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ORIGINAL RESEARCH

Meeting Physical Activity Guidelines Through Community-Based Group Exercise: "Better Bones and Balance"

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Objective: Community-based exercise programs are popular for achieving physical activity among older adults, but the amount of physical activity obtained through such programs is unknown. This study quantified the bone-loading forces and levels of 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 postmenopausal women age 73.2 ± 7.6 yr engages in BBB participated in this study. Ground-reaction forces (GRFs) associated with BBB exercises were evaluated using a force platform. Session and weekly totals of minutes of moderate to vigorous physical activity (MVPA) and total time spent above 55% maximum heart rate (HR) were measured using accelerometers and HR monitors, respectively. ***Results:*** BBB exercises produced mean 1-leg GRFs of 1.4–2.2 units body weight. Weekly BBB participation was associated with 126 ± 31 min of MVPA. ***Conclusion:*** Activity obtained by BBB participation meets recommended guidelines for skeletal and cardiovascular health.

Keywords: older adults, accelerometer, heart rate, ground-reaction forces

Physical inactivity among older adults is a growing problem in U.S. society. Over two thirds of older adults fail to accumulate the recommended minimum of 150 min/week of moderate physical activity or 75 min of vigorous activity to optimize health and help prevent 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 regular exercise (Centers for Disease Control and Prevention, 2011), and 80–90% of adults of age 65 report they never perform vigorous activity (Khort, 2010). This carries a large public health impact, as inactivity is known to contribute to obesity and chronic diseases such as cardiovascular disease, Type II diabetes, and cancer. Furthermore, physical inactivity can decrease quality of life and contribute to a loss of independence among older adults (Nelson et al., 2007). Participation in physical activity may address these general health issues and can be

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specifically targeted to enhance musculoskeletal health and function, such as in the prevention of osteoporosis (Khort, Bloomsfield, Little, Nelson, & Yingling, 2004).

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 benefits such as social interaction. However, whether the exercise doses experienced by participants in community-based exercise programs meet current guidelines for moderate to vigorous physical activity (MVPA) is largely unknown, as there has been little research to quantify the associated physical activity doses. Information regarding the dose delivered by exercise programs is needed to assess the influence and effectiveness of programs in producing the desired health outcomes. For example, when enhancement of skeletal health is the outcome of interest, it becomes necessary to know the impact forces delivered by the prescribed exercises to determine if those forces are sufficient to promote skeletal adaptation. Yet, while some researchers have quantified ground reaction forces (GRFs) associated with specific exercises that target skeletal health (Bassey, Littlewood, & Taylor, 1997; Bassey & Ramsdale, 1995; Kemmler et al., 2002; Weeks & Beck, 2008; Young, Weeks, & Beck, 2007), such data are sparse and have not been assessed in a community-based setting. There remains a pressing need to quantify both the amount and the intensity of exercise delivered by community-based exercise programs for older adults so that these programs may be objectively evaluated in relation to the relevant guidelines and one another.

"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 static and dynamic balance-training activities, lower body resistance training with weighted vests, and impact exercises. It is delivered as three 50-min sessions/week and is taught by community fitness instructors. The program emphasizes six "key" weight-bearing exercises: stepping onto benches, forward and side lunges, squats, and heel drops and/or jumps. Recently, stomping has been included in the program, 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. Since the last published report (Snow, Shaw, Winters, & Witzke, 2000), BBB has grown to include over 300 participants in western Oregon, with more classes emerging throughout the United States. There are data to support the program's efficacy in improving function and reducing risk factors for falls and fractures in postmenopausal women (Gunter & McNamara, 2010). However, the dose of physical activity typically experienced by participants in the community setting has yet to be quantified.

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, in terms of minutes of MVPA, average and peak heart rates (HR), and time above 55% of maximum heart rate (HR_{max}) that participants accrue during one BBB class session and over a typical week of BBB participation (three sessions/week). We also aimed to assess the osteogenic potential, in terms of the peak magnitude of the ground-reaction force (GRF), of the key bone-loading exercises in BBB. Secondarily, we sought to examine the influence of participant age on exercise dose.

