collected data on balance confidence and fall worry in addition to fitness related fall risk factors allowing a broader evaluation of parameters that may increase one's risk for falls.

In conclusion, *BBB* participation is associated with enhanced strength, balance and mobility and better balance confidence within our sample of older women compared to controls. These results indicate a successful translation of this program out of the laboratory and into the community. A future randomized, prospective trial evaluating *BBB* is warranted to determine causal relationships between *BBB* and parameters of functional fitness and fall risk as well as fall incidence in the community setting. Nonetheless, *BBB* appears to be a safe, enjoyable and effective exercise program for enhancement of fall risk indicators related to functional fitness and balance confidence among older women.

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CHAPTER FOUR

MEETING THE PHYSICAL ACTIVITY GUIDELINES THROUGH COMMUNITY BASED GROUP EXERCISE: QUANTIFYING THE PHYSICAL ACTIVITY DOSE FROM PARTICIPATION IN *BETTER BONES AND BALANCE*.

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ABSTRACT

Objective: Community based exercise programs are a popular method for obtaining physical activity among older adults, but the amount of physical activity obtained through such programs is largely unknown. This study quantified the dose of physical activity, in regards to bone loading forces and cardiovascular activity, associated with participation in *Better Bones and Balance (BBB),* a community based fall and fracture prevention program for older adults. **Methods:** Thirty-six BBB participants, aged 73.2 ± 7.6 participated in this study. Ground reaction forces (GRF) associated with key BBB exercises were evaluated using a force plate. Session and weekly totals of minutes of moderate to vigorous physical activity (MVPA) and total time spent above 55% maximum HR were measured using accelerometers and heart rate monitors, respectively. **Results:** BBB exercises produced mean *one-leg* GRFs ranging from 1.4-2.2 x BW while weekly participation was associated with 126 ± 31 minutes of MVPA. **Conclusion:** Activity obtained by BBB participation is adequate to meet recommended guidelines for skeletal and cardiovascular health.

Key words: Community exercise, older adults, accelerometer, heart rate, ground reaction forces

INTRODUCTION

Physical inactivity is a growing problem in U.S. society. Over two-thirds of adults, specifically older adults, fail to accumulate the recommended minimum 150 minutes a week of moderate physical activity or 75 minutes of vigorous activity in order to optimize health and aid in the prevention of chronic disease (Nelson, et al., 2007). In fact, older adults are the least active segment of the U.S. population. Only 30% of those over 65 years of age report engaging in any regular exercise (CDC, 2010; Heath & Stuart, 2002). This carries a large public health impact, as inactivity is known to contribute to multiple chronic diseases such as obesity, cardiovascular disease, type II diabetes, cancers and osteoporosis. Furthermore, physical inactivity can decrease quality of life and contribute to the loss of independence among older adults (Nelson, et al., 2007).

Community-based exercise classes are a popular option for older adults to engage in physical activity, as they are often inexpensive, held in convenient community centers and provide other desirable benefits, such as social interaction. However, whether the dose of exercise provided by most community based exercise programs meets the current guidelines for physical activity is largely unknown. This is due to a lack of proper research evaluation of most community programs, and in particular, a lack of objective quantification of physical activity dose. Consequently, it is difficult to determine the influence or effectiveness of any exercise program on various health outcomes without fully understanding the dose of exercise delivered by that program, and whether that dose is adequate to produce the desired outcome. For example, when the enhancement of skeletal health is the outcome of interest, it becomes necessary to know the impact forces delivered by the prescribed exercise to determine if those forces are sufficient to promote skeletal adaptation. While some authors have quantified ground reaction forces associated with specific exercises in bone loading exercise protocols (Bassey & Ramsdale, 1995; Kemmler, et al., 2002; Weeks & Beck, 2008; Young, et al., 2007), the majority of authors do not, making objective comparisons between various exercise protocols a difficult task. This is also true when other disease states associated with physical inactivity, such as cardiovascular disease, type II diabetes, and hypertension are of primary concern. Objectively quantifying both the amount and the intensity of exercise delivered by a program via the use of accelerometers and heart rate monitors would allow comparison of the actual exercise dose to current guidelines for cardiovascular health. Unfortunately, studies using such objective assessments of physical activity among older adults are scarce.

Better Bones and Balance (BBB) is an evidence-based fall and fracture prevention program that has been widely translated into a community setting and has been ongoing for 15 years, boasting high enjoyment and sustainability among its older adult participants. The *BBB* program incorporates lower body resistance training with weighted vests, impact and balance exercises and is delivered as three 50-minute sessions per week and taught by community fitness instructors. Specifically, the program emphasizes five “key” weight-bearing exercises: stepping onto benches, forward and side lunges, squats, heel drops and/or jumps (without weighted vests). Recently stomping has been included in the protocol based on evidence that this exercise may have osteogenic potential (Young, et al., 2007). A minimum of 30 repetitions of each exercise are performed during each class session. Each class also includes balance training. Participants engage in activities that challenge dynamic and static balance with balance activities often integrated into strength activities. *BBB* began as a lab-based research program in 1994 (Shaw & Snow, 1998) with 18 participants and has grown to include over 300 participants in the mid-Willamette Valley in Oregon, as well as others throughout the West Coast. Data exist to support the program's efficacy as a lab-based program in improving function and reducing fall and fracture risk factors in postmenopausal women (Shaw & Snow, 1998; Snow, et al., 2000), and a community-based evaluation has recently been completed. However, an objective quantification of the dose of physical activity (activity amount, exercise intensity, force magnitudes), typically experienced by participants in the community setting had yet to be conducted. Therefore, the aim of this study was to quantify the exercise dose associated with the *BBB* exercise program. Specifically we aimed to determine the typical amount and intensity of physical activity (minutes of moderate to vigorous physical activity (MVPA), time above 55% maximum heart rate [HR max]) that participants accrue during one *BBB* class session and over a typical week of *BBB* participation (3 sessions/week) as well as the ground reaction forces (GRF) associated with the key bone loading exercises in *BBB*.

METHODS

Participants

Postmenopausal women (n=36) were recruited from four different *BBB* classes in Corvallis, Oregon offered through Linn-Benton Community College. Women were eligible to participate if they 1) were currently enrolled in a *BBB* class and had been actively participating for at least one year and 2) if they were free from any musculoskeletal injury that would hinder their full participation in the program or hinder their ability to complete the testing procedures. During recruitment, participants were stratified into three age categories: 60-69 (n=13), 70-79 (n=14) and 80+ (n=9), so as to include a sample of age ranges typical of the *BBB* program.

This study was approved by the Oregon State University Intuitional Review Board. All participants gave written informed consent prior to participation in this study.

Procedures

Demographic information. Initial testing took place at the Oregon State University Bone Research Laboratory. A health history questionnaire (HHQ) was used to collect information regarding participants' age and menopausal status, along with their past participation with BBB. Height (cm) and body mass (kg) using a fixed stadiometer and digital scale, respectively, were also assessed at this time.

*Ground Reaction Forces (GRF).*Peak one-leg vertical GRFs (N) associated with the key exercises of the *BBB* program (steps, stomps, heel drops or jumps)were collected using a portable force plate system (Kistler Instrument Corp, Amherst, New York). Data was collected employing a sampling rate of 1500 Hz. Participants performed each exercise so that only the right foot contacted the force plate. Therefore, all data are presented as one-leg forces. Based on information derived from observing class sessions, interviews with 4 instructors, and participation in the instructor training workshop, we estimated that a standard *BBB* class includes at least 30 repetitions (varies between continuous or broken into multiple sets) of each of the key exercises. In order to accurately capture the forces associated with a typical class, participants performed a single set of 30 repetitions of each exercise. The first 5 repetitions were performed on the force platform (collected as a single trial). Participants then performed 20 repetitions off the platform, and completed the final 5 repetitions on the platform. This was done to minimize data processing, and to capture any fatigue-related changes in force production that may occur toward the end of the set. Consequently we obtained data for 10 repetitions of each exercise. Prior to data collection, all participants were given detailed instructions for foot placement and asked to perform the exercises in the manner that she would perform them in class. Steps were performed by stepping off a 9 inch step with data collected for the lead leg upon landing. Jumps were performed in a counter-movement fashion with a brief pause between repetitions. Jump height was determined by participant comfort and desired effort level. Participants performed *either* jumps (n=24) or heel drops (n=12), whichever corresponded with their usual exercise behavior. Likewise, participants performed the steps wearing a weighted vest only if wearing the vest was a typical behavior for them (n=7). The BBB program does not encourage the use of vests during jumps, heel drops or stomps. Therefore, we did not have participants wear vests during these activities. The peak GRF was obtained for each repetition in each trial using Bioware software (Kistler Instrument Corp, Amherst, New York) . A low pass 100 Hz dual pass Butterworth filter was applied to each trial before extracting peak GRF data. Data points were averaged across all 10 trials for each exercise and normalized to units of body weight (BW).

MVPA. The physical activity data collection occurred during regularly scheduled *BBB* classes. MVPA occurring during the *BBB* classes was collected using a multidirectional Actical accelerometer (Phillips Respironics, Bend, OR). During their initial lab visit, participants were fitted with the accelerometer and instructed in its use. Prior to the in-class data collection, the accelerometers were initialized with the participants' height, weight and age. Upon arrival to the participants' respective class, a researcher secured the accelerometer to the participants' right hip using a neoprene waistband. Participants were instructed to maintain normal class behaviors while wearing the accelerometers. At the completion of each class, the participant returned the accelerometer to the researcher, and the data were downloaded into specialized software (Actical 2.12, Philips Respironics, Bend OR) and the device was re-initialized for the next exercise session. Each participant wore the accelerometer during three separate *BBB* classes over a period of one to two weeks.

Custom intervals were created corresponding to the 50 minute class session, plus two minutes to account for variations in class end time. Data points (MVPA, average and peak HR, time spent above 55% HR max) across the three exercise sessions were averaged to indicate normal activity associated with a single *BBB* class. Data were also summed across all three sessions to indicate the MVPA associated with a typical week of *BBB* participation in order to compare the mean weekly dose in *BBB* to the 2008 Physical Activity Guidelines for older adults (DHHS, 2008). If a participant failed to complete all three sessions with the accelerometer (n=5), her data were averaged across the two completed sessions and these data were not used to calculate weekly exercise dose.

Heart Rate. Average and peak HR per *BBB* class session was assessed using the Polar RS400 heart rate monitors (Polar Electro Oy, Finland). Heart rate data was collected concurrently with accelerometer data. Similar to the accelerometers, each device was initialized with the participants' individual information (height, weight, date of birth, estimated max heart rate) prior to use. At the commencement of each class, a researcher assisted each participant in securing the chest transmitters and starting the watches. Upon class completion, data were downloaded using specialized software (Polar Pro Trainer 5, Polar Electro Oy, Finland). Peak HR per session and average HR per session were recorded for each individual. Average and peak heart rate data from all exercise sessions were then averaged. In the cases where less than three exercise sessions were completed, only the completed sessions were averaged. However only those with complete data were included in the calculations for mean weekly exercise dose. Peak and average heart rates were normalized to a percentage of age-predicted maximum heart rate using the modified prediction equation [208- (.7*age)]. This equation is found to more accurately reflect the true maximum heart rate among older adults (Mazzeo & Tanaka, 2001). Moderate to vigorous intensity physical activity was defined as greater than 55% of predicted maximum HR (Gordon, et al., 2004; Mazzeo & Tanaka, 2001; Nelson, et al., 2007). The percent of time and total time per session spent above 55% of maximum HR was calculated to compare to accelerometer MVPA.

Data Analysis

All data were analyzed using PASW 17 software (SPSS inc, Chicago, IL). Means and standard deviations were computed for all variables. Participants were stratified into age cohorts and class cohorts and descriptive statistics were run within the entire sample, as well as within the age and class strata. One-way analysis of variance was used to assess differences in variables between age cohorts and between class sessions as well as differences in GRF between individual exercises. Alpha levels were set at 0.05.

RESULTS

Descriptive variables for the entire sample and each age cohort are reported in table 4.1. There were no significant differences between age cohorts on any demographic variable. There were also no significant differences in age, height and body mass across class sections, although duration of *BBB* participation was significantly shorter in class section 4 compared to all other class sections (Table 4.2).

