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ORIGINAL ARTICLE

Effects of short-term step aerobics exercise on bone metabolism and functional fitness in postmenopausal women with low bone mass

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Abstract
Summary Measurement of bone turnover markers is an alternative way to determine the effects of exercise on bone health. A 10-week group-based step aerobics exercise significantly improved functional fitness in postmenopausal women with low bone mass, and showed a positive trend in reducing resorption activity via bone turnover markers.
Introduction The major goal of this study was to determine the effects of short-term group-based step aerobics (GBSA) exercise on the bone metabolism, bone mineral density (BMD), and functional fitness of postmenopausal women (PMW) with low bone mass.
Methods Forty-eight PMW (aged 58.2 ± 3.5 years) with low bone mass (lumbar spine BMD T-score of −2.00 ± 0.67) were recruited and randomly assigned to an exercise group (EG) or to a control group (CG). Participants from the EG attended a progressive 10-week GBSA exercise at an intensity of 75–85 % of heart rate reserve, 90 min per session, and three sessions per week. Serum bone metabolic markers (C-terminal telopeptide of type 1 collagen [CTX] and osteocalcin), BMD, and functional fitness components were measured before and after the training program. Mixed-models repeated measures method was used to compare differences between the groups ($\alpha = 0.05$).
Results After the 10-week intervention period, there was no significant exercise program by time interaction for CTX; however, the percent change for CTX was significantly different between the groups (EG = −13.1 ± 24.4 % vs. CG = 11.0 ± 51.5 %, $P < 0.05$). While there was no significant change of osteocalcin in both groups. As expected, there was no significant change of BMD in both groups. In addition, the functional fitness components in the EG were significantly improved, as demonstrated by substantial enhancement in both lower- and upper-limb muscular strength and cardiovascular endurance ($P < 0.05$).
Conclusion The current short-term GBSA exercise benefited to bone metabolism and general health by significantly reduced bone resorption activity and improved functional fitness in PMW with low bone mass. This suggested GBSA could be adopted as a form of group-based exercise for senior community.

Keywