Osteoporos Int
DOI 10.1007/s00198-011-1816-6

ORIGINAL ARTICLE

The influence of participation in Better Bones and Balance™ on skeletal health: evaluation of a community-based exercise program to reduce fall and fracture risk

A. McNamara · K. Gunter

Received: 29 March 2011 / Accepted: 31 August 2011
© International Osteoporosis Foundation and National Osteoporosis Foundation 2011

Abstract
Summary Older women participating in *Better Bones and Balance*™ (BBB) had similar bone mass at the hip compared to a sample of low active/sedentary controls. However, both groups had higher than expected hip BMD, despite higher risk for osteoporosis among BBB participants.
Introduction BBB is a community-based fall and fracture risk reduction program shown to reduce bone loss at the hip in older women under controlled laboratory conditions. Whether bone benefits are derived from BBB as delivered in the community setting is unknown. The purpose of this study is to evaluate the relationship between community-based BBB participation and parameters of skeletal health in postmenopausal women.
Methods Women were recruited from BBB classes (n=69) and compared to low active/sedentary controls (n=46); total sample aged 69 + 7.7 years. Bone mineral density (BMD) of the hip and spine was measured using DXA; 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 and body mass.
Results While controls were heavier and exhibited greater total body BMD compared to BBB participants (p<0.05), there were no differences between groups in hip or spine BMD or bone structural outcomes (p>0.05) despite BBB participants reporting more frequent prior diagnoses of or risk factors for osteoporosis compared to controls. Both controls and BBB participants had higher than average T-scores at the hip (p<0.05) when compared to an age-matched cohort from NHANES.
Conclusions These data suggest that participation in BBB may not result in direct benefits to bone. However long-term participation may be associated with other positive outcomes.

Keywords Bone health · Community-based exercise · Older women

A. McNamara · K. Gunter (✉)
Biological and Population Health Sciences,
Oregon State University,
Corvallis, OR, USA
e-mail: kathy.gunter@oregonstate.edu

Introduction

Osteoporosis is a disease characterized by alterations in bone mass and bone architecture leading to skeletal fragility and subsequently, bone fractures [1]. Hip fractures are the most costly as they contribute to 72% of the estimated 20 billion dollar annual cost associated with all osteoporotic fractures [2]. These costs are only expected to rise in the coming decades as incidence of osteoporosis is expected to double by the year 2050 [2]. Consequently, strategies to attenuate bone loss and prevent osteoporosis and subsequent hip fractures 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 fracture. 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 [3–9], the public health impact from such programs is not

Published online: 27 October 2011

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 [10, 11]. Therefore, it is crucial to offer exercise programs that are not only effective, but enjoyable, 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 has been ongoing since 1995 and incorporates lower body resistance training with weighted vests, impact and balance exercises, and is delivered as three 50-min sessions per week and taught by community fitness instructors. Specifically, the program emphasizes five "key" weight-bearing exercises: stepping onto (and off) benches, forward and side lunges, squats, heel drops, and/or jumps. As recently as 2008, stomping has been included in the protocol based on new evidence that this exercise may have osteogenic potential [12]. 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 areal bone mineral density (aBMD) after 5 years of participation [13, 14]. Since the last published report [14], BBB has been successfully translated into the community setting and has grown in size and popularity with over 300 local participants in the two neighboring counties from where the program was initiated and many more throughout Oregon. Further, new instructors are becoming trained every year and more classes are emerging throughout the USA, thereby increasing the need for evidence as to the effectiveness of the program in the community setting.

The purpose of this study was to evaluate whether measures of hip and spine aBMD and hip structural parameters differ between postmenopausal women who participate in community-based BBB programs and women who do not participate in the BBB program. Given the program's emphasis on lower extremity strengthening and fall risk, we hypothesized that BBB participation would be associated with higher hip aBMD and more favorable hip structure compared to controls and there would be no difference between groups at the spine.