Table 4.1: Descriptive variables by age cohort; means (SD)

Variable	**Total sample (n=36)**	**60-69 (n=13)**	**70-79 (n=14)**	**80-89 (n=9)**
Age	73.2(7.6)	65.1 (1.7)	74.2 (3.5)	83.4 (2.1)
Height (cm)	161.4 (6.8)	163.3 (5.7)	163.3 (5.5)	155.8 (7.7)
Body Mass (kg)	66.3 (12.4)	65.8 (14.7)	69.2 (11.5)	62.5 (9.9)
Years in BBB	7.5 (4.3)	5.5 (3.7)	9.3 (4.2)	7.7 (4.5)

Table 4.2: Descriptive variables by class section; means (SD)

Variable	**Class 1 (n=9)**	**Class 2 (n=6)**	**Class 3 (n=14)**	**Class 4 (n=7)**
Age	72.5 (7.1)	72.5 (9.4)	75.1 (7.3)	70.8 (8.2)
Height (cm)	161.9 (9.0)	163.6 (4.8)	162.1 (5.3)	157.6 (7.7)
Body Mass (kg)	62.6 (9.7)	67.3 (4.2)	67.9 (13.6)	66.8 (18.1)
Years in BBB	10.1 (4.5)	7.6 (2.0)	8.3 (4.0)	2.4 (0.54)*

* differs from all other classes, p<0.05

GRF Results. Force data represent the peak GRF experienced by one leg on each of the four key impact activities associated with BBB: steps, heel drops, stomps, and jumps, averaged across trials. Figure 4.1 represents GRF data for participants in each age cohort as well as data combined across all age cohorts. The forces elicited by jumping were significantly higher than forces from each of the other exercises ($p<0.05$). There were no significant differences between mean forces produced by steps, heel drops or stomps. There were no significant differences between age cohorts for any exercise (Figure 4.1). Participants were also stratified by class section to examine instructor contribution to GRF levels. There were no significant differences across class section for any exercise (Figure 4.2).Furthermore, there were no differences in recorded GRF of steps between participants who wore their vests during testing (n=7) and those who did not (n=29) (1.47BW ± 0.20 vs 1.46 BW ± 0.23, $p>0.05$, respectively) .

Exercise Intensity (HR and MVPA). Table 4.3 displays the heart rate and accelerometer data for the total sample, and each age cohort. Mean heart rates ranged from 97.7 to 161.6 beats per minute. When normalized to predicted maximum, participants spent 126 minutes per week, or 84.0 ± 21.3% of total class time at or above 55% of maximum HR. When measured via accelerometers, participants only spent 28.5 ± 12.1% of total class time in MVPA, equating to 14.3 ± 6.2 minutes of MVPA per session, and 44.1 ± 19.2 minutes of MVPA per week. There were no differences between age cohorts on any HR or accelerometer variable, with the exception of absolute heart rate, expressed in beats per minutes (Table 4.3). There were also no significant differences across class sections on any variable (Table 4.4).

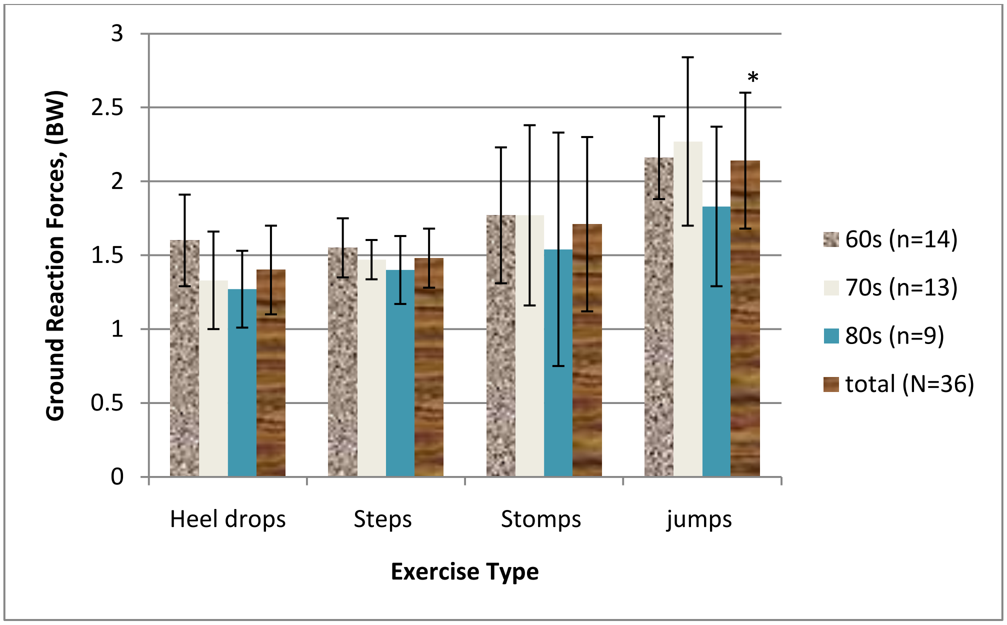

Figure 4.1: GRF for key BBB exercises stratified by age decade. Data represent the forces experiences by a single leg and are expressed as means and standard deviations in units of body weight. There were no differences in GRF between any age group on any exercise. * GRF from jumps (total sample) significantly higher than GRF for each other exercise.

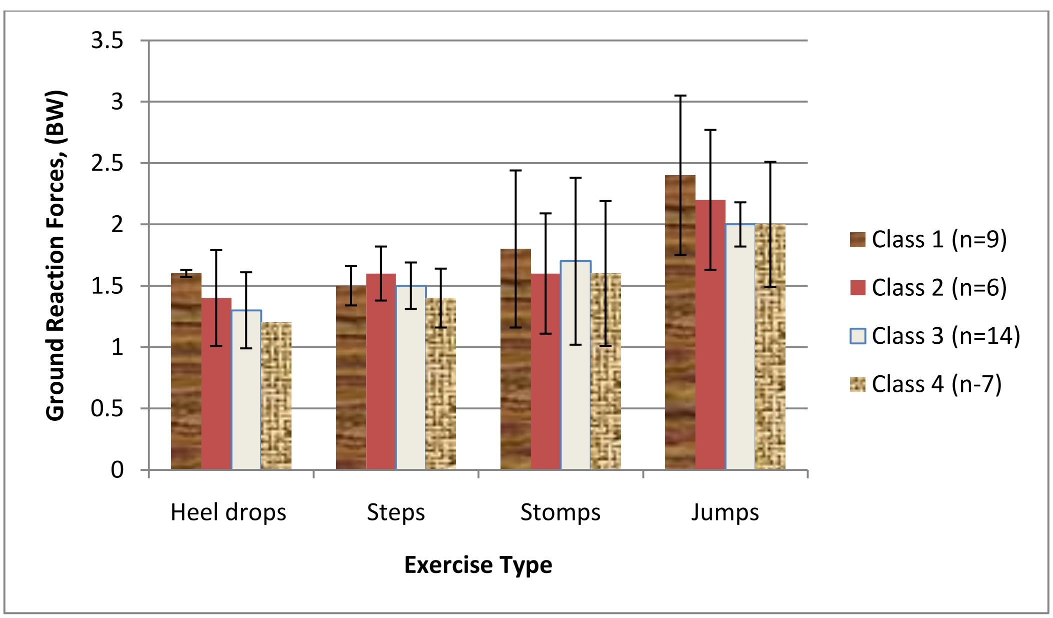

Figure 4.2: GRF for key BBB exercises stratified by class session. Data represent the forces experienced by a single leg and are expressed as means and standard deviations. There were no differences in recorded GRF between class sessions.

Table 4.3: Physical activity duration and intensity stratified by age , means (SD)

Variable	Total sample (n=36)	60-69 (n=14)	70-79 (n=13)	80-89 (n=9)
Accelerometry				
Total activity counts per session	14,357 (9,067)	14,969 (5,968)	15,564 (12,427)	11,596 (6,600)
Average activity counts (counts/min)	272.9 (178.4)	277.5 (132.9)	300.7 (238.6)	223.0 (126.9)
MVPA (min/session)	14.3 (6.2)	15.2 (5.5)	14.3 (7.0)	12.9 (7.0)
MVPA (min/week)	44.1 (19.2)	45.4 (17.1)	42.4 (22.8)	43.7 (21.6)
Time in MVPA (% of sessions)	28.5 (12.7)	30.3 (10.9)	28.5 (14.0)	25.9 (14.0)
Heart Rate				
Average session HR (beats per minute)	102.7 (14.1)	110.1 (14.8)*	96.5 (13.1)*	101.6 (10.6)
Average session HR (% HR max)	65.5 (8.7)	67.7 (9.4)	61.8 (8.3)	67.9 (7.1)
Peak exercise HR (% HR max)	82.9 (10.9)	85.8 (9.8)	78.8 (11.1)	85.0 (11.2)
Peak Exercise HR (beats per minute)	129.9 (17.9)	139.4 (15.7)*	122.9 (17.6)*	127.2 (17.1)
Time above 55% HR max (% of session)	84.0 (21.3)	87.7 (17.4)	76.9 (28.1)	89.5 (10.6)
Time above 55% HR max (min/week)	126.0 (32.1)	131.6 (26.2)	115.4 (42.2)	134.2 (15.9)

* Values for age group 60-69 significantly different from age group 70-79, p<0.05.

Table 4.4: Physical activity duration and intensity stratified by class section, means (SD)

Variable	Class 1 (n=9)	Class 2 (n=6)	Class 3 (n=14)	Class 4 (n=7)
Accelerometry				
Total activity counts per session	17,766 (4,538)	10,815 (5,808)	14,942 (12,946)	11,840 (4,943)
Average activity counts (counts/min)	341.6 (81.2)	208 .0 (111.7)	279.1 (256.4)	227.7 (94.8)
MVPA (min/session)	18.7 (3.1)	11.1 (4.7)	13.9 (7.9)	11.7 (4.6)
MVPA (min/week)	58.1 (8.1)	32.7 (15.4)	43.2 (24.8)	35.1 (13.8)
Time in MVPA (% of sessions)	37.6 (6.2)	22.2 (9.4)	27.9 (15.8)	23.4 (9.2)
Heart Rate				
Average session HR (beats per minute)	107.1(17.1)	97.7 (16.9)	100.1 (11.4)	106.3 (13.1)
Average session HR (% HR max)	68.1 (9.8)	62.0 (9.4)	64.5 (7.7)	67.2 (9.1)
Peak exercise HR (% HR max)	85.8 (10.8)	78.5 (11.2)	81.5 (10.5)	85.6 (12.2)
Peak Exercise HR (beats per minute)	135.1(13.2)	123.8 (20.1)	126.7 (16.7)	135.2 (16.5)
Time above 55% HR max (% of session)	87.5 (21.1)	70.6 (31.2)	86.9 (15.3)	85.1 (23.1)
Time above 55% HR max (min/week)	131.2(30.9)	105.7 (46.7)	130.3 (22.9)	127.6 (34.7)

DISCUSSION

The aim of this study was to quantify the amount and intensity of the physical activity dose experienced by women participating in community-based *Better Bones and Balance* classes. We found that, on average, older women participating in *BBB* spend approximately 126 $\pm$ 31 minutes per week engaged in exercise where their heart rates exceed 55% of their predicted maximum heart rates and maintain an average heart rate per session 65 $\pm$ 7% maximal heart rate. This level of intensity is considered moderate to vigorous (Gordon, et al., 2004; Mazzeo & Tanaka, 2001). Consequently, regular participation in *BBB* may provide sufficient weekly activity required to meet current national guidelines related to the performance of aerobic activity. When accelerometry alone was used to assess exercise intensity, this is not apparent. Accelerometers are designed to measure accelerations during vertical displacement of the hip, with activities resulting in greater acceleration producing the highest activity counts. Therefore the nature of many of the exercises that comprise *BBB* (lunges, squats, balance activities, upper body resistance training) do not lend themselves well to assessment via accelerometers. However, these exercises do apparently provoke a substantial HR response indicating that participants may be getting cardiovascular benefits along with benefits to strength, balance and bone as a result of this class. This study also suggests that while accelerometers are an effective, objective measure of MVPA in some settings, they significantly underestimated exercise intensity among participants in the *BBB* program. It is likely that the accelerometers were most effective at picking up activity associated with the impact component of the class which was also measured separately outside of the class using force platforms. Observation of class sessions indicated that approximately 13.0 $\pm$ 2.9 minutes of programming time were devoted to the impact exercise (stepping, stomping, jumps, heel drops) and walking. This value closely relates to the minutes of MVPA per class recorded via accelerometry. Therefore, accelerometers may have usefulness in assessing impact exercise among older adults.

Our results indicate that *BBB* likely delivers an adequate dose of exercise for the promotion of optimal health in older adults. Current recommendations indicate that older adults should get a minimum of 150 minutes per week of moderate aerobic physical activity, 75 minutes per week of vigorous physical activity or a comparable combination thereof (DHHS, 2008; Nelson, et al., 2007). In addition, adults are encouraged to engage in at least two days of muscle strengthening per week in association with balance activities for those at risk of falls (DHHS, 2008). Based on HR data, it appears that *BBB* provides an adequate dose of aerobic activity to meet the recommendations related to cardiovascular fitness. This finding is corroborated with data from a related study in our laboratory which compared *BBB* participants to sedentary age matched controls and found that *BBB* participation was associated with superior cardiovascular fitness, as measured by the two minute step test, when compared to sedentary age-matched controls (data not yet published). This relationship between *BBB* and cardiovascular fitness was surprising as *BBB* was designed to target skeletal health, muscular strength and balance and has not been marketed as an aerobic program. However, direct observation of classes indicated that many of the *BBB* exercises are being performed in an aerobic manner (i.e. travelling lunges, continuous stepping, walking for warm up, etc.) and this adaptation to the classes has added an aerobic stimulus likely sufficient to achieve an appropriate training zone for cardiovascular health. It is also interesting to note that participants in the oldest age cohort (80-90) achieved similar relative heart rates (peak % maximum HR, and average % maximum HR) as participants in the younger age groups. Since participants are often encouraged to exercise at their own pace, these results highlight the suitability and effectiveness of *BBB* for participants of varying ages. This ability for participants to self-select pace may also influence the program's observed sustainability as many participants, particularly those in the oldest age cohorts, have been faithfully partaking in

BBB for over 10 years. Consequently, *BBB* could play a role in the long term maintenance of health for such dedicated participants.