Methods

Participants

Postmenopausal women (N = 36, age 72.0± 6.8 years) were recruited from four different BBB classes in Corvallis, OR. Women were eligible to participate if they were currently enrolled in a BBB class and had been actively participating for at least 1 year and 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 with ages ranging from 60 to 87 were stratified into three age categories: 60–69 (n = 13), 70–79 (n = 14), and 80+ (n = 9), to include a range of ages typical of BBB-program participants. This study was approved by Oregon State University's institutional review board. All participants gave written informed consent before participation.

Procedures

Initial testing took place at the Oregon State University Bone Research Laboratory. At this visit, participants were oriented to the use accelerometers and HR monitors. In addition, GRFs of the key bone-loading exercises associated with BBB were measured at this time. Furthermore, a questionnaire was used to collect information regarding participants' age, menopausal status, and past participation with BBB. Height and body mass were also measured.

GRF. Peak one-leg vertical GRFs associated with the key bone-loading exercises of the BBB program were collected in the laboratory during the initial visit using a portable force platform (Kistler Instrument Corp., Amherst, NY). One-leg values were chosen to avoid the potential confounding in peak forces caused by asymmetrical landing patterns. However, to avoid the potential for participants to treat the force platform as a target and favor the measurement leg, two parallel force platforms were used. Participants were asked to perform each exercise with one foot on each platform and were unaware of which platform was actively collecting data. Each participant performed three exercises: steps, stomps, and either jumps (n = 24) or heel drops (n = 12), whichever corresponded to their usual exercise behavior. Steps were performed up and down a 23 cm-high step, leading with the right leg. Stomps were performed while marching in place. Jumps were performed in a countermovement fashion, with a brief pause between repetitions. Heel drops were performed with both feet simultaneously from a raised-on-toes position. Participants performed a single set of 30 repetitions of each exercise. To closely mimic the loading patterns achieved in the class setting, exercises were performed in the same order for each participant (steps, stomps, heel drops, jumps) with minimal rest. The first five repetitions were performed on the force platform, collected as a single trial. Participants then performed 20 repetitions off the platform and completed the final five repetitions on the platform. Each exercise was performed so that only the right foot contacted the active force platform. Therefore, all data are presented as one-leg forces. Before data collection, all participants were given detailed instructions for foot placement and were asked to perform the exercises as they would perform them in class. To this end, participants who typically wore a weighted vest while performing steps in class (n = 7) wore a vest of that weight for the steps performed during testing. Because the BBB program does not encourage the use of weighted vests during jumps, heel drops, or stomps, participants did not wear vests during these exercises. Force-plate data were collected at 1,500 Hz during each trial. For steps, data were collected only for contact with the "ground," not with the step.

The peak vertical GRF was obtained for each repetition in each trial using Bioware software (Kistler Instrument Corp., Amherst, NY). A fourth-order, Butterworth, no-lag, low-pass filter with a cut-off of 100 Hz was applied to each trial before extracting the peak GRFs. Peak values were averaged across all 10 repetitions for each exercise and normalized to body weight (BW).

Physical Activity Data. Physical activity data were collected during regularly scheduled BBB classes. MVPA occurring during the BBB classes was collected using a multidirectional Actical accelerometer (Phillips Respironics, Bend, OR). Simultaneously, HR data were collected using a Polar RS400 HR monitor (Polar Electro Oy, Finland). During their initial laboratory visit, participants were fitted with an accelerometer and instructed in its use. Before the in-class data collection, the accelerometers and HR monitors were initialized with the participants' height, weight, age or date of birth, and, for the HR monitor, estimated maximum HR. When participants arrived at their respective classes, a researcher secured the accelerometer to their right hip using a neoprene waistband. The researcher also helped participants secure the chest transmitters and start the watches of the HR monitors. Participants were instructed to maintain normal class behaviors while wearing the devices. At the completion of each class, the participants returned the devices to the researcher, the data were downloaded into specialized software for the accelerometer and HR monitor, and the accelerometer was reinitialized for the next session. Each participant wore the same accelerometer, together with an HR monitor, during three separate BBB classes over a period of 1–2 weeks. Every attempt was made to measure classes in consecutive order. However, to account for absences, one make-up session was offered to ensure that each participant had the opportunity to participate in three measurement sessions.