Methods

Participants

Postmenopausal women (n=69) participating in a BBB program for at least 1 year were recruited from all BBB classes offered in Oregon's Linn and Benton counties and invited to participate in the study. Community-based BBB classes are offered 3 days per week for 50 min and focus on lower extremity strength, mobility, bone loading and balance. Exercises include squats, multi-direction lunges, stepping, stomps, and jumps [15]. Control participants (n= 46), matched by age to the BBB sample, were recruited via fliers in Linn and Benton counties, and from the Oregon State University (OSU) Center for Healthy Aging Research 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, 60–79, 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 [16, 17] while "sufficient functional ability" was defined as scoring less than 16 out of 24 on the composite physical function scale [18]. In addition, we recruited control participants who were classified as low active or inactive; defined as performing less than 60 min a week of moderate to vigorous physical activity and no resistance training for the previous 12 months [19]. Due to the minimal impact of walking and stretching on bone, control participants were still considered eligible for study participation even if time spent engaging in these light activities exceeded the 60 min/week activity criterion.

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 (centimeters) was measured directly using a fixed, wall mounted stadiometer and body mass (kilogram) was measured using a digital scale. Height and body mass were used to calculate body mass index (BMI; kilogram per square meter).

Physical activity

In order to control for the influence of physical activity outside of BBB classes among BBB participants, and to verify activity levels among controls, all participants filled out the Aerobics Center longitudinal physical activity questionnaire (ACLPAQ) [20]. This instrument quantifies individuals' regular levels of moderate to vigorous physical activity (MET × hours per week) during the previous 3 months. The Compendium of Physical Activities [21] 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 years [22]. 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 × hours per 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 [23]. 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. 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 (average 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. Data reported include total energy (kilocalories), protein (grams per kilogram body weight), calcium (milligrams), and vitamin D (international units) from food and supplemental sources. This instrument is a self-report questionnaire and has been validated against multiple diet record methods [24].

Areal bone mineral density, body composition, and hip structure

Areal bone mineral density (aBMD, grams per sqaure centimeter) of the proximal femur (total hip, femoral neck, and greater trochanter) and anterior posterior lumbar spine were assessed using dual energy x-ray absorptiometry (DXA) (QDR-4500A Elite, Waltham, MA). Whole body scans were also conducted in order to derive information on body composition including whole body lean mass and body fat percentage. Hip structural analysis (HSA) was performed on hip DXA scans to evaluate cross-sectional area (CSA, square centimeter), cross-sectional moment of inertia (CSMI, centimeter to the fourth power) and section modulus (Z, cubic centimeter) 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 measures and can provide additional information about skeletal strength beyond that given by measurements of mass alone. In-house operator precision presented as the coefficient of variation for hip aBMDwas calculated at 0.7% and precision from spine aBMD was 0.9% in this sample of older adults while precision for hip structure parameters ranged from 1.9% (NN CSA) to 4.6% (NN CSMI).

Data analysis

All data were analyzed using Predicted Analytics Software version 17 (SPSS Inc, Chicago, IL). Group differences on descriptive variables were calculated by independent *t* tests. Stepwise regression was applied to determine covariates (e.g., age, body weight, lean body mass, BPAQ scores, total calcium, total vitamin D, BMI) for aBMD at each bone site (femoral neck, intertrochanter, total hip, lumbar spine) (Table 1). Age and body weight were significant predictors of aBMD at the total hip, intertrochanter, and lumbar spine

Table 1 Covariate stepwise regression model summaries for aBMD parameters

Model	R	R^2	Adjusted R^2	Standard error of the estimate	F	$df1$	$df2$	Significant F
Total hip aBMD	0.610[a]	0.373	0.361	0.085259	32.967	1	111	0.000
Intertrochanter aBMD	0.552[a]	0.304	0.298	0.075756	49.031	1	112	0.000
Lumbar spine aBMD	0.561[a]	0.314	0.302	0.119162	24.774	1	108	0.000
Femoral neck aBMD	0.508[b]	0.258	0.252	0.084993	38.998	1	112	0.000

[a] Predictors: (constant), age, weight (kilogram); excluded variables: BMI, total calcium (milligrams), total vitamin D (international unit), BPAQ score, whole body lean mass (kilogram)

[b] Predictors: (constant), whole body lean mass (kilogram); excluded variables: age, BMI, weight (kilogram), total calcium (milligram), total vitamin D (international unit), BPAQ score