Not only do the physical activity guidelines for older adults suggest obtaining 150 minutes a week of moderate activity or 75 minutes a week of vigorous activity , they also recommend older adults accrue the activity in bouts longer than 10 minutes in order to provide adequate aerobic overload (Nelson, et al., 2007). A recent study evaluating general physical activity patterns in older adults (Copeland, 2009) found that of the MVPA accrued by older adults during free-living conditions, 66% of all activity was sporadic and lasting for durations less than 10 minutes. Others have shown that older adults participating in a structured physical activity program including both group and home based exercise had higher MVPA levels with more activity accrued in bouts longer than 10 minutes compared to controls participating in an education based “successful aging” class (Pruitt, et al., 2008). This emphasizes the important role that structured exercise programs can play in helping older adults meet the physical activity guidelines. On that line, the exercise dose delivered from *BBB* is achieved within a 50 minute time frame, three times a week (as opposed to activity spread throughout the time course of a day) so that the accumulated exercise is likely occurring in bouts of sufficient duration for promoting cardiovascular health. Further, qualitative data from class observations indicate that participants are maintaining activity for the majority of the class session with the exception of warm up and cool down stretching lasting approximately 10 minutes total.

A large discrepancy was observed between exercise dose measured using heart rate monitors and MVPA measured via accelerometers. According to accelerometer data, participants spent about 37% of their exercise time in moderate to vigorous activity. The data from heart rate monitors suggest that participants spent 84% of time in MVPA. This is a difference of approximately 28 minutes in a 50 minute session. According to the accelerometer data, we would infer that BBB is not providing sufficient exercise intensity to meet the physical activity guidelines. One explanation for the difference could be in the nature of the exercises: some were performed in a supine position (such as abdominal work or planks) and others involved upper body exercise, both of which would result in elevation of heart rate without registering changes in activity counts from the accelerometers. Still others (lunges, squats, chair stands) involved hip displacement, but with a fixed base of support; the intensity of these activities were likely underestimated by accelerometry. However, another explanation may lie in the MET values used to distinguish moderate or vigorous activity. Nelson et al (2007) suggested that using the standard 3 and 6 MET cut points to define MVPA for older adults is not recommended and suggests that using a measure relative to fitness (such as 55-85% oxygen uptake reserve) may be more appropriate for this population. We did not collect oxygen uptake on participants in this study, nor did we collect data on resting heart rate to calculate a heart rate reserve. However, we did standardize intensity by age through use of an older adult specific max heart rate prediction equation. Others have also found that using traditional MET cutoffs for accelerometer in older adults underestimates actual intensity. Ayabe et al (2009) observed an age-associated decrease in accelerometer measured MVPA in a large cohort of people age 19-69 (Ayabe, et al., 2009). In addition, they found that the proportion of total activity classified as light activity increased with age independent of total step count indicating that the intensity of free-living activity declines with age. The authors comment however that even though an activity may be classified as “light” by an accelerometer, depending on the fitness level of the individual, the activity may still be sufficient to elicit a cardiovascular response. Other authors have attempted to remedy this issue with accelerometry in older adults by establishing individualized cut-points based on 400 meter walk time (Pruitt, et al., 2008) or cohort specific cut-points based on oxygen uptake for a 3.2km/h treadmill walk (Copeland & Esliger, 2009). Using these modified cut-points, both of these studies observed higher MVPA than was observed in the current study. However, while these methods may have yielded more accurate results (e.g. higher observed MVPA with modified cutoffs versus traditional cutoffs), the practicality of these methods for widespread use in community settings is limited. Consequently, the field would benefit from standardized age-dependent cut-points that may be applicable across devices in order to increase the validity of accelerometry in older adults. In addition, these findings in conjunction with those of the current study emphasize the importance of utilizing multiple methods of activity monitoring, such heart rate monitoring, to cross-validate accelerometer results in older populations.

In regards to bone loading, we found that the exercises in the *BBB* program provided a GRF equivalent (one-leg) of 1.4-2.2 x BW. Previous research indicates the threshold for improving hip BMD is less than 100 impacts a day with accelerations exceeding 3.9 x acceleration of gravity, a measure significantly correlated to GRF (R=.735) and associated with jumping exercise (Vaninionpaa, Korpelainen et al, 2006). We did not measure gravitational acceleration to allow direct comparison to this threshold, but GRF forces of 4-5 x BW (two-leg) have also been associated with positive changes in adult bone (Winters and Snow 2000; Uusi Rasi et al 2003, Young et al 2007). Therefore the exercises with the highest impact (i.e. jumps and stomps) may provide sufficient stimulus to achieve skeletal overload. The heel drops are likely most effective as preparatory exercises for jumps and stomps, and the steps are likely most effective for strength, balance and cardiovascular fitness.

Our results showed that the GRF associated with the key *BBB* exercises are in accordance with other reported values. Uusi Rasi et al (2003) reported GRF values of 2.1-5.6 x BW (2 leg values) associated with jumping off 10-25 cm foam fences in a 12 month protocol that increased cortical area and section modulus of the tibia in postmenopausal women. The women in our study performed counter-movement jumps from the floor and produced GRFs ranging from 1.1-3.7 x BW (jumps only, one leg values). Winters and Snow (2000) found similar GRF ranging from 4-5 x BW from a jumping protocol similar to *BBB* that was found to enhance BMD in premenopausal women (two-leg values) (Winters and Snow 2000). Bassey and Ramsdale (1995) compared forces associated with heel drops measured using a force platform (two-leg) and measured by femoral implant (Bassey & Ramsdale, 1995). The mean two-leg GRF for the heel drop was 2.73 BW (range 2.1-3.6) and values from the femoral implant were within 5% of those measured from the force platform. They also compared one leg versus two leg data collection and found an even distribution of weight during the heel drops on each force plate. The women in our study produced one-leg forces of approximately 1.4 ± 0.30 x BW which, when extrapolated to two leg values, is consistent with the forces produced by the women in the Bassey study.

We were surprised to observe that the heel drops elicited the lowest forces of the exercises tested, especially since the heel drops are traditionally included in the class to serve as an impact exercise and as a training exercise prior to initiating jumps, or as an alternative to jumping for those who are unable or unwilling to do so. It is likely that technique plays a role in the relatively low forces observed. For example, many participants are performing this activity as a rocking motion, rather than a forceful drop from toes to heels. However, our values for heel drops are similar to what others have reported (Bassey et al 1995). Stomping elicited higher forces than expected, with impact forces close to that of jumping, although there was a significant difference in forces between the two exercises. This concurs with data from others who also report stomping impact forces higher than heel drops and similar to those of jumping (Weeks & Beck, 2008). Technique may also influence stomping as there were noticeable differences in the manner in which women performed the exercise ranging from simply walking in place to forcefully stamping the foot. In fact, the variability for stomps was greatest among all the exercises measured with minimum values comparable to the minimum values of the heel drop (0.97 vs. 1.0 BW), although participants were able to elicit substantially higher forces in the stops than heel drops when proper technique was employed (maximum values: 3.47 BW stomps vs. 1.89 BW heel drops). Young et al (2007) also found GRF forces from stomping to be higher than those of heel drops (4.7

BW vs. 2.4 BW, respectively, two leg data) and that compliance with stomping during a 12 month exercise intervention was significantly correlated to hip BMD among postmenopausal women (Young, et al., 2007) In light of these findings, the *BBB* instructor training program will emphasize the inclusion of correctly executed stomps over heel drops, as stomping may have greater osteogenic potential and seems more acceptable for those who may be unable to correctly execute the heel drop.

Ground impact forces are not the only mechanism by which exercise may elicit an osteogenic effect at the hip. Muscle pull at bony attachment sites can also provide overload to the skeleton and stimulate adaptation. In fact, studies on exercise and bone have shown bone adaptations through both impact forces and joint reaction forces in postmenopausal women (Kohrt, et al., 1997; Maddalozzo, et al., 2007). Bassey and Littwood (1997) found that, during exercises involving both impact and large muscle contraction (such as jumping), forces measured by femoral implant were 1.5-3 times higher than those measured by ground reaction forces (Bassey, Littwood et al , 1997). This indicated the additive contribution of both muscle and ground reaction forces in bone strain. Several of the core exercises included in the *BBB* program, such as the lunge, squat and potentially stepping likely provide their stimulus through muscle action rather than impact and therefore the intensity of that stimulus would not be captured using force plate measurement. Unfortunately direct measurement of bone strain from resistance exercise, such as through femoral implant devices, is invasive and unrealistic for field studies. However, it is certainly possible to evaluate these forces indirectly and such measurements should be the focus of future studies. Therefore we do not know the effectiveness of these primarily resistance exercises in comparisons to our measured impact exercises. What is clear is that, not only does the *BBB* program produce a sufficient dose of cardiovascular exercise, it also includes the muscle strengthening activities recommended for older adults.

Owing to the popularity of community exercise among older adults it is particularly beneficial to understand the amount and intensity of exercise provided in order to appropriately prescribe such programs for the optimization of health. Therefore the primary strength of this study was the objective evaluation of different parameters related to exercise intensity, allowing a full description of the exercise dose achieved though participation in *BBB*. This is particularly unique due to the community setting of this program. An additional strength of this study was the inclusion of a wide sample of ages among participants so as to better understand any relationship between age and exercise dose.

Our study does have limitations. First, our sample sizes within each age cohort and class section were small, and analyses indicated that observed power to detect differences between groups was low (0.16-0.29). However, the primary objective of our study was to describe the activity dose associated with *BBB* and not to evaluate the influence of age on participation. Consequently our total sample size of 36 allowed us to meet this primary aim. As previously mentioned, we did not collect resting heart rate data from our participants and therefore could not calculate an intensity range based on fitness levels. We also did not collect GRF data for steps with all participants wearing weighted vests to compare to our data without vests. However, the majority of our sample reported not regularly wearing their vests during class, and we chose not to enforce vest use this during data collection to more accurately capture what is occurring in the community setting. We do recognize, however, that this comparison would have been valuable in order to assess the influence of weighted vests on the impact forces. However, we did compare the GRF among those who did wear the vests and those who didn't and found no differences in the GRFs produced during stepping. Lastly, we did not randomly select the classes that were evaluated. Rather, we selected classes that were based close to the university and whose instructors were most responsive to having researchers in their classes. However, each class had a wide range of exercise participants in regards to age and fitness and each was taught by a separate instructor so that we feel we captured a representative sample of the typical *BBB* population.

In conclusion, this study indicates that regular participation in *BBB* delivers an adequate dose of exercise to meet national guidelines to optimize health. Older women are getting sufficient cardiovascular responses and muscle strengthening in these classes to meet the recommended weekly exercise prescription. Further, we found that even in the community setting the impact exercises included in the *BBB* program provide moderate impact and may be adequate to promote skeletal health. Considering the long-term compliance of many participants, this program proves to be a safe and enjoyable method for obtaining adequate physical activity for older adults.

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CHAPTER 5: CONCLUSIONS

Osteoporosis is on the rise in U.S. society and is expected to affect 14 million people by the year 2020 (Burge, Dawson-Hughes, 2007). Among the most costly outcomes of osteoporosis are hip fractures, which carry an estimated annual economic burden of 17 billion dollars with costs expected to double by the year 2050 (Burge, Dawson-Hughes et al, 2007). Falls are also a major concern for older adults as one third of older adults fall each year and are at substantial risk for injury (CDC, 2006, April 18, 2008; Sattin, et al., 1990). In fact, 95% of all hip fractures occur as a result of a fall (Jarvinen et al 2008). Therefore, the need exists to identify safe, effective mechanisms to enhance bone health and prevent falls among older adults. Prior research has shown that lab based exercise programs of varying modalities have been successful in attenuating bone loss among older adults and/or decreasing fall incidence and risk factors for falls among such populations. Therefore, it can be concluded that exercise has the potential to decrease hip fracture risk among older adults. However, in order for research interventions to influence falls and hip fractures among the general population, it is imperative to translate and disseminate such evidence based programs out of the laboratory and into the community setting. Whether such programs remain efficacious in preventing falls and fractures after translation to the community is not known. Furthermore, there is a paucity of data quantifying the amount of physical activity (e.g. bone loading forces, duration and intensity of exercise, etc.) delivered by such community programs. This is especially important in light of the recent recommendations that older adults accumulate 150 minutes of moderate to vigorous activity each week to optimize general health (DHHS, 2008). Therefore, comprehensive evaluations of evidence based programs that are disseminated to the community must be performed in order to fully understand the impact of community exercise programs on health parameters for older adults.