In processing the accelerometer data, custom intervals were created corresponding to the 50-min class sessions, plus 2 min to account for variations in class end time. The time spent in MVPA (defined as accelerometer counts >3 METS for moderate and >6 METS for vigorous, according to device defaults) was averaged across the three class sessions to indicate normal activity associated with a single BBB class. These times were also summed across all three sessions to indicate the MVPA associated with a typical week of BBB participation. If a participant failed to complete all three sessions (due to class absence and failure to complete the make-up session; $n = 5$), her data were averaged across the two completed sessions and these data were not used to calculate weekly exercise dose.

From the recorded HR data, average and peak HR per class session were extracted for each individual and normalized to a percentage of age-predicted maximum heart rate using the modified prediction equation $HR_{max} = (208 - 0.7) \times$ age. This equation is found to more accurately reflect the maximum HR among older adults (Mazzeo & Tanaka, 2001). The time spent with HR above 55% of predicted HR_{max} was also computed from the data as an alternative measure of the time spent in MVPA during each BBB session (Gordon et al., 2004; Heath & Stuart, 2002). Average HR, peak HR, and the time spent above 55% of HR_{max} were each averaged across class sessions. Only data from completed sessions were included in the averages. For participants who completed all three sessions, the time spent above 55% of HR_{max} was also summed across the three sessions.

Data Analysis

Differences in peak vertical GRF between exercises were assessed in a pairwise manner using paired-samples *t* tests. To control for multiple comparisons (i.e., six *t* tests), differences were considered significant at $p < .01$. An independent-samples *t* test was also used to determine whether the peak GRF during steps differed between participants who wore a weighted vest and those who did not.

Differences between age cohorts in the peak vertical GRF for each exercise and in the measures of physical activity duration and intensity derived from the accelerometer and HR data were assessed using one-way analysis of variance. Effects were considered significant at $p < .05$. All analyses were performed using Predicted Analytic Software (PASW) version 17 (SPSS Inc., Chicago, IL).

Results

There were no differences in body mass or years of BBB participation between age cohorts of participants ($p > .05$), although participants over the age of 80 were significantly shorter than participants of the other two age cohorts ($p < .05$; Table 1). The proportion of participants who performed heel drops instead of jumps was 23%, 29%, and 56% among participants age 60–69, 70–79, and 80–89, respectively.

The peak vertical GRFs during key exercises of the BBB program differed between exercises. Specifically, among those who performed jumps, the peak GRFs elicited by the jumps (2.1 ± 0.5 BW) did not differ from the peak GRFs during stomps (1.9 ± 0.6 BW), $t(23) = 2.35$, $p > .01$, but they were higher than the peak GRFs during steps (1.5 ± 0.2 BW), $t(23) = 6.75$, $p < .01$. Among those performing heel drops, the peak GRFs during the heel drops (1.4 ± 0.3 BW) did not differ from the peak GRFs during steps (1.4 ± 0.3 BW), $t(10) = -0.477$, $p > .01$, or during stomps (1.3 ± 0.5 BW), $p > .05$. For the sample as a whole, peak GRFs did not

Table 1 Demographic Variables by Age Cohort, *M* (*SD*)

Variable	60–69, *n* = 14	70–79, *n* = 13	80–89, *n* = 9	*F*	*df*
Age (years)	65.1 (1.7)	74.2 (3.5)	83.4 (2.1)	134.5	35
Height (cm)	163.3 (5.7)	163.3 (5.5)	155.8 (7.7)	4.9[a]	35
Body mass (kg)	65.8 (14.7)	69.2 (11.5)	62.5 (9.9)	0.817	35
Body-mass index (kg/m^2)	24.5 (1.7)	25.9 (3.9)	25.6 (3.2)	0.445	35
Years in BBB	5.5 (3.7)	9.3 (4.2)	7.7 (4.5)	2.91	35

Note. BBB = Better Bones and Balance.