($p<0.001$ for each model); total body lean mass was the only significant predictor of femoral neck aBMD ($p<0.001$). The covariates for structural parameters differed in that, lean mass, and height were predictive of femoral neck structural parameters ($p<0.001$) and lean mass only was predictive of intertrochanteric structural parameters ($p<0.001$); these variables were included as covariates when examining the influence of BBB participation on bone structural measures. Analysis of covariance (ANCOVA) was used to determine bone differences between groups adjusting for age and body weight at the total hip, intertrochanter, and spine; and whole body lean mass only at the femoral neck. Type III sum of square analysis was used in the ANCOVA to account for the unequal sample size among groups. One sample *t* tests were used to compare group hip and spine T-scores to National Health and Nutrition Examination Survey (NHANES) reference values. 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 Oregon's 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, 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 5 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 69 BBB participants. The average duration of BBB participation was 5.7±4.3 years with 91.3% of participants attending greater than ten out of a possible 12 classes a month, and 95.7% attending classes year round.

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, 47 interested participants met our inclusion criteria and were enrolled in the study. One participant failed to complete her questionnaires and was therefore excluded, leaving 46 control participants who completed the study.

Descriptive characteristics and nutrient intakes of the two groups are presented in Tables 2 and 3, respectively. Analyses of data from the physical activity questionnaires showed there were no differences in *past* or *lifetime total* BPAQ scores between groups after removing the influence of BBB participation. BBB participants did report higher *current* BPAQ scores outside of BBB compared to controls (2.35±4.7 for BBB vs. 0.65±0.95 for controls; $p<0.05$; Table 2). However to put this difference in practical perspective, adding the activity done during BBB back into to the BPAQ score changed the current BPAQ mean value from 2.35 to 24.97 among BBB participants. Consequently, the small magnitude of initial differences in BPAQ scores between groups are likely meaningless. Unfortunately, as the BPAQ is a relatively new instrument, it is not yet known if the differences in bone loading that we observed between groups would be considered a physiological threshold for bone adaptation. Examining data from the ACLPAQ showed there were no differences in general physical activity performed outside of BBB

Table 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 min)	111.5 (21.8)	96.5 (24.9)	<0.001
ALPAQ scores (MET × h/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

All physical activity measures were calculated excluding the influence of BBB

BPAQ bone-specific physical activity questionnaire, *ALPAQ* Aerobics Center longitudinal physical activity questionnaire (measure of general physical activity)

Table 3 Energy and nutrient intakes, means (SD)

Variable	BBB (n=69)	Control (n=46)	p value
Dietary energy intake (kcal/day)	1,467 (501)	1,422 (433)	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)	ns
Total calcium from diet and supplements (mg/day)	1,693 (568)	1,355 (630)	<0.01
Calcium from diet only (mg/day)	768 (352)	727 (326)	ns
Calcium from supplements only (mg/day)	907 (440)	629 (521)	<0.05

Values unadjusted for under-reporting

between groups (Table 2). While our control participants were defined as inactive or participating in light activity (no moderate to vigorous physical activity), both control and BBB participants reported regular walking, housework, and gardening. Results from whole body bone scans revealed that BBB participants had more optimal body composition compared to controls; specifically, they had lower percent body fat, lower body weight, and a higher proportion of lean body mass than controls (p<0.01; Table 2).

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 intakes of these nutrients (p<0.05). 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 [25]. Individuals whose energy intake to estimated BMR ratio was less than 1.30 were considered to be under-reporters [26]. 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 under-reporting may have influenced our calcium and vitamin D results. However, even with under-reporting, both groups reported total calcium intakes above the Recommended Daily Allowance of 1,200 mg/day, and therefore likely have adequate calcium intakes. Further, covariate regression analyses indicated these variables were not predictive of bone measures in our sample of older women. BBB participants also reported higher protein intakes when expressed relative to total body weight. However, both groups consumed close to the RDA for protein, and with the prevalence of under-reporting, it is probable that both groups had adequate protein status.