Better Bones and Balance (BBB) is one such community based exercise program designed to reduce the risk of hip fractures through the enhancement of bone health and reduction of fall risk factors in older adults. Prior evidence suggests that the *BBB* program is associated with improved strength, power and balance after 9 months participation under controlled laboratory conditions, and maintenance in hip BMD after 5 years of participation (Shaw & Snow, 1998; Snow, et al., 2000). Since the last published report (Snow, et al., 2000) *BBB* has grown in size and popularity with over 300 exercisers in Western Oregon with more classes emerging each year throughout the west coast. While the program has been disseminated widely throughout Oregon, the effectiveness of the program in its current community setting remains unknown. Therefore, the purpose of this study was 1) to evaluate the relationship between *BBB* participation and parameters of bone health and fall risk factors among postmenopausal women and 2) to quantify the dose of physical activity, in regards to duration and intensity of exercise as well as bone loading forces associated with regular participation in *BBB*.

This cross-sectional study found that older women participating in *Better Bones and Balance* had no differences in bone mass at the hip or spine, and no differences in bone structure of the hip compared to sedentary age-matched controls. However, when compared to national normative data, both *BBB* participants and controls had higher than expected hip t-scores, indicating better than average skeletal health. It is likely that our stringent exclusion criteria produced a selection bias so that we were comparing our *BBB* participants to controls with greater skeletal health than would be expected based on their age and sedentary activity patterns. Therefore our ability to see differences between groups in skeletal outcomes may have been confounded. However, that our *BBB* participants were lighter and leaner, but did not have lower hip bone mass than controls, may indicate the potential positive influence of *BBB* on bone health, as higher body weight is typically associated with greater BMD (Ensrud, et al., 2003). Furthermore, considering that more *BBB* participants reported having greater risk factors for or prior diagnosis of osteoporosis than controls and that 40% of participants indicated enrolling in *BBB* due to concerns about their bone health, it is possible that *BBB* participation may have contributed to their better than expected skeletal health at the hip. A randomized prospective trial evaluating BBB is needed in order to eliminate any such recruitment bias.

A key difference between *BBB* and most reported programs designed to reduce fracture risk, is that *BBB* is delivered in a community setting where instructors are trained by researchers in annual workshops, but delivery is left to the community-based instructors. Hence, another potential explanation for the lack of bone differences between groups is the possibility that program fidelity has decreased upon translation of *BBB* into the community, thereby decreasing the impact on skeletal health. For example, the original program conducted by Shaw and Snow (1998) advocated wearing weighted vests beginning at the fourth month of participation and continuing throughout the rest of the 9 month intervention, systematically increasing weight vest over time. In contrast, only 18.8% of our population reported faithfully wearing vests, while 40% reported never wearing vests. It is therefore possible that without the added resistance provided by vests, adequate skeletal overload is not achieved, thus decreasing the efficacy of the program. However, results from this study show that mean ground reaction forces (GRF) associated with the exercises of the *BBB* program range from 1.3 x body weight (BW) for heel drops up to 2.2 x BW for jumps (one leg values) and are similar to what others have reported (Bassey & Ramsdale, 1995; Uusi-Rasi, et al., 2008; Weeks & Beck, 2008). We were surprised that the heel drops elicited the lowest forces, as this is an exercise traditionally included to provide impact while stomps, an exercise recently added to the *BBB* program based on recent reports of osteogenic potential (Young, et al., 2007) elicited higher forces than expected (1.8 BW, one leg). Therefore it is likely that jumps and stomps supply adequate impact forces to provide moderate overload to the skeleton with heel drops and steps less being effective. It should be noted that observation of class sessions and force plate testing did reveal that that many activities were not being performed with proper technique which may contribute both to the large variability observed in GRFs from the various exercises and to the lack of observed differences in skeletal outcomes between groups . In light of these findings, future training of *BBB* instructors emphasizing program fidelity and proper technique may lead to more favorable bone results associated with this program.

Considering that exercise behaviors must be maintained in order to observe a lasting influence on bone (Englund, et al., 2009; Winters & Snow, 2000), and given that many *BBB* participants attended classes faithfully for many years, we sought to determine whether long-term participation was associated with increased bone mass or enhanced bone structure within our sample of *BBB* participants. Specifically, we evaluated the relationship between years of participation in *BBB* on bone mass and bone structural outcomes and found no correlation between bone health and years of *BBB* participation after accounting for age, lean mass and BMI. One potential explanation may be that after an unknown duration of time, participants may enter a maintenance phase of training whereby the habitual activities performed in class no longer supply a novel overload to the skeleton to stimulate further adaptation. It is also possible that strict adherence to program protocol may decrease as length of participation increases. However, our cross sectional design may have been inadequate to properly assess this question as our established *BBB* participants would likely already be in such a maintenance phase. Therefore, a long term prospective trial evaluating new *BBB* participants is necessary to fully elucidate this issue.

Despite the lack of observable differences in skeletal outcomes between groups, this study indicated that *BBB* participation is associated with more positive outcomes on performance-based and self-reported indicators of fall risk compared to controls—results important in decreasing fracture risk. Specifically, our *BBB* participants exhibited enhanced functional fitness (i.e. greater lower body strength, dynamic balance and mobility) compared to controls. Prior research on *BBB* indicated that under controlled conditions, the program was associated with enhanced power, balance and strength after 9 months participation. That the program in its current setting is still associated with enhanced strength and balance suggests the successful translation from the lab to community setting in regards to performance based risk factors for falls. The current study differs from prior research on *BBB* in that previous reports on *BBB* did not evaluate the self reported indicators of fall risk; balance confidence, fall worry or fall incidence. Results from the current study show that *BBB* participants displayed better balance confidence than controls, a factor also associated with reduced fall risk. There were, however, no differences between groups in self reported worry about falling or in the proportion of group members experiencing a single fall or multiple falls. One potential explanation is that we did not measure falls prospectively and instead relied on a self-report measure requiring participants to recall all falls they experienced in the 12-months preceding the study. The validity of using such retrospective reporting among older adults has been questioned (Ganz, Higashi et al. 2005). Additionally, it is unknown whether participation in activity outside of class contributed to the reported falls. Examining the reasons by which participants fell and the activity that preceded the fall (e.g. leisure activities versus spontaneous loss of balance) would help delineate this issue. A longitudinal study prospectively tracking number of falls and reasons for falling is necessary to truly understand the relationship between *BBB* and fall incidence. Nevertheless, our results do support positive outcomes related to performance-based and self-reported indicators of fall risk in association with *BBB* partcipation.

There were several unexpected outcomes observed during this cross-sectional study as we observed *BBB* participation may be associated with additional positive health outcomes. We found that *BBB* participants had favorable body composition compared to controls. Specifically, BBB participants had lower body mass index (BMI), lower percent body fat, greater percentage of lean mass and lower fat mass index scores (FMI) when compared to controls. FMI; a measure of weight attributed to body fat normalized to body height (kg fat/m^2) is a gender specific measure of fat that is not confounded by lean tissue and therefore has a higher correlation with cardiovascular disease risk than does BMI. Consequently, the lower scores exhibited by the *BBB* participants are indicative of lower risk of cardiovascular disease. *BBB* participants also had significantly higher cardiovascular fitness, as measured by the two minute step test, compared to controls—findings also indicative of reduced risk for cardiovascular disease. While *BBB* has not been traditionally marketed for cardiorespiratory fitness, it appears that the program offered in the community setting is adequate to elicit substantial cardiorespiratory response among the participants. This is corroborated with results from our heart rate monitors which indicate that participating in the *BBB* program three times a week results in participants spending an average of 126 minutes in moderate to vigorous physical activity. As current guidelines recommend accruing 150 minutes a week of moderate activity, 75 minutes a week of vigorous physical activity or a comparable combination thereof (DHHS, 2008), it appears that participation in *BBB* provides an adequate dose of physical activity in order to reduce the risk of cardiovascular disease.

While adequate levels of physical activity were observed using heart rate monitors, it should be noted that we failed to observe this same result when measuring physical activity using accelerometers. According to accelerometer data, participants only spent about 37% of their exercise time, or 44 minutes per week in moderate to vigorous activity in comparison to 84% of time spent in MVPA measured by HR monitors. One potential explanation for this discrepancy is that many of the exercises often included in *BBB* (squats, lunges, supine abdominal work, upper body resistance training) may not lend themselves well to assessment via accelerometers, but still elicit a significant cardiorespiratory response. Therefore, it appears that accelerometers significantly underestimate the exercise intensity associated with *BBB.* However, observation of class sessions indicated accelerometer measured MVPA was correlated with total class time devoted to activities involving impact (stepping, jumping, heel drops, stomping) and walking. Therefore, accelerometers may have utility to estimate impact exercises among older adults. Overall, these results suggest the necessity of utilizing multiple methods of monitoring physical activity levels among elderly populations.

In conclusion, participation in *Better Bones and Balance* is associated with enhanced physical function, and better balance confidence compared to controls suggesting successful translation of the program from the laboratory to the community. Furthermore, *BBB* participation is associated with enhanced cardiorespiratory endurance, favorable body composition and likely provides adequate levels of physical activity to meet current guidelines for cardiovascular health. Despite these beneficial findings, the relationship between *BBB* participation and skeletal health and fall incidence still remains unclear. Therefore, a future randomized, prospective trial evaluating *BBB* is warranted to determine causal relationships between *BBB* and parameters of fracture risk and cardiovascular health in the community setting. Nevertheless, *BBB* appears to be a safe, palatable and sustainable program for reducing risk factors associated with falls, and improving cardiovascular fitness among postmenopausal women.

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APPENDICES

APPENDIX A

Informed Consent document; Better Bones and Balance participants

Nutrition and Exercise Science
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Tel 541-737-2643| **Fax** 541-737-6914 | mendy.gayler@oregonstate.edu/ www.hhs.oregonstate.edu/nes/index.html

INFORMED CONSENT DOCUMENT

Project Title:	Efficacy of community-based exercise in reducing fall and fracture risk factors in older postmenopausal women: *Better Bones and Balance, revisited*
Principal Investigator:	Katherine Gunter, PhD, Extension Family Community Development Program; Department of Nutrition and Exercise Science.
Co-Investigator(s):	Adrienne McNamara, M.S., Department of Nutrition and Exercise Science.

WHAT IS THE PURPOSE OF THIS STUDY?

You are being invited to take part in a research study to examine whether participation in the *Better Bones and Balance* program is associated with better outcomes related to skeletal health and fall risk factors in older women. We believe that there is a positive relationship between this exercise program and bone health and fall risk factors compared to adults not participating this program. The results from this study are intended to be used for publication. We are studying this to understand the best way to prescribe exercise for the prevention of falls and osteoporosis-related fractures. The *Better Bones and Balance* program is based on a research study conducted over 10 years ago. Since its beginning, this program has grown considerably. Therefore we need to re-examine the effectiveness of the program for enhancing hip bone mass and reducing falls risk factors.

WHAT IS THE PURPOSE OF THIS FORM?

This consent form gives you the information you will need to help you decide whether you would like to be in the study or not. Please read the form carefully. You may ask any questions about the research, the possible risks and benefits, your rights as a volunteer, and anything else that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not.

WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are a postmenopausal woman (at least 5 years post menopause), without cognitive impairment, not taking any bone altering medication and who is currently participating in a Better Bones and Balance class in the Willamette Valley and has done so for at least one year. In total we are hoping to recruit 300 women to participate in this study.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

If you agree to participate in this study, your involvement will include coming to the Bone Research Laboratory at Oregon State University and completing the following assessments:

1. Bone Mineral Density Assessment: Five x-ray scans will be conducted to evaluate the bone mineral density of your spine, hip and whole body. To assess operator and machine precision we will perform the hip and spine scan twice. Hip, spine and whole body scans will be used to determine bone mass and strength. The whole body scan will also be used to determine your body composition (fat and lean mass). There is a relationship between lean mass and bone mineral density and the whole body scan helps us to establish this relationship. During the scans you will be asked to lie still on an open table while the machine arm moves above you and beside you. Hip and spine scans take 30-45 seconds each and the whole body scan takes 3 minutes. The bone scans will take approximately 20 minutes to complete.

Questionnaires (researchers will be present/available to help participants fill out all questionnaires)

2. **Memory and Problem Solving:** You will be asked to complete a short examination that will be used to assess your memory and problem solving ability. You will be asked to do simple tasks including writing a sentence, naming simple objects, repeating a sentence out loud, copying shapes, and performing a 3-stage command. This exam will take approximately 10 minutes to complete.
3. **Physical Activity and Nutrition:** You will be asked to fill out two physical activity questionnaires to assess your general activity level and exercises that you do that may affect your bone health You will also fill out a nutrition questionnaire that will assess eating patterns and nutrient intake. It will take approximately 60 minutes to fill out the questionnaires.
4. **Health History:** You will be asked to complete a health history questionnaire in order to assess lifestyle and medical factors that may affect bone, such as certain diseases, habits, or medicine use. In addition, this will assess your history of falling as well as your ability to do various activities of daily living. This information will be used in the final analysis. We will ask that you bring your medications so that we can verify dose and type. This questionnaire will take approximately 10 minutes to complete.
5. **Quality of Life and Balance Confidence:** You will be asked to fill out a questionnaire that will be used to assess variables that affect quality of life in older adults. In addition, you will be asked to fill out a questionnaire that assesses how confident you feel about your balance. It will take about 20 minutes to complete these questionnaires.
6. **Better Bones and Balance Participation History**: You will be asked to fill out a questionnaire that will be used to determine your previous participation in the Better Bones and Balance program. This information will be used in the final analysis. It will take about 10 minutes to complete this questionnaire.