[a]Participants in the 80- to 89-year range were significantly shorter than those of the other two age cohorts ($p = .02$). There were no differences in body mass or years in BBB between age groups (all $p > .05$).

differ between steps (1.5 ± 0.2 BW) and stomps (1.7 ± 0.5 BW), $t(11) = 0.385$, $p > .01$. There were also no differences in peak GRFs between age cohorts for any of the exercises (all $p > .05$; Figure 1). Finally, the peak GRFs during steps did not differ between those who wore weighted vests during testing and those who did not (1.5 ± 0.2 BW in each set of participants), $t(33) = 0.288$, $p > .05$. Participants spent 42 ± 11 min/session, or 84% ± 21% of total class time, above 55% of HR_{max}.. HR averaged 66% ± 9% of HR_{max} over the course of a session, with a peak of 83% ± 11% of HR_{max}. The time spent above 55% of HR_{max} during a session and during a week did not differ between age cohorts, nor did the peak or average HR (Table 2).

When measured via accelerometers, participants only spent 14 ± 6 min/session, or 29% ± 12% of total class time, in MVPA. The time spent in accelerometer-measured MVPA during a session and during a week did not differ between age cohorts (Table 2).

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 BBB classes. We found that, on average, older women participating in BBB spend approximately 126 ± 32 min/week engaged in exercise where their HR exceed 55% of their predicted HR_{max} and maintain an average HR per session of 66% ± 9% HR_{max}. This level of intensity is considered moderate to vigorous (Gordon et al., 2004; Mazzeo & Tanaka, 2001). Consequently, regular participation in BBB (3 days/week) may provide sufficient weekly activity to fulfill most of the current national guidelines related to the performance of aerobic activity. However, when accelerometry alone was used to assess exercise intensity, this was 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 BBB comprises (lunges, squats, balance activities, upper body resistance training) does not lend them well to assessment via accelerometer. 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 ± 2.9 min 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.

Even though accelerometer-measured MVPA was low, the exercises associated with BBB 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 (Gunter & McNamara, 2010; McNamara & Gunter, 2012). 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. Others have also found that accelerometers underestimate the intensity of exercise among older adults when the traditional 3-MET definition of MVPA is applied (Ayabe et al., 2009; Nelson et al., 2007) and that using cutoffs relative to fitness levels or