Bone mass and structure

Regression analyses indicated that body weight (kilogram), body height (centimeter), age and lean mass (kilogram) were significantly (though differently) predictive of bone variables and were thus included as covariates for analyses to determine the influence of BBB participation on bone measures (Table 1). Total calcium intake (milligrams per day), total Vitamin D intake (international units per day), BPAQ scores, and BMI were not predictive of aBMD or bone structure at any measured site and were thus not included as covariates.

The adjusted group means for aBMD are presented in Fig. 1. There were no differences between groups in total spine, total hip, greater trochanter, or femoral neck aBMD. There were no group differences in any of the adjusted hip structural parameters between groups (Table 4).

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). The T-score compares an individual's bone health to a reference of a young healthy adult [1]. Thus in order to gain a better understanding of how well our sample represented older women in general, we compared total hip T-scores from the

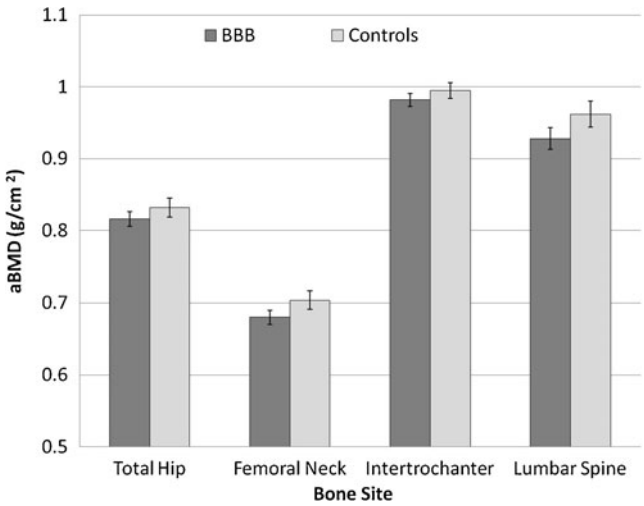

Fig. 1 Areal bone mineral density of the total hip, femoral neck, intertrochanter, and lumbar spine in BBB participants and controls. Data presented as means and standard errors. Total hip, intertrochanter, and lumbar spine values adjusted for age and weight. Femoral neck values adjusted for whole body lean mass. There were no differences between groups on any bone variables (p>0.05)

Table 4 Adjusted hip structural parameters; means (SE)

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

NN narrow neck, *IT* intertrochanteric, *CSA* cross-sectional area, *CSMI* cross-sectional moment of inertia, *Z* section modulus

[a] values adjusted for whole body lean mass (kilogram) and height (centimeter)

[b] values adjusted for whole body lean mass (kilogram)

BBB and controls participants to NHANES data [27, 28]. Although there were no differences between controls and BBB participants in hip aBMD at any measured site or total hip T-score (−1.055±0.086 for BBB vs. −0.862±0.105 for controls, p>0.05), both BBB and control participants between the ages of 60–80 years had higher (more positive) hip T-scores when compared to normative data (p<0.05; Fig. 2). Only two participants (both BBB) from our sample were classified as osteoporotic at the hip. At the spine, despite no difference in aBMD, controls had significantly higher lumbar spine T-scores compared to BBB participants (−0.591±1.3 for control vs. −1.2±1.2 for BBB, p<0.05) and compared to national reference values (−1.3, p<0.05) [29]. There were no differences between BBB participants' spine T-scores and those from the NHANES reference group (p>0.05). Two controls and eight BBB participants were classified as osteoporotic at the lumbar spine.

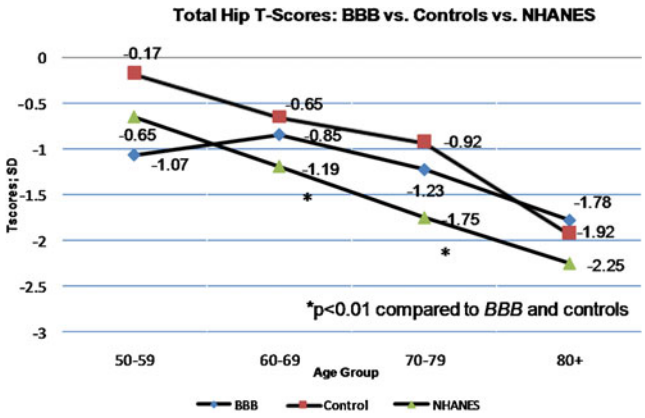

Fig. 2 Comparison of BBB and control group hip T-scores to NHANES reference values. *Asterisk* denotes both BBB and control groups exhibiting higher T-scores compared to NHANES values for ages 60–79 years