Performance Assessments

6. **Fitness Level and Balance:** To assess your level of physical fitness and balance, you will be asked to complete the following tasks:

Test	**Description**	**Purpose**
Bicep Curl	Lift a 5 pound weight using your arm as many times as you can in 30 seconds	This will measure your upper body strength. You will do this one time and the score will be recorded.
Chair Stands	With your arms folded across your chest, stand up from a chair and sit back down as many times as you can in 30 seconds	This will measure your lower body strength. You will do this one time and the score will be recorded
Timed Up and Go	Get up out of a chair, walk 8 feet, turn 180 degrees and return to the chair and sit down. You will be asked to do this as quickly as you are able	This will measure your mobility. You will do this two times and the best score will be recorded.
2-minute Step Test	Complete as many full steps as possible in 2 minutes, raising your knees to a point midway between your kneecap and top of your hip bone	This will measure your aerobic endurance. You will do this one time and the score will be recorded

Test	Description	Purpose
Tandem Stance	Stand with one foot directly in front of the other (toes of back foot touching heel of front foot) up to 30 seconds.	This is used to measure your balance. You will do this two times and the best score will be recorded.
One-leg Stance	Stand on one leg up to 30 seconds.	This is used to measure your balance. You will do this two times and the best score will be recorded.
Tandem Walk	Walk in a straight line for 10 feet placing one foot directly in front of the other (heel of front foot touching toes of back foot).	This is used to measure your balance. The better of 2 successful trials will be recorded with a maximum of 3 trials performed.

If you agree to take part in this study, your involvement will last for approximately 3 hours. You may opt to take some of the questionnaires home and return them to us at the lab within one week. We will be available for email or phone consultation if you choose to do this.

WHAT ARE THE RISKS OF THIS STUDY?

The risks involved in this study are minimal. There is a risk of radiation from the bone scans. The hip, spine and whole body scans together deliver a total effective dose equivalent (dose ranges: 0.77- 1.15 mrem) which is less than the radiation exposure from a chest x-ray (5.0 mrem) or a flight across the country (4.0 mrem). In addition, you may experience mild fatigue and/or soreness from the strength and fitness assessments. For most individuals, this resolves within 1-3 days. You are free to rest or stop testing at any time.
The investigators will minimize all risks by providing safe equipment and adequate instruction of the strength assessments. In addition, all bone scans will be performed by a trained and licensed technician.

WHAT ARE THE BENEFITS OF THIS STUDY?

We do not know if you will benefit from being in this study. We hope that, in the future, other people might benefit from this study because of the information we gain concerning the effectiveness of the *Better Bones and Balance* program for reducing fracture risk. However, we will provide you with copies of your bone scans upon completion of the study and a report of your balance and fitness test scores. Evaluation of bone mineral density is used for diagnosis of osteoporosis, and will provide you with an accurate measure of your bone mass. Any questions concerning the results of such tests should be addressed with your physician who has the authority to make the appropriate diagnosis. We will be happy to provide you a copy of your scan as well as copies of all questionnaires and tests, or send them to your physician upon your request.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO WILL SEE THE INFORMATION I GIVE?

The information you provide during this research study will be kept confidential to the extent permitted by law. To help protect your confidentiality, we will keep all records in a secure location to which only the research team has access. However, federal government regulatory agencies and the Oregon State

University Institutional Review Board (a committee that reviews and approves research studies involving human subjects) may inspect and copy records pertaining to this research. It is possible that these records could contain information that personally identifies you. The investigators will assign your data to a code number which will be used in all analysis.

If the results of this project are published your identity will not be made public.

DO I HAVE A CHOICE TO BE IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decide not to take part in this study, your decision will have no effect on the quality of services you receive through your participation in the Better Bones and Balance classes.

You will not be treated differently if you decide to stop taking part in the study. While completing the questionnaires, you are free to skip any question which you would prefer not to answer.

WHAT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact: Kathy Gunter at 541-737-1405, Kathy.gunter@oregonstate.edu or Adrienne McNamara, 541-990-7820, mcnamara@onid.orst.edu

If you have questions about your rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, at (541) 737-4933 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed): ____

______________________________ ______________________

(Signature of Participant) (Date)

[illegible] Expiration Date: [illegible]

Appendix B

Informed Consent Document: Control Participants

OSU
Oregon State University

Nutrition and Exercise Science
Oregon State University, 101 Milam Hall, Corvallis, Oregon 97331
Tel 541-737-2643| Fax 541-737-6914 | mendy.gayler@oregonstate.edu/ www.hhs.oregonstate.edu/nes/index.html

INFORMED CONSENT DOCUMENT

Control Participants

Project Title:	Efficacy of community-based exercise in reducing fall and fracture risk factors in older postmenopausal women: *Better Bones and Balance, revisited*
Principal Investigator:	Katherine Gunter, PhD, Extension Family Community Development Program; Department of Nutrition and Exercise Science.
Co-Investigator:	Adrienne McNamara, M.S., Department of Nutrition and Exercise Science.

WHAT IS THE PURPOSE OF THIS STUDY?

You are being invited to take part in a research study to examine whether participation in the *Better Bones and Balance* program is associated with better outcomes related to skeletal health and fall risk factors in older women. However, to determine this we must compare *Better Bones and Balance* participants to similar-age women who have not been participating in the program. The results from this study will be used for publication. We are studying this to understand the best way to prescribe exercise for the prevention of falls and osteoporosis-related fractures.

WHAT IS THE PURPOSE OF THIS FORM?

This consent form gives you the information you will need to help you decide whether you would like to be in the study or not. Please read the form carefully. You may ask any questions about the research, the possible risks and benefits, your rights as a volunteer, and anything else that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not.

WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are a postmenopausal woman (at least 5 years post menopause), not taking bone altering medication, without cognitive impairment, and who is not participating in any resistance training or vigorous exercise for more than 60 minutes a week. In total we are hoping to recruit 300 women to participate in this study.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

If you agree to participate in this study, your involvement will include coming to the Bone Research Laboratory at Oregon State University to complete the following assessments:

1. Bone Mineral Density Assessment: Five x-ray scans will be conducted to evaluate the bone mineral density of your spine, hip and whole body. To assess operator and machine precision we will perform the hip and spine scan twice. Hip, spine and whole body scans will be used to determine bone mass and strength. The whole body scan will also be used to determine your body composition (fat and lean mass). There is a relationship between lean mass and bone mineral density and the whole body scan helps us to establish this relationship. During the scans you will be asked to lie still on an open table while the machine arm moves above you and beside you. Hip and spine scans take 30-45 seconds each and the whole body scan takes 3 minutes. The entire process (positioning and discussion) will take approximately 20 minutes.

Questionnaires (researchers will be present/available to help participants fill out all questionnaires)
2. Memory and Problem Solving: You will be asked to complete a short examination that will be used to assess your memory and problem solving ability. You will be asked to do simple tasks including writing a sentence, naming simple objects, repeating a sentence out loud, copying shapes, and performing a 3-stage command. This exam will take approximately 10 minutes to complete.
3. Physical Activity and Nutrition: You will be asked to fill out two physical activity questionnaires to assess your general activity level and exercises that you do that may affect your bone health You will also fill out a nutrition questionnaire that will assess eating patterns and nutrient intake. It will take approximately 60 minutes to fill out the questionnaires.
4. Health History questionnaire: You will be asked to complete a health history questionnaire in order to assess lifestyle and medical factors that may affect bone, such as certain diseases, habits, or medicine use. In addition, this will assess your history of falling as well as your ability to do various activities of daily living. This information will be used in the final analysis. We will ask that you bring your medications so that we can verify dose and type. This questionnaire will take 10 minutes to complete.
5. Quality of Life and Balance Confidence questionnaires: You will be asked to fill out a questionnaire that will be used to assess variables that affect quality of life in older adults. In addition, you will be asked to fill out a questionnaire that assesses how confident you feel about your balance. It will take about 20 minutes to complete these questionnaires.

Performance Assessments

6. Fitness Level and Balance: To assess your level of physical fitness and balance, you will be asked to complete the following tasks:

Test	Description	Purpose
Bicep Curl	Lift a 5 pound weight using your arm as many times as you can in 30 seconds	This will measure your upper body strength. You will do this one time and the score will be recorded.
Chair Stands	With your arms folded across your chest, stand up from a chair and sit back down as many times as you can in 30 seconds	This will measure your lower body strength. You will do this one time and the score will be recorded
Timed Up and Go	Get up out of a chair, walk 8 feet, turn 180 degrees and return to the chair and sit down. You will be asked to do this as quickly as you are able	This will measure your mobility. You will do this two times and the best score will be recorded.
2-minute Step Test	Complete as many full steps as possible in 2 minutes, raising your knees to a point midway between your kneecap and top of your hip bone	This will measure your aerobic endurance. You will do this one time and the score will be recorded
Tandem Stance	Stand with one foot directly in front of the other (toes of back foot touching heel of front foot) up to 1 minute.	This is used to measure your balance. You will do this two times and the best score will be recorded.
Test	**Description**	**Purpose**

One-leg Stance	Stand on one leg up to 30 seconds.	This is used to measure your balance. You will do this two times and the best score will be recorded.
Tandem Walk	Walk in a straight line for 10 feet placing one foot directly in front of the other (heel of front foot touching toes of back foot).	This is used to measure your balance. The better of 2 successful trials will be recorded with a maximum of 3 trials performed.

If you agree to take part in this study, your involvement will last for approximately 3 hours. You may also opt to take some of the questionnaires home and return them to us at the lab within one week. We will be available for email or phone consultation if you choose to do this.

WHAT ARE THE RISKS OF THIS STUDY?

The risks involved in this study are minimal. However there is a risk of radiation. The hip, spine and whole body scans together deliver a total effective dose equivalent (dose ranges: 0.77- 1.15 mrem) which is less than the radiation exposure from a chest x-ray (5.0 mrem) or a flight across the country (4.0 mrem). In addition, you may experience mild fatigue and/or soreness from the strength and fitness assessments. For most individuals, this should resolve within 1-3 days. You are free to rest or stop testing at any time

The investigators will minimize all risks by providing safe equipment and adequate instruction of the strength and fitness assessments. In addition, all bone scans will be performed by a trained and licensed technician.

WHAT ARE THE BENEFITS OF THIS STUDY?

We do not know if you will benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because of the information that we hope to gain concerning the effectiveness of the Better Bones and Balance program for improving bone health. However, we will provide you with copies of your bone scans upon completion of the study and a report of your balance and fitness test scores. Evaluation of bone mineral density is used for diagnosis of osteoporosis, and will provide you with an accurate measure of your bone mass. Any questions concerning the results of such tests should be addressed with your physician who has the authority to make the appropriate diagnosis. We will be happy to provide you a copy of your scan as well as copies of all questionnaires and tests, or send them to your physician upon your request.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO WILL SEE THE INFORMATION I GIVE?

The information you provide during this research study will be kept confidential to the extent permitted by law. To help protect your confidentiality, we will keep all records in a secure location to which only the research team has access. However, federal government regulatory agencies and the Oregon State

University Institutional Review Board (a committee that reviews and approves research studies involving human subjects) may inspect and copy records pertaining to this research. It is possible that these records could contain information that personally identifies you. The investigators will assign your data to a number which will be used in all analysis.

If the results of this project are published your identity will not be made public.

DO I HAVE A CHOICE TO BE IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

You will not be treated differently if you decide to stop taking part in the study. While completing the questionnaires, you are free to skip any question which you would prefer not to answer.

WHAT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact: Kathy Gunter at 541-737-1405, Kathy.gunter@oregonstate.edu or Adrienne McNamara, 541-990-7820, mcnamara@onid.orst.edu

If you have questions about your rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, at (541) 737-4933 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed): ____

______________________________ ______________________

(Signature of Participant) (Date)

APPENDIX C

Health History Questionnaire

Last Name, First ______ Date ______ ID # ______

Medical History Questionnaire
Better Bones and Balance Study

Last Name	First Name	MI	Age	Date of Birth

Address ______ City, State, Zip ______

Phone (land line) ______ Work/Cell phone ______ E-mail Address ______

How do you prefer to be contacted regarding this study?

- ☐ Email
- ☐ Phone
- ☐ Other ______

Which describes your ethnic category?

- ☐ **Not Hispanic or Latino**
- ☐ **Hispanic or Latino**: *A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race. The term "Spanish origin" can be used in addition to "Hispanic or Latino"*
- ☐ **Decline to respond**

Which describes your racial category?