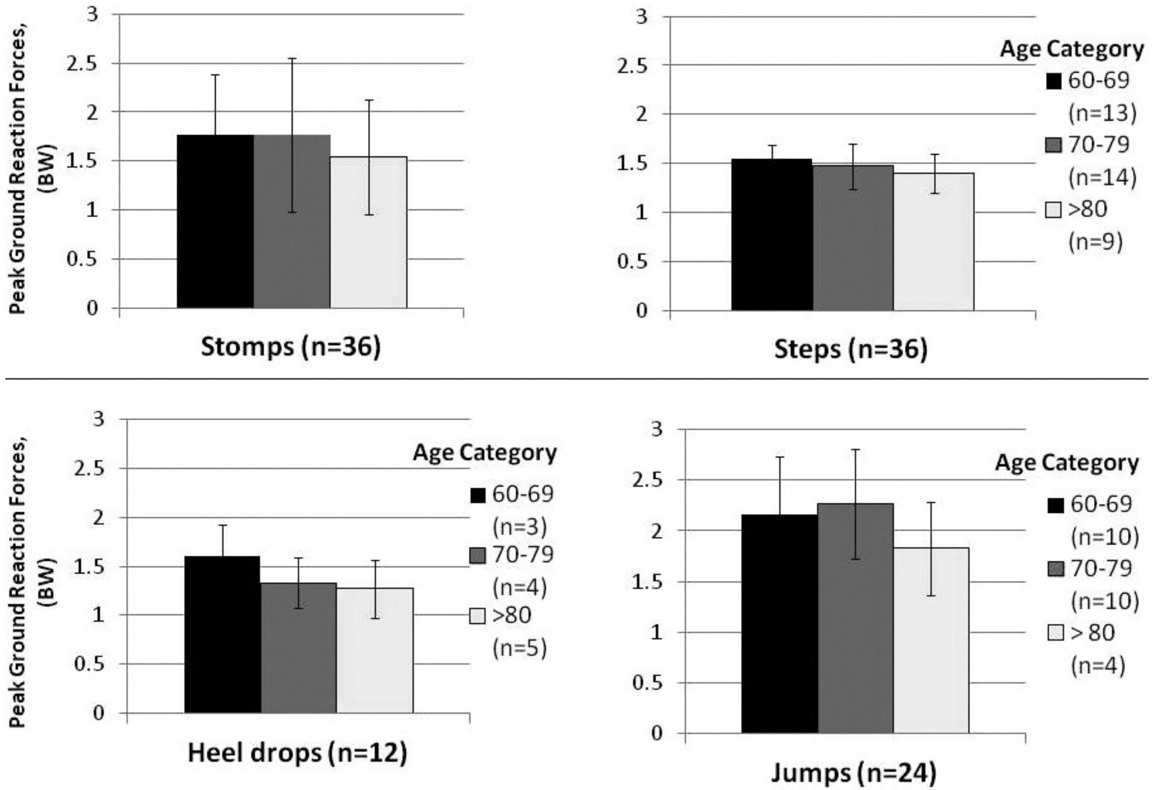

Figure 1 — Peak vertical ground-reaction forces (GRF) for each of the key Better Bones and Balance exercises, stratified by age group. Data represent the forces experienced by a single leg and are expressed as means and standard deviations in units of body weight (BW). There were no differences in peak GRFs between age groups for any of the exercises.

Table 2 Physical Activity Duration and Intensity Stratified by Age Cohort, *M* (*SD*)

Variable	60–69, n = 14	70–79, n = 13	80–89, n = 9	F	η^2	df
Average session HR (% HR_{max})	67.7 (9.4)	61.8 (8.3)	67.9 (7.1)	2.16	.16	1, 35
Peak session HR (% HR_{max})	85.8 (9.8)	78.8 (11.1)	85.0 (11.2)	3.36	.17	1, 35
Time above 55% HR_{max} (min/session)	43.9 (8.7)	38.5 (14.1)	44.8 (5.3)	1.27	.07	1, 35
Accelerometry time in MVPA (min/session)	15.2 (5.5)	14.3 (7.0)	12.9 (7.0)	0.31	.02	1, 35

Note. HR = heart rate; HR_{max} = maximum HR; MVPA = moderate to vigorous physical activity. There were no differences between age groups (all $p > .05$).

individualized walking speeds may be more effective in assessing MVPA (Copeland & Esliger, 2009; Pruitt et al., 2008). Unfortunately adopting such cutoffs may not be a practical field-based assessment protocol for the community-based setting. Our findings suggest the value of using multiple methods of activity monitoring for older populations, particularly when the exercise dose comprises a mixed mode of activity types (impact, aerobic, balance, strengthening). In the BBB setting, we found that HR monitoring gave a clear representation of the overall intensity of the class, while the accelerometers adequately captured the time spent performing a specific type of activity (impact).

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 30 min of moderate aerobic physical activity 5 days/week (or 150 min/week), 20 min of vigorous physical activity 3 days/week, or a comparable combination thereof (Nelson et al., 2007). Based on HR data, it appears that participation in BBB provides an adequate dose of aerobic activity to fulfill most of the recommendations related to cardiovascular fitness, especially as BBB includes both moderate and vigorous physical activity. This finding is corroborated by a related study in our laboratory that found that BBB participation was associated with superior cardiovascular fitness, as measured by the 2-min step test, compared with sedentary age-matched controls (McNamara & Gunter, 2012). This relationship between BBB and cardiovascular fitness was surprising as BBB was designed to target skeletal health, muscle 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 performed in a manner that evokes an aerobic response (i.e., traveling lunges, continuous stepping, walking for warm-up, etc.) sufficient to achieve an appropriate training zone for cardiovascular health. Furthermore, this aerobic stimulus is great enough to elicit peak HRs of nearly 83% of HR_{max}, so that the participants are engaging in not only moderate but also vigorous physical activity during each class. It is also interesting to note that participants in the oldest age cohort (80–89) achieved relative HRs similar to those of 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 of 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.