Discussion

This study found that older women participating in *Better Bones and Balance* did not exhibit enhanced hip or lumbar spine bone mass, or hip structural parameters compared to age-matched minimally active controls. However, when compared to NHANES data, both BBB and control groups had higher total hip bone mass (as expressed in T-scores) than national age-matched norms. Only control participants exhibited higher spine bone mass (expressed in T-scores) compared to NHANES data. Considering that the BBB protocol emphasizes lower body resistance training without employing exercises specifically targeting the spine, we would not expect an effect on spine bone mass from this program. However, that the BBB participants did show higher total hip bone mass compared to normative data, without the concomitant trend seen in the spine, may suggest a potential influence of the BBB program on *hip* bone mass among older women. Previous reports on the BBB program showed improvements in strength, balance, and power after 9 months participation with no differences in hip aBMD between the intervention group and controls [13]. However, after 5 years participation, program participants had maintained hip aBMD compared to controls who lost bone [14]. Results of the current study show no differences in hip bone measures compared to controls, although both groups had higher than expected hip bone mass.

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 aBMD in response to multi-component exercise programs [3, 4, 14, 30–33]. 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 aBMD in response to similar exercise protocols. For example, Villareal (2003) found no change in hip aBMD in response to 9 months of

resistance, balance, and aerobic training in elderly women taking HRT [34]. This is also the case for Liu-Ambrose et al. (2004) who found no changes in bone mass after 6 months of resistance and agility training in community dwelling osteopenic women [8]. Like the original report on BBB [13] 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. Our sample of women, both controls and BBB participants, have healthier than typical bone mass at the total hip when compared to national age-matched norms, although there were no differences in hip aBMD between groups. It is likely that our stringent inclusion criteria 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 prior 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. Further, there were no differences in total hip or spine aBMD compared to the control group, who reported fewer risk factors for osteoporosis. Thus, it is possible that participation in BBB *may* contribute 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.

With respect to bone structural parameters, we found no differences between BBB participants and controls. While there are fewer data examining the effects of exercise on bone structure in older women, there are a few worth mentioning that suggest exercise may influence bone structure more readily than bone mass. Both Liu-Ambrose et al. (2003) and Uusi-Rasi et al. (2003) observed favorable changes in bone structure of the tibia and/or radius with no changes in bone mass, as measured by peripheral quantitative computed tomography (pQCT) following 9 or 12 months of weight-bearing activity (respectively) [8, 35]. 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 [36, 37]. Therefore it appears 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, we found no differences in hip structure or mass between BBB participants and controls in this cross-sectional study.

There are limitations in making comparisons between our study and those cited above as the methods of assessing structural parameters differed. We employed hip structural analysis which utilizes two-dimensional data from DXA scans to estimate three-dimensional structural parameters and these studies used pQCT. A recent meta-analysis by Nikander et al. (2010) suggest that exercise has a positive, though modest effect on bone strength and structure in older women [38]. Further, they cite that these effects appear to be dependent on long-term participation and maintaining sufficient exercise intensity [38]. The BBB participants in our study had been attending classes consistently for an average of 5.7 years and data on a subset of participants regarding exercise intensity suggests that even long-term participants achieve moderate to high ground reaction forces during impact activities, and sustain heart rates over 55% of their predicted maximum for a majority of class sessions [39]. However, despite long-term participation and moderate to high exercise intensity, we did not observe differences in hip structural parameters between BBB and control participants in this current study.