- ☐ **White:** *a person having origins in any of the original peoples of Europe, North Africa, or the Middle East.*
- ☐ **Asian:** *A person having origins in any of the original peoples of the Far East, Southern Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.*
- ☐ **Black or African American:** *A person having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black or African American".*

- ☐ **Native Hawaiian or Other Pacific Islander:** *A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.*
- ☐ **American Indian or Alaska Native:** *A person having origins in any of the original peoples of North, Central, or South America and maintains tribal affiliation or community.*
- ☐ **Decline to respond**

PRESENCE OF DISEASE/ILLNESS

Do you currently have or have you ever had any of the following? (Check if yes)

		Year of onset?	Current symptom (circle one)?	
____	High blood pressure	________	yes	no
____	Heart trouble	________	yes	no
____	Disease of the arteries	________	yes	no
____	Lung disease	________	yes	no
____	Epilepsy	________	yes	no
____	Diabetes	________	yes	no
____	Rheumatoid Arthritis	________	yes	no
____	Back injury	________	yes	no
____	Cancer	________	yes	no
____	Stroke	________	yes	no
____	Broken bones	________	yes	no
____	Orthopedic operations	________	yes	no
____	High or low thyroid	________	yes	no
____	High cholesterol	________	yes	no
____	Lactase deficiency	________	yes	no
____	Musculoskeletal injury	________	yes	no
____	Other operations	________	yes	no
____	Osteoarthritis	________	yes	no

If yes to any of the above, please explain:

____

____

____

____

____

FALLS

1. How many times have you fallen in the past year? ___________

Did you require medical treatment? YES or NO

If you answered YES to either question, please list the approximate date of the fall, the medical treatment required, and the reason you fell in each case (e.g. uneven surface, going down stairs).

____

____

____

2. Are you worried about falling? (circle the appropriate number)

1	2	3	4	5	6	7
No	a little	moderately		very	extremely	

PHYSICAL FUNCTION

1. Please indicate your ability to do each of the following.	**Can do**	**Can do with difficulty or with help**	**Cannot do**
a. Take care of your own personal needs—such as dressing yourself.	**2**	**1**	**0**
b. Bathe yourself using tub or shower	**2**	**1**	**0**
c. Climb up and down a flight of stairs (e.g. to a second story in a house)	**2**	**1**	**0**
d. Walk outside one or two blocks	**2**	**1**	**0**
e. Do light household activites—cooking, dusting washing dishes, sweeping a walkway	**2**	**1**	**0**
f. Do own shopping for groceries or clothes	**2**	**1**	**0**
g. Walk ½ mile (6-7 blocks)	**2**	**1**	**0**
h. Walk 1 mile (12-14 blocks)	**2**	**1**	**0**
i. Lift and carry 10 pounds (full bag of groceries)	**2**	**1**	**0**
j. Lift and carry 25 pounds (medium to large suitcase)	**2**	**1**	**0**
k. Do most heavy household chores—scrubbing floors vacuuming, raking leaves	**2**	**1**	**0**
l. Do strenuous activities—hiking, digging in garden, moving heavy objects, bicycling, aerobic dance exercises, strenuous calisthenics, etc.	**2**	**1**	**0**

GENERAL QUESTIONS

1. Do you drink alcohol? YES or NO

2. Do you drink two or more drinks per day? YES or NO

3. Do you currently smoke tobacco? YES or NO

4. Do you smoke more than 10 tobacco cigarettes a day? YES or NO

5. Were you a tobacco smoker in the past? YES or NO

   If you have quit, when did you quit? ________

   For how long did you smoke tobacco? ________

   Did you smoke more than 10 tobacco cigarettes a day? YES or NO

6. Please indicate how many years post-menopause you currently are. __________

7. Please indicate if you have had a hysterectomy? YES or NO

   If yes, was it partial or full? __________

   Please indicate the year of the operation? __________

8. Please indicate if you have experienced any urinary incontinence ("leaking") in the previous 3 months? YES or NO

   If yes, on average how many incidents per week __________

9. Have you had any procedure within the past 7 days involving either nuclear medicine or any contrast agents (e.g., iodine, barium swallow, etc.)? YES or NO

10. On average, how many hours per day do you spend outdoors? __________

11. When outside, do you regularly use sunscreen? ____________________

Question about Supplements and Medications:

1. Do you currently take any nutritional supplements (vitamins/ minerals, or herbal supplements)? YES or NO

If yes, what type, amount and how often?

Type of supplement/Brand	Amount	Frequency
______________	________	______________
______________	________	______________
______________	________	______________
• ______________	________	______________

2. Do you currently, or have you ever taken Hormone Replacement Therapy? YES or NO

If so, what type, and for how long?

____

3. Please list all medications that you currently take (including over-the-counter medications)

Type of medication	For what condition
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________

Thank you for your participation!!

APPENDIX D

Mini-Mental State Examination

Instructions For Administration of Mini-Mental State Examination

Orientation

1. Ask for the Date. Then ask specifically for parts omitted, eg, "Can you also tell me what season it is?" Score one point for each correct answer.
2. Ask in turn, "Can you tell me the name of this hospital?" (town, county, etc.) Score one point for each correct answer.

Registration

Ask the patient if you may test his/her memory. Then say the names of 3 unrelated objects, clearly and slowly, about one second for each. After you have said all 3, ask the patient to repeat them. This first repetition determines his/her score (0-3) but keep saying them until he/she can repeat all 3, up to 6 trials. If all 3 are not eventually learned, recall cannot be meaningfully tested.

Attention and Calculation

Ask the patient to spell the word "world" backwards. The score is the numbers of letters in correct order (eg, DLROW=5; DLRW=4; DLORW, DLW=3; OW=2; DRLWO=1).

Recall

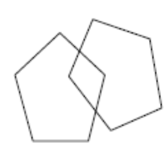
Ask the patient if he/she can recall the 3 words you previously asked him/her to remember. Score 0 – 3.

Language

Naming:	Show the patient a wristwatch and ask him/her what it is. Repeat for pencil. Score 0 – 2.
Repetition:	Ask the patient to repeat the sentence after you. Allow only one trial. Score 0 – 1.
3-stage command:	Give the patient a piece of plain blank paper and repeat the command. Score 1 point for each part correctly executed.
Reading:	On a blank piece of paper print the sentence, "Close your eyes," in letters large enough for the patient to see clearly. Ask him/her to read it and do what it says. Score 1 point only if he actually closes his eyes.
Writing:	Give the patient a blank piece of paper and ask him/her to write a sentence for you. Do not Dictate a sentence; it is to be written spontaneously. It must contain a subject and verb and be sensible. Correct grammar and punctuation are not necessary.
Copying:	On a clean piece of paper, draw intersecting pentagons, each side about 1 in., and ask him/her to copy it exactly as it is. All 10 angles must be present and 2 must intersect to score 1 point. Tremor and rotation are ignored.

Mini-Mental State Examination (MMSE)

Maximum Score	Score	
		ORIENTATION
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we: (state) (county) (town or city) (hospital) (floor).
		REGISTRATION
3	( )	Name 3 Common objects (eg, "apple," "table," "penny"). Take 1 second to say each. Then ask the patient to repeat all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials:
		ATTENTION AND CALCULATION
5	( )	Spell "world" backwards. The score is the number of letters in correct order (D__L__R__O__W__).
		RECALL
3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct answer. [Note: recall cannot be tested if all 3 objects were not remembered during registration]
		LANGUAGE
2	( )	Name a "pencil," and "watch." (2 points)
1	( )	Repeat the following, "no ifs, ands, or buts." (1 point)
3	( )	Follow a 3-stage command: "Take a paper in you right hand, fold it in half, and put it on the floor." (3 points)
		Read and obey the following:
1	( )	Close your eyes. (1 point)
1	( )	Write a sentence. (1 point)
1	( )	Copy the following design. (1 point)



Total score ________

No construction problem.

APPENDIX E

Aerobics Center Longitudinal Physical Activity Questionnaire

In this section, we would like to ask you about your current physical activity and exercise habits that you perform regularly, at least once a week. Please answer as accurately as possible. Circle your answer or supply a specific number when asked.

EXERCISE/PHYSICAL ACTIVITY

1. For the last **three months**, which of the following moderate or vigorous activities have you performed **regularly**? (Please circle **YES** for all that apply and **NO** if you did not perform the activity; provide an estimate of the amount of activity for all marked YES. Be as complete as possible.

Walking

NO YES → How many sessions per week? ____________________

How many miles (or fractions) per session? ____________________

Average duration per session? ______________(minutes)

What is your usual pace of walking (Please circle one)

Casual or strolling (<2 mph)	Average or normal (2 to 3mph)	Fairly Brisk (3 to 4 mph)	Brisk or Striding (4 mph or faster)

Stair climbing

NO YES → How many flights of stair do you climb UP each day? ___________
(1 flight = 10 steps)

Jogging or Running

NO YES → How many sessions per week? ____________________

How many miles per session? ____________________

Average duration per session? ______________(minutes)

Treadmill

No YES → How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Speed? _____(mph) Grade? ________(%)

Bicycling

NO YES ⟶ How many sessions per week? ____________________

How many miles per session? ____________________

Average duration per session? ______________(minutes)

Swimming laps

NO YES ⟶ How many sessions per week? ____________________

How many miles per session? ____________________
(880 yds = 0.5 mile)

Average duration per session? ______________(minutes)

Aerobic Dance/Calisthenics/Floor Exercise

NO YES ⟶ How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Moderate Sports (e.g. Leisure volleyball, golf (not riding), social dancing , doubles tennis)

NO YES ⟶ How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Vigorous Racquet Sports (e.g. singles tennis, racquetball)

NO YES ⟶ How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Other vigorous sports or exercise involving running (e.g. basketball, soccer, etc)

NO YES ⟶ Please specify ____

How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Weight Training (machines, free weights)

NO YES ⟶ How many sessions per week? ____________________

Average duration per session? ______________(minutes)

Household activities (Sweeping, vacuuming, washing clothes, scrubbing floors)

NO YES → How many hours per week? ______________

Lawn Work and Gardening

NO YES → How many hours per week? ______________

2. How many times a week do you engage in vigorous physical activity long enough to work up a sweat? __________ (times per week)

Please list any other physical activity that you do regularly

________________________ How many sessions per week? ______________

Average duration per session?____________(minutes)

________________________ How many sessions per week? ______________

Average duration per session?____________(minutes)

________________________ How many sessions per week? ______________

Average duration per session?________(minutes)

________________________ How many sessions per week? ______________

Average duration per session?____________(minutes)

________________________ How many sessions per week? ______________

Average duration per session?____________(minutes)

________________________ How many sessions per week? ______________

Average duration per session?____________(minutes)

APPENDIX F

Bone Specific Physical Activity Questionnaire

Bone-Specific Physical Activity Questionnaire (BPAQ)

SUBJECT ID:	DATE:

1. Please list <u>any</u> sports or other physical activities you have participated in regularly. Please <u>tick</u> the boxes to indicate how old you were for each sport/activity and how many years you participated for.

Activities / Age:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Activities / Age:	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60

Activities / Age:	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90

Bone-Specific Physical Activity Questionnaire (BPAQ)

SUBJECT ID:	DATE:

2. Please list the sports or other physical activities (be as specific as possible) you participated in regularly during the <u>last 12 months</u> and indicate the average frequency (sessions per week)?

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

Activity: ______________________ Frequency (per week): ________

APPENDIX G

Better Bones and Balance Participation History Questionnaire

Participant ID ___________

Better Bones and Balance

Participation History Questionnaire

1. Please indicate how long, in years and months, you have been participating in the *Better Bones and Balance* program. ____________years ___________months

2. Please indicate how many classes **on average** you have attended each month since you began participating in *Better Bones and Balance*.

   0-3 3-6 7-9 10-12

3. Do you regularly participate in *Better Bones and Balance* classes during summer session?

   YES NO

   If yes, how many summer sessions have you completed? ______________

4. Were there any prolonged periods of time (> 3 months) in which you were unable to attend any classes? YES NO

If yes, please indicate the approximate length of time in which you did not participate and the reason for which you stopped participating.

____

5. Which of the following describes how often that you wear your weighted vest during class?

Never	Occasionally	Sometimes	Always
	(<1class per week)	(1-2classes/week)	(3 classes/week)

6. Which level of jumps do you usually perform? (circle one)

   No jumping Heel drops/Faux jumps Full jumps

7. At what age did you first begin your participation in *Better Bones and Balance*?

   ____

8. Please indicate if you were premenopausal, perimenopausal or postmenopausal when you first started participation in the program (circle one).

   Premenopausal **Perimenopausal** **Postmenopausal**

   If you answered postmenopausal, please indicate how many years past menopause you were at the onset of participation ____________________

9. Barring any unforeseen events, how long do you anticipate continuing your participation in *Better Bones and Balance*? ____________________

APPENDIX H

2005 Block Full-length Food Frequency Questionnaire

FOOD QUESTIONNAIRE

RESPONDENT ID #

TODAY'S DATE

Month	DAY	YEAR
Jan		
Feb		
Mar		2005
Apr		2006
May		2007
Jun		2008
Jul		2009
Aug		2010
Sep		2011
Oct		2012
Nov		2013
Dec		2014

ABOUT THIS SURVEY

This form is about the foods you usually eat. It will take about 30 - 40 minutes to complete. Please answer each question as best you can. Estimate if you aren't sure.

- **USE ONLY A NO. 2 PENCIL.**
- **Fill in the circles completely, and erase completely if you make any changes.**

Please write your name in this box.

ABOUT YOU

SEX
- Male
- Female

If female, are you pregnant or breast feeding?
- No
- Yes
- Not female

AGE

WEIGHT pounds

HEIGHT ft. in.

INSTRUCTIONS

There are usually two kinds of questions to answer for each food.