In regard to bone loading, we found that the exercises in the BBB program provided a GRF equivalent (one leg) of 1.4–2.2 BW. Previous research indicates that the threshold for improving hip bone mineral density is approximately 100 impacts/day with pelvis accelerations exceeding 3.9 times the acceleration of gravity, a measure significantly correlated with GRF ($R = .735$) and associated with jumping exercise (Vainionpaa et al., 2006). We did not measure pelvis acceleration to allow direct comparison with this threshold, but GRF forces of 4–5 BW (two legs) have also been associated with positive changes in adult bone (Uusi-Rasi et al., 2003; Winters & Snow 2000; Young et al., 2007). Therefore, the exercises with the highest impact (i.e., jumps and stomps) may provide sufficient stimulus to achieve skeletal overload. This supposition is supported by a recent report indicating that BBB participants have higher than expected bone mass at the hip (McNamara & Gunter, 2012).

Our results showed that the GRFs associated with the key BBB exercises are in accordance with other reported values from programs that have been successful in promoting bone adaptation. Researchers have reported GRF values associated with jumping of 2.1–5.6 BW (two-leg values) in both postmenopausal and premenopausal women (Uusi-Rasi et al., 2003; Winters & Snow, 2000). Bassey and Ramsdale (1995) found that the mean two-leg GRF for the heel drop was 2.73 BW (range 2.1–3.6) They also compared one-leg versus two-leg forces during the heel drop and found an even distribution of weight across each force plate, indicating the potential to extrapolate one-leg force data to two-leg forces. The women in our study produced one-leg GRFs from jumping ranging from 1.1 to 3.7 BW and an average one-leg GRF from heel drops of 1.4 ± 0.30 BW. When extrapolated to two-leg values, our results are consistent with the forces produced by the women in the aforementioned studies. Furthermore, in the current study, stomping elicited higher forces than expected, with impact forces close to that of jumping. This concurs with data from Weeks and Beck (2008), who also reported stomping impact forces higher than those elicited by heel drops and similar to those of jumping. Furthermore, compliance with stomping during a 12-month exercise intervention has been found to be significantly correlated with hip BMD among postmenopausal women (Young et al., 2007). These data support the recent addition of stomping to the BBB protocol as an exercise with osteogenic potential.

Owing to the popularity of community exercise among older adults, it is particularly beneficial to understand the amount and intensity of exercise provided 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, enabling a full description of the exercise dose achieved though participation in BBB. This is particularly unique due to the community setting of this program. Furthermore, we used multiple methods of physical activity assessment, thereby reducing the influence of potential underestimation of physical activity that can occur when accelerometers alone are used in a population of older adults. An additional strength of this study was the inclusion of a wide sample of ages among participants to better measure any relationship between age and exercise dose.

Our study does have limitations. First, the sample sizes in each age cohort were small, and analyses indicated that observed power to detect differences between groups was low (.16–.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 GRF data for steps with all participants wearing weighted vests to compare with our data on those without vests. We do recognize, however, that this comparison would have been valuable to assess the influence of weighted vests on the impact forces. Furthermore, several of the core exercises included in the BBB program, such as the lunge, squat, and possibly 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. Consequently, we do not know the osteogenic potential of these primarily resistance exercises in comparison with our measured impact exercises. An additional limitation is that we failed to measure the rate of loading associated with the BBB exercises. As faster rates of loading may provide bone stimulus independent of load magnitude, this information would have added to our knowledge of the osteogenic potential of the BBB program. In addition, our sample consisted only of participants who had been engaging in BBB for at least 1 year. Therefore, we do not know whether the exercise dose, particularly HR and bone-loading forces, associated with BBB would differ for participants new to the program. Finally, 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 terms of age and fitness, and each was taught by a separate instructor, so we feel that we captured a representative sample of the typical BBB population.

In conclusion, this study indicates that thrice-weekly participation in BBB delivers an adequate dose of exercise to meet national guidelines to optimize health. Older women are getting sufficient cardiovascular responses in these classes to fulfill the majority of the recommended weekly exercise prescription. Furthermore, 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 viable and sustainable method for achieving adequate physical activity for older adults.

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