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. 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 9-month intervention and wore them consistently to the end; systematically increasing vest weight over time. Among our participants, the fidelity to vest wearing was not as strong as observed in the laboratory setting. Specifically, only 19% of study participants faithfully wear their weighted vests every class period, while as many as 40.6% of participants report never wearing a weighted vest during class. 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 forces elicited by the heel drops, steps, and stomps were lower than those elicited by jumping (mean GRF for jumps $=2.14\pm0.28$ BW, one leg values) [39]. Therefore, it is possible that without the added resistance supplied by the vests, and with many participants not engaging in the activities eliciting the highest forces, participants may not be achieving adequate overload to stimulate skeletal

adaptation, This may account for the lack of skeletal differences between groups and discordance between our study and the report by Snow et al. (2000). 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.

Despite the lack of group differences in bone parameters, there were observable positive differences between BBB participants and controls in that BBB participants exhibited more favorable body composition. 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 aBMD [40]. 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 (kilogram fat per square meter) 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 [41]. BBB participants have also been found to have superior cardiorespiratory fitness, as measured by the 2-min step test, compared to controls [39]. Thus, it is possible that BBB participation may be associated with reduction in risk for cardiovascular disease. Furthermore, this sample of BBB participants was found to have enhanced strength, balance, and balance confidence compared to controls [42], factors associated with reduced risk for falls. 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 [43].

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 likely resulted in selection bias so that we were comparing our BBB participants, a group who generally enroll in BBB due to concern with both health, to a control group with better than average skeletal health. We attempted to account for this in part by making comparisons between both our BBB and control samples to NHANES data. However, despite the stringent exclusion criteria, we unfortunately failed to match groups based on body size. This discrepancy may have altered our results and potentially accounted for the higher than expected bone mass of our controls. However, we did attempt to control for these differences by including body weight as a covariate in the bone analyses. An additional limitation was that we were unable to recruit enough participants for our control group to match the number of participants in the BBB group. Likely, this was also a result of our exclusion criteria, as only 18% of women invited to participate in the study met our eligibility criteria. In particular, the exclusion of physically active individuals posed a specific challenge as we were recruiting from a community where many older adults regularly engage in exercise. Further, the cross-sectional design of this study does not allow for causal inferences about the influence of the BBB program on skeletal health.

There are several strengths to this study as well. There is a dearth of data evaluating the influence of true community-based programs for older adults 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. Similarly, if a program is not systematically evaluated after translation to the community, its effectiveness in a real world setting remains unknown. Though cross-sectional—this study provides much needed information to facilities, instructors, and participants, all of whom must make decisions whether to deliver or participate in one program over another. Furthermore, we have detailed the consistency of the program from its original format upon translation into the community setting and have also identified program components associated with lower fidelity (i.e., jumps and vest wearing). This not only helps to explain differences we may observe in actual versus expected results, but allows for enhanced instructor training and an opportunity to re-evaluate. An additional finding from this study worth noting was the long-term involvement in the program by 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 [44]. 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 enjoyable 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 [10, 11]. 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 [8, 35].

In conclusion, BBB participants did not exhibit differences in bone mass or structure compared to age-matched sedentary controls. 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 compared to controls; results that suggest BBB may confer health benefits that extend beyond improving fall and fracture risk.

Acknowledgments Funding was provided by the Oregon State University Foundation College of Health and Human Sciences Dean's Excellence Fund.

Conflicts of interest None.