1. **HOW OFTEN,** on average, did you eat the food during the past year?
   *Please DO NOT SKIP any foods. Mark "Never" if you didn't eat any of the food in the question.

2. **HOW MUCH** did you usually eat of the food?
   *Sometimes we ask how many you eat, such as 1 egg, 2 eggs, etc., ON THE DAYS YOU EAT IT.
   *Sometimes we ask "how much" as A, B, C or D. **LOOK AT THE ENCLOSED PICTURES.**
   For each food, pick the picture (bowls or plates) that looks the most like the serving size you usually eat. (If you don't have pictures: A=1/4 cup, B=1/2 cup, C=1 cup, D= 2 cups.)

3. **EXAMPLE:** This person drank apple juice twice a week, and had one glass each time.
   Once a week he ate a "C"-sized serving of rice (about 1 cup).

	HOW OFTEN IN THE PAST YEAR									HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)				
	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY					
Apple juice	○	○	○	○	○	●	○	○	○	How many glasses each time	● 1	○ 2	○ 3	○ 4
Rice	○	○	○	○	●	○	○	○	○	How much each time	○ A	○ B	● C	○ D

PLEASE DO NOT WRITE IN THIS AREA

This section is about your usual eating habits in the past year or so. This includes all meals or snacks, at home or in a restaurant or carry-out. We will ask you about different TYPES (low-fat, low-carb) at the end of the survey. Include all types (like low-fat, sugar-free). Later you can tell us which type you usually eat.

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS SEE PORTION SIZE PICTURES FOR A-B-C-D				
Breakfast sandwiches with eggs, like Egg McMuffins										How many sandwiches in a day	1	2		
Other eggs like scrambled, boiled or omelets (not egg substitutes)										How many eggs a day	1	2	3	
Breakfast sausage, including in sausage biscuits, or in breakfast sandwiches										How many pieces	1	2	3	
Bacon										How many pieces	1	2	3	4
Pancakes, waffles, French toast or Pop Tarts										How many pieces	1	2	3	
Cooked cereals like oatmeal, grits or cream of wheat										Which bowl		B	C	D
Cold cereals, ANY KIND, like corn flakes, fiber cereals, or sweetened cereals.										Which bowl		B	[illegible]	D
Milk or milk substitutes on cereal														
Yogurt or frozen yogurt										Which bowl		B	[illegible]	
Cheese, sliced cheese or cheese spread, including on sandwiches										How many slices	1	[illegible]	3	

How often do you eat the following foods all year round? Estimate your average for the whole year.

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS				
Bananas										How many each time	1/2	1		
Apples or pears										How many each time	1/2	1	2	
Oranges or tangerines										How many each time	1/2	1	2	
Grapefruit										How much	A little	1/2	1	
Peaches or nectarines, fresh										How many	1/2	1	2	
Other fresh fruits like grapes, plums, honeydew, mango										How much	A	B	C	
Canned fruit like applesauce, fruit cocktail, canned peaches or canned pineapple										How much	A	B	C	

How often do you eat each of the following 3 fruits, just during the summer months when they are in season?

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS				
Cantaloupe, in season										How much	1/8	1/4	1/2	
Strawberries or other berries, in season										How much	A	B	C	
Watermelon, in season										How much	A	B	C	D

How often do you eat each of the following vegetables all year round, including fresh, frozen, canned or in stir-fry, at home or in a restaurant?

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS				
Broccoli										How much	A	B	C	
Carrots, or mixed vegetables with carrots										How much	A	B	C	
Corn										How much	A	B	C	

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS SEE PORTION SIZE PICTURES FOR A-B-C-D				
Lunch meat like bologna, sliced ham, turkey bologna, or any other lunch meat										How many slices	1	2	3	4
Meat loaf, meat balls										How much		B	C	D
Steak, roast beef, or beef in frozen dinners or sandwiches										How much	A	B	C	D
Tacos, burritos, enchiladas, tamales, with meat or chicken										How much	A	B	C	D
Ribs, spareribs										How much	A	B	C	D
Pork chops, pork roasts, cooked ham (including for breakfast)										How much	A	B	C	D
Veal, lamb, deer meat										How much	A	B	C	
Liver, including chicken livers or liverwurst										How much	A	B	C	
Pigs feet, neck bones, oxtails, tongue										How much	A	B	C	
Menudo, pozole, caldo de res, sancocho, ajiaco										Which bowl		B	C	D
Any other beef or pork dish, like beef stew, beef pot pie, corned beef hash, Hamburger Helper										How much		B	C	D
Fried chicken, including chicken nuggets, wings, chicken patty										How many medium pieces	1	2, [illegible]	3	
Roasted or broiled chicken or turkey										How much	A	B	C	
Any other chicken dish, like chicken stew, chicken with noodles, chicken salad, Chinese chicken dishes										How much		B	C	D
Oysters										How much	A	B	C	
Shellfish like shrimp, scallops, crabs										How much	A	B	C	D
Tuna, tuna salad, tuna casserole										How much of the tuna	A	B	C	
Fried fish or fish sandwich										How much	A	B	C	
Other fish, <u>not</u> fried										How much	A	B	C	
BREADS														
Biscuits, muffins, croissants (<u>not</u> counting breakfast sandwiches with eggs)										How many	1 sm	1 med	2	
Hamburger buns, hotdog buns, hoagie buns, submarines										How many	1	2		
Bagels, English muffins, dinner rolls										How many	1/2	1		
Tortillas (<u>not</u> counting those eaten in tacos or burritos)										How many in a day	1	2	3	4
Corn bread, corn muffins, hush puppies										How many pieces in a day	1/2	1	2	
Any other bread or toast, including white, dark, whole wheat, and what you have in sandwiches										How many slices in a day	1	2	3	4
Rice, or dishes made with rice										How much in a day		B	C	D

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)				
Margarine (not butter) on bread or on vegetables										How many pats (tsp)	1	2	3	4
Butter (not margarine) on bread or on vegetables										How many pats (tsp)	1	2	3	4
Energy bars, like Power Bars, Clif bars, Balance, Luna, Atkins bars										How many	1	2		
Breakfast bars, cereal bars, granola bars (not energy bars)										How many	1	2		
Peanuts, sunflower seeds, other nuts or seeds										How much	A	B	C	
Peanut butter										How many tablespoons	1/2	1	2	3
Snack chips like potato chips, tortilla chips, Fritos, Doritos, popcorn (not pretzels)										How much	A	B	C	D
Crackers, like Saltines, Cheez-Its, or any other snack cracker										How much	A	B	C	
Jelly, jam										How many tablespoons	1/2	1	2	
Mayonnaise, sandwich spreads										How many tablespoons	1/4	1	2	
Catsup, salsa or chile peppers										How many tablespoons	1/2	1	2	3
Mustard, barbecue sauce, soy sauce, gravy, other sauces										How many tablespoons	1/2	1	2	3
Donuts										How many	1	2	3	
Cake, or snack cakes like cupcakes, Ho-Hos, Entenmann's, or any other pastry										How many pieces	1 sm	1 med	2	3
Cookies										How many	1-2	3-4	5-6	7+
Ice cream, ice cream bars										How much		B	C	D
Chocolate syrup or sauce (like in milk or on ice cream)														
Pumpkin pie, sweet potato pie										How many pieces	1/2	1	2	
Any other pie including fast food pies or snack pies										How many pieces	1/2	1	2	
Chocolate candy like candy bars, M&Ms, Reeses										How much	1 mini	1 med	1 lrg	1 king
Any other candy, not chocolate, like hard candy, Lifesavers, Skittles, Starburst										How much in a day	1-2 pcs	1/2 pkg	1 pkg	

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH on the days you drink it?			
Glasses of milk (any kind, including soy), not counting on cereal or coffee										How many GLASSES	1	2	3
Drinks like Slim Fast, Sego, Slender, Ensure or Atkins										How many CANS OR GLASSES	1	2	
Tomato juice or V-8 juice										How many GLASSES	1/2	1	2
Real 100% orange juice or grapefruit juice. Don't count orange soda or Sunny Delight										How many GLASSES	1/2	1	2
Apple juice, grape juice, pineapple juice or fruit smoothies										How many GLASSES	1/2	1	2

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH on the days you drink it?
Hi-C, Cranberry Juice Cocktail, Hawaiian Punch, Tang										How many GLASSES: 1/2, 1, 2, 3
Drinks with some juice, like Sunny Delight, Knudsen										How many GLASSES: 1/2, 1, 2, 3
Iced tea, homemade, instant, or bottled like Nestea, Lipton, Snapple, Tazo										How many GLASSES OR BOTTLES: 1, 2, 3, 4
Kool-Aid, lemonade, sports drinks like Gatorade, or fruit flavored drinks (<u>not</u> including iced teas)										How much IN A DAY: 1 glass; 1 20-ounce bottle; 2 glasses; 2 20-ounce bottles
Any kind of soft drink, like cola, Sprite, orange soda, regular or diet										How much IN A DAY: 1 can; 1 20-ounce bottle; 2 cans; Big Gulp or 3 cans
Beer or non-alcoholic beer										How much IN A DAY: 1 can; 2 cans; 3-4 cans or small pitcher; 5+ cans or large pitcher
Wine or wine coolers										How many GLASSES in a day: 1/2 glass; 1 glass; 2 glasses or half bottle; 3 glasses
Liquor or mixed drinks										How many DRINKS: 1, 2, 3, 4
Glasses of water, tap or bottled										How many GLASSES: 1, 2, 3-4, 5+
Coffee, regular or decaf										How many CUPS: 1, 2, 3, 4+
Hot tea (<u>not</u> including herbal teas)										How many CUPS: 1, 2, 3, 4+

What do you <u>usually</u> add to **coffee? MARK ONLY ONE:**
Cream or half & half | Nondairy creamer | Milk | None of these | Don't drink it

What do you <u>usually</u> add to **tea? MARK ONLY ONE:**
Cream or half & half | Nondairy creamer | Milk | None of these | Don't drink it

Do you usually add sugar (or honey) to **coffee?** No | Yes | IF YES, how many teaspoons <u>each cup</u>? 1 | 2 | 3 | 4

Do you usually add sugar (or honey) to **tea?** No | Yes | IF YES, how many teaspoons <u>each cup</u>? 1 | 2 | 3 | 4

	RARELY	1-2 PER WEEK	3-4 PER WEEK	5-6 PER WEEK	1 PER DAY	1 1/2 PER DAY	2 PER DAY	3 PER DAY	4+ PER DAY
About how many servings of vegetables do you eat, per day or per week, not counting salad or potatoes?									
About how many servings of fruit do you eat, not counting juices?									
How often do you use fat or oil in cooking?									

PLEASE DO NOT WRITE IN THIS AREA

SERIAL #

If you eat the following foods, what type do you usually eat? MARK ONLY ONE ANSWER FOR EACH QUESTION

Milk	Whole milk Reduced-fat 2% milk	Low-fat 1% milk Non-fat milk	Soy milk Rice milk	Don't drink
Slim Fast, Sego, Slender or Ensure		Low-Carb like Atkins	Regular	Don't drink
Orange juice	Calcium-fortified	Not calcium-fortified	I don't know	Don't drink
Soda or pop	Diet soda, low-calorie	Regular	Don't drink	
Iced tea	Homemade, no sugar / Homemade, w/sugar	Bottled, no sugar	Bottled, regular	Don't drink
Beer	Regular beer / Light beer	Low-Carb beer	Non-alcoholic beer	Don't drink
Hamburgers or cheeseburgers		Hamburgers	Cheeseburgers	Don't eat
Hot dogs	Low fat or turkey dogs	Regular hot dogs	Don't eat	
Lunch meats	Low-fat or turkey lunch meats	Regular lunch meats	Don't eat	
Spaghetti or lasagna	Meatless	With meat sauce or meatballs		Don't eat
Cheese	Low Fat	Not Low Fat	Don't eat	
Salad dressing	Low-Carb	Low-fat	Regular	Don't use
Energy bars like Power Bar, Clif, Atkins	Low-Carb, low sugar	Low-fat	Regular	Don't eat
Breakfast bars, cereal bars, or granola bars	Low-Carb, low sugar	Low-fat	Regular	Don't eat
Bread	100% whole wheat	Low-Carb	Regular	Don't eat
Tortillas	Corn	Flour	Don't know or don't eat	
Chocolate candy or chocolate candy bars	Low-Carb, low sugar	Low-fat	Regular	Don't eat
Cookies	Low-Carb, low sugar	Low-fat	Regular	Don't eat
Cake, snack cakes, and other pastries	Low-Carb, low sugar	Low-fat	Regular	Don't eat
Ice cream	Low-Carb, low sugar	Low-fat or ice milk	Regular	Don't eat
Jelly or jam	Low-Carb, low sugar	Regular	Don't use	
Beef or pork	Avoid eating the fat	Sometimes eat the fat	Often eat the fat	Don't eat
Chicken or Turkey	Avoid eating the skin	Sometimes eat the skin	Often eat the skin	Don't eat

What kinds of **fat or oil** do you usually use in cooking? **MARK ONLY ONE OR TWO**

- Don't know, or Pam
- Butter
- Butter/margarine blend
- Stick margarine
- Soft tub margarine
- Low-fat margarine
- Corn oil, vegetable oil
- Olive oil or canola oil
- Lard, fatback, bacon fat
- Crisco

If you eat **cold cereals**, what do you eat? Choose one or two that you eat most often. (If you usually just eat one kind, just choose one.)

- Low-carb cereals like Atkins, Low-Carb Special K
- Cheerios, Grape Nuts, Shredded Wheat, Wheaties, Wheat Chex
- Total
- Fiber One
- Product 19, Complete
- All Bran, Bran Buds
- Other fiber cereals like Raisin Bran, Fruit-n-Fiber
- Sweetened cereals like Frosted Flakes, Froot Loops
- Other cold cereals, like Corn Flakes, Rice Krispies, Special K

What vitamin supplements do you take fairly regularly?	HOW OFTEN: DIDN'T TAKE	A FEW DAYS per MONTH	1-3 DAYS per WEEK	4-6 DAYS per WEEK	EVERY DAY	FOR HOW MANY YEARS?: LESS THAN 1 YEAR	1 YEAR	2 YEARS	3-4 YEARS	5-9 YEARS	10+ YEARS
Multiple Vitamins. Did you take...											
Prenatal vitamins											
Regular Once-A-Day, Centrum, Theragran, "senior" vitamins or house brands of multiple vitamins											
Stress-tabs or B-Complex type											
Single Vitamins, not part of multiple vitamins											
Vitamin A (not beta-carotene)											
Beta-carotene											
Vitamin C											
Vitamin E											
Folic Acid, Folate											
Calcium or Tums											
Vitamin D, alone or combined with calcium											
Zinc											
Iron											
Selenium											
Omega-3, fish oil, flax seed oil											

If you took Once-a-day, Centrum or Thera-type multiple vitamins, did you usually take types that
○ contain minerals, iron, zinc, etc. ○ do not contain minerals ○ Don't know

If you took vitamin C, how many milligrams of **vitamin C** did you usually take, on the days you took it?
○ 100 ○ 250 ○ 500 ○ 750 ○ 1000 ○ 1500 ○ 2000 ○ 3000+ ○ Don't know

If you took vitamin E, how many IUs of **vitamin E** did you usually take, on the days you took it?
○ 100 ○ 200 ○ 300 ○ 400 ○ 600 ○ 800 ○ 1000 ○ 2000+ ○ Don't know

Did you take any of these supplements at least once a week?
○ Ginkgo ○ St. John's Wort ○ Echinacea ○ DHEA ○ Didn't take these
○ Ginseng ○ Kava Kava ○ Melatonin ○ Glucosamine/Chondroitin

SOME LAST QUESTIONS ABOUT YOU

Would you say your health is ○ Excellent ○ Very good ○ Good ○ Fair ○ Poor

Are you currently trying to lose weight? ○ Yes ○ No

Was there ever a time in your life when you once drank more beer, wine or liquor than you do now? ○ Yes ○ No

Do you smoke cigarettes now? ○ Yes ○ No
IF YES, On average about how many cigarettes a day do you smoke now? ○ 1-5 ○ 6-14 ○ 15-24 ○ 25-34 ○ 35+

Are you ○ Hispanic or Latino ○ Not Hispanic or Latino

What race do you consider yourself to be? (MARK ALL THAT APPLY)
○ White ○ Asian ○ Native Hawaiian or Other Pacific Islander
○ Black or African American ○ American Indian or Alaska Native ○ Do not wish to provide this information

Thank you very much for filling out this questionnaire.
Please take a minute to go back and fill in anything you may have skipped.

PLEASE DO NOT WRITE IN THIS AREA

SERIAL #

APPENDIX I

Balance Efficacy Scale

Subject ID ____________________

The Balance Efficacy Scale

(Reprinted from the Center of Successful Aging at California state University, Fullerton)

Listed below are a series of tasks that you may encounter in daily life. Please indicate how confident you are, **today**, that you can complete each of these tasks without losing your balance. Your answers are confidential. **Please answer as you feel, not how you think you should feel.**

(Circle one number from 1 to 100%)

1. How confident are you that you can get up out of a chair (using your hands) without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

2. How confident are you that you can get up out of a chair (*not* using your hands) without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

3. How confident are you that you can walk up a flight of 10 stairs (using the handrail) without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

4. How confident are you that you can walk up a flight of 10 stairs (*not* using the handrail) without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

5. How confident are you that you can get out of bed without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

6. How confident are you that you can get into or out of a shower or bathtub (*with* the assistance of a handrail or support wall) without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

7. How confident are you that you can get into or out of a shower or bathtub (*without* the assistance of a handrail or support wall) without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

8. How confident are you that you can walk down a flight of 10 stairs (using the handrail) without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

9. How confident are you that you can walk down a flight of 10 stairs (*not* using the handrail) without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

10. How confident are you that you can remove an object from a cupboard located at a height that is *level* with your shoulder without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

11. How confident are you that you can remove an object from a cupboard located at a height that is *above* your shoulder without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

12. How confident are you that you ca walk across uneven ground (*with* assistance) when good lighting is available without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

13. How confident are you that you ca walk across uneven ground (*with no* assistance) when good lighting is available without losing your balance?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident somewhat confident absolutely confident

14. How confident are you that you ca walk across uneven ground (*with* assistance) at night without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

15. How confident are you that you ca walk across uneven ground (*with no* assistance) at night without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

16. How confident are you that you could stand on one leg (*with* support) while putting on a pair of trousers without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

17. How confident are you that you could stand on one leg (*with no* support) while putting on a pair of trousers without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

18. How confident are you that you could complete a daily task *quickly* without losing your balance?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident					somewhat confident					absolutely confident

APPENDIX J

Informed Consent Document; Quantification Study

DEPARTMENT of Nutrition and Exercise Science
Oregon State University, 101 Milam Hall , Corvallis, Oregon 97331
Tel 541-737-2643 | **Fax** 541-737-6914 | mendy.gayler@oregonstate.edu/ www.hhs.oregonstate.edu/nes/index.html

INFORMED CONSENT DOCUMENT

Project Title:	Quantification of physical activity amount and intensity associated with the *Better Bones and Balance* community-based exercise program.
Principal Investigator:	Kathy Gunter, PhD Extension Community and Family Development Department of Nutrition and Exercise Science.
Co-Investigator:	Adrienne McNamara, M.S. Department of Nutrition and Exercise Science.

WHAT IS THE PURPOSE OF THIS STUDY?

You are being invited to take part in a research study designed to measure the amount of physical activity that class members typically do during *Better Bones and Balance* (BBB) class sessions. We are also going to measure the impact forces associated with the key exercises of the BBB program such as lunges, steps, and jumps. The results from this study are intended to be used for publication. We are studying this because we want to evaluate if the amount of exercise performed in the BBB program meets the national recommendations for weekly amounts of moderate to vigorous physical activity. We are also studying this so that we can objectively compare this exercise program to other bone loading exercises programs.

WHAT IS THE PURPOSE OF THIS FORM?

This consent form gives you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask any questions about the research, the possible risks and benefits, your rights as a volunteer, and anything else that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not.

WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are a postmenopausal woman, who has been participating in the *Better Bones and Balance* program for at least one year without significant musculoskeletal injury that prevents you from full participation in this exercise program. In total, we are hoping to recruit a maximum of 60 women for this study.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

If you agree to participate in this study, your involvement will include the following:

1. **Accelerometry:** You will be asked to wear an accelerometer (physical activity measuring device) around your waist during **three** *Better Bones and Balance* class sessions. The accelerometer is very small and will not hinder your ability to perform the class exercises. A researcher will be available to help position and turn on the device before each class. You will return the accelerometer to the researcher after each class session and will be given the same device for the remaining sessions. You will be asked to maintain your usual behaviors and intensity of activity during the class sessions while your activity is being monitored. This testing will take place in your usual class location.

2. **Heart rate monitoring**: You will also be asked to wear a heart rate monitor during the BBB class. The heart rate monitor consists of a chest strap and a wrist watch. A researcher will be available to instruct you on proper placement and use of the heart rate monitor. You will be instructed to turn on the monitor after the class warm up and to turn off the monitor just prior to the class cool down. This is achieved by a simple press of a button on the watch. Researchers will be present during class sessions to help you do this. You will return the heart rate monitor to the researcher after each class session and be given the same device for the remaining sessions.
3. **Force plate analysis**. You will be asked to perform several trials of each key BBB exercise (lunges, heel drops, jumps, stepping and stomping) while standing on or adjacent to a force platform. The researcher will inform you when to start and stop each trial. This testing will take place at the Bone Research Laboratory and should take approximately 20 minutes to complete. This measure will be used to assess the ground reaction forces associated with the BBB exercise program. Ground Reaction forces are a measure of exercise intensity related to bone loading. Height and Weight will also be assessed at this time.
4. **Health History questionnaire.** You will be asked to complete a brief health history questionnaire addressing diseases or illness, medication and supplement use, as well as your participation history in BBB. This questionnaire should take approximately 5-10 minutes to complete.

If you agree to take part in this study, your involvement will last for three *BBB* class sessions (approximately 1 week) in addition to the 20 minutes necessary for the force plate assessments.

WHAT ARE THE RISKS OF THIS STUDY?

The risks involved in this study are minimal. There is a risk of mild soreness or fatigue from the force plate assessments as this is physical activity in addition to what you do in a typical week. For most individuals this resolves within 1-3 days. You are free to rest or stop testing at any time. There are no known risks associated with the wearing of the accelerometers or the heart rate monitors.

WHAT ARE THE BENEFITS OF THIS STUDY?

We do not know if you will benefit from being in this study. However you will be informed how the amount and intensity of the activity you do during class compares with the recently released guidelines regarding the amount and intensity of physical activity that older adults should be getting each week. We hope that, in the future, other people might benefit from this study because of the information we gain concerning the exercise dose associated with the *Better Bones and Balance* program.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO WILL SEE THE INFORMATION I GIVE?

To help protect your confidentiality, we will keep all records in a secure location to which only the research team has access. However, federal government regulatory agencies and the Oregon State University Institutional Review Board (a committee that reviews and approves research studies involving human subjects) may inspect and copy records pertaining to this research. It is possible that these records could contain information that personally identifies you. The investigators will assign your data to a code number which will be used in all analysis. If the results of this project are published your identity will not be made public.

DO I HAVE A CHOICE TO BE IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decide not to take part in this study, your decision will have no effect on the quality of services you receive through your participation in the *Better Bones and Balance* classes. Nor will you be treated differently if you decide to stop taking part in the study.

WHAT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact: Kathy Gunter at 541-737-1405, Kathy.gunter@oregonstate.edu or Adrienne McNamara, 541-990-7820, mcnamara@onid.orst.edu

If you have questions about your rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, at (541) 737-4933 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed): ____

______________________________ ______________________

(Signature of Participant) (Date)

APPENDIX K

Health History Questionnaire; Quantification Study

Last Name, First ______ Date ______ ID # ______

Medical History Questionnaire
Better Bones and Balance Sub-study

Last Name	First Name	MI	Age	Date of Birth

Address	City, State, Zip

Phone (land line)	Work/Cell phone	E-mail Address

How do you prefer to be contacted regarding this study?

- ☐ Email
- ☐ Phone
- ☐ Other ______

MEDICATIONS AND SUPPLEMENTS

Please list all medications that you currently take (including over-the-counter medications and dietary supplements)

Type of medication	For what condition

PRESENCE OF DISEASE/ILLNESS

Do you currently have or have you ever had any of the following? (Check if yes)

		Year of onset?	Current symptom (circle one)?	
____	High blood pressure	________	yes	no
____	Heart trouble	________	yes	no
____	Disease of the arteries	________	yes	no
____	Lung disease	________	yes	no
____	Epilepsy	________	yes	no
____	Diabetes	________	yes	no
____	Rheumatoid Arthritis	________	yes	no
____	Back injury	________	yes	no
____	Cancer	________	yes	no
____	Stroke	________	yes	no
____	Broken bones	________	yes	no
____	Orthopedic operations	________	yes	no
____	High or low thyroid	________	yes	no
____	High cholesterol	________	yes	no
____	Lactase deficiency	________	yes	no
____	Musculoskeletal injury	________	yes	no
____	Other operations	________	yes	no
____	Osteoarthritis	________	yes	no

If yes to any of the above, please explain:

____

____

____

____

____

GENERAL QUESTIONS

1. Please indicate how many years post-menopause you currently are. ___________

2. Please indicate if you have experienced any urinary incontinence ("leaking") in the previous 3 months? YES or NO

   If yes, on average how many incidents per week __________

3. Please indicate how long, in years and months, you have been participating in the *Better Bones and Balance* program. ____________years ___________months

4. Please indicate how many classes **on average** you have attended each month since you began participating in *Better Bones and Balance.*

   0-3 4-6 7-9 10-12

5. Have you ever sustained an injury while participating in a *Better Bones and Balance* class? YES or NO

   If yes, please explain: ______________________________________

   ____

6. Which of the following describes how often that you wear your weighted vest during *Better Bones and Balance* class?

Never	Occasionally	Sometimes	Always
	(<1class per week)	(1-2classes/week)	(3 classes/week)

7. Which level of jumps do you usually perform in *Better Bones and Balance* class? (circle one)

   No jumping Heel drops/Faux jumps Full jumps