References

1. National Institutes of Health (2001) Osteoporosis prevention, diagnosis, and therapy. JAMA 285(6):785–795
2. Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, Tosteson A (2007) Incidence and economic burden of osteoporosis-related fractures in the United States, 2005–2025. J Bone Miner Res 22(3):465–475
3. Engelke K, Kemmler W, Lauber D, Beeskow C, Pintag R, Kalender WA (2006) Exercise maintains bone density at spine and hip efops: A 3-year longitudinal study in early postmenopausal women. Osteoporos Int 17(1):133–142
4. Going S, Lohman T, Houtkooper L, Metcalfe L, Flint-Wagner H, Blew R, Stanford V, Cussler E, Martin J, Teixeira P, Harris M, Milliken L, Figueroa-Galvez A, Weber J (2003) Effects of exercise on bone mineral density in calcium-replete postmenopausal women with and without hormone replacement therapy. Osteoporos Int 14(8):637–643
5. Kohrt WM, Ehsani AA, Birge SJ Jr (1997) Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. J Bone Miner Res 12(8):1253–1261
6. Maddalozzo GF, Snow CM (2000) High intensity resistance training: effects on bone in older men and women. Calcif Tissue Int 66(6):399–404
7. Maddalozzo GF, Widrick JJ, Cardinal BJ, Winters-Stone KM, Hoffman MA, Snow CM (2007) The effects of hormone replacement therapy and resistance training on spine bone mineral density in early postmenopausal women. Bone 40(5):1244–1251
8. Liu-Ambrose TY, Khan KM, Eng JJ, Heinonen A, McKay HA (2004) Both resistance and agility training increase cortical bone density in 75- to 85-year-old women with low bone mass: a 6-month randomized controlled trial. J Clin Densitom 7(4):390–398
9. Karinkanta S, Heinonen A, Sievanen H, Uusi-Rasi K, Pasanen M, Ojala K, Fogelholm M, Kannus P (2007) A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. Osteoporos Int 18(4):453–462
10. Englund U, Littbrand H, Sondell A, Bucht G, Pettersson U (2009) The beneficial effects of exercise on bmd are lost after cessation: a 5-year follow-up in older post-menopausal women. Scand J Med Sci Sports 19(3):381–388
11. Winters KM, Snow CM (2000) Detraining reverses positive effects of exercise on the musculoskeletal system in premenopausal women. J Bone Miner Res 15(12):2495–2503
12. Young CM, Weeks BK, Beck BR (2007) Simple, novel physical activity maintains proximal femur bone mineral density, and improves muscle strength and balance in sedentary, postmenopausal caucasian women. Osteoporos Int 18(10):1379–1387
13. Shaw JM, Snow CM (1998) Weighted vest exercise improves indices of fall risk in older women. J Gerontol A Biol Sci Med Sci 53(1):M53–M58
14. Snow CM, Shaw JM, Winters KM, Witzke KA (2000) Long-term exercise using weighted vests prevents hip bone loss in postmenopausal women. J Gerontol A Biol Sci Med Sci 55(9):M489–M491
15. Oregon State University Extension Family and Community Health Program (2008) The Better Bones and Balance program. http://extension.oregonstate.edu/physicalactivity/bbb. Accessed October 10 2010
16. Schultz-Larsen K, Lomholt RK, Kreiner S (2007) Mini-mental status examination: a short form of mmse was as accurate as the original mmse in predicting dementia. J Clin Epidemiol 60 (3):260–267
17. Folstein MF, Folstein SE, McHugh PR (1975) Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 12(3):189–198
18. Rose D (2003) Fall proof! A comprehensive balance and mobility training program, 1st edn. Human Kinetics, Champaign
19. Bennett JA, Winters-Stone K, Nail LM, Scherer J (2006) Definitions of sedentary in physical-activity-intervention trials: a summary of the literature. J Aging Phys Act 14(4):456–477
20. Kohl HW, Blair SN, Paffenbarger RS Jr, Macera CA, Kronenfeld JJ (1988) A mail survey of physical activity habits as related to measured physical fitness. Am J Epidemiol 127(6):1228–1239
21. Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, Paffenbarger RS Jr (1993) Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 25(1):71–80
22. Pereira MA, FitzerGerald SJ, Gregg EW, Joswiak ML, Ryan WJ, Suminski RR, Utter AC, Zmuda JM (1997) A collection of physical activity questionnaires for health-related research. Med Sci Sports Exerc 29(6 Suppl):S1–S205
23. Weeks BK, Beck BR (2008) The BPAQ: a bone-specific physical activity assessment instrument. Osteoporos Int 19 (11):1567–1577
24. Block G, Woods M, Potosky A, Clifford C (1990) Validation of a self-administered diet history questionnaire using multiple diet records. J Clin Epidemiol 43(12):1327–1335
25. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO (1990) A new predictive equation for resting energy expenditure in healthy individuals. Am J Clin Nutr 51 (2):241–247
26. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM (1991) Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 45(12):569–581
27. Ott S (2010) Osteoporosis and bone physiology. http://courses.washington.edu/bonephys/opbmdtz.html#tcalc. Accessed October 2010
28. Looker AC, Wahner HW, Dunn WL, Calvo MS, Harris TB, Heyse SP, Johnston CC Jr, Lindsay R (1998) Updated data on proximal femur bone mineral levels of us adults. Osteoporos Int 8(5):468–489
29. Kanis JA, Gluer CC (2000) An update on the diagnosis and assessment of osteoporosis with densitometry. Committee of scientific advisors, international osteoporosis foundation. Osteoporos Int 11(3):192–202
30. Jessup JV, Horne C, Vishen RK, Wheeler D (2003) Effects of exercise on bone density, balance, and self-efficacy in older women. Biol Res Nurs 4(3):171–180
31. Kemmler W, Engelke K, Lauber D, Weineck J, Hensen J, Kalender WA (2002) Exercise effects on fitness and bone mineral density in early postmenopausal women: 1-year EFOPS results. Med Sci Sports Exerc 34(12):2115–2123
32. Kemmler W, Lauber D, Weineck J, Hensen J, Kalender W, Engelke K (2004) Benefits of 2 years of intense exercise on bone density, physical fitness, and blood lipids in early postmenopausal osteopenic women: results of the Erlangen Fitness Osteoporosis

Prevention Study (EFOPS). Arch Intern Med 164(10):1084–1091
33. Park H, Kim KJ, Komatsu T, Park SK, Mutoh Y (2008) Effect of combined exercise training on bone, body balance, and gait ability: a randomized controlled study in community-dwelling elderly women. J Bone Miner Metab 26(3):254–259
34. Villareal DT, Binder EF, Yarasheski KE, Williams DB, Brown M, Sinacore DR, Kohrt WM (2003) Effects of exercise training added to ongoing hormone replacement therapy on bone mineral density in frail elderly women. J Am Geriatr Soc 51 (7):985–990
35. Uusi-Rasi K, Kannus P, Cheng S, Sievanen H, Pasanen M, Heinonen A, Nenonen A, Halleen J, Fuerst T, Genant H, Vuori I (2003) Effect of alendronate and exercise on bone and physical performance of postmenopausal women: a randomized controlled trial. Bone 33 (1):132–143
36. Sornay-Rendu E, Boutroy S, Munoz F, Delmas PD (2007) Alterations of cortical and trabecular architecture are associated with fractures in postmenopausal women, partially independent of decreased bmd measured by dxa: the OFELY Study. J Bone Miner Res 22(3):425–433
37. Vico L, Zouch M, Amirouche A, Frere D, Laroche N, Koller B, Laib A, Thomas T, Alexandre C (2008) High-resolution pqct analysis at the distal radius and tibia discriminates patients with recent wrist and femoral neck fractures. J Bone Miner Res 23(11):1741–1750
38. Nikander R, Sievanen H, Heinonen A, Daly RM, Uusi-Rasi K, Kannus P (2010) Targeted exercise against osteoporosis: a systematic review and meta-analysis for optimising bone strength throughout life. BMC Med 8:47
39. McNamara A (2010) 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. Dissertation, Oregon State University, Corvallis
40. Ensrud KE, Ewing SK, Stone KL, Cauley JA, Bowman PJ, Cummings SR (2003) Intentional and unintentional weight loss increase bone loss and hip fracture risk in older women. J Am Geriatr Soc 51(12):1740–1747
41. Kelly TL, Wilson KE, Heymsfield SB (2009) Dual energy X-ray absorptiometry body composition reference values from NHANES. PLoS One 4(9):e7038
42. Gunter KB, McNamara AJ (2010) Successful translation of better bones and balance: a community-based fall and fracture risk reduction exercise program for older adults. Med Sci Sports Exerc 42(5):s48
43. Jarvinen TL, Sievanen H, Khan KM, Heinonen A, Kannus P (2008) Shifting the focus in fracture prevention from osteoporosis to falls. BMJ 336(7636):124–126
44. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, Macera CA, Castaneda-Sceppa C (2007) Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 39 (8):1435–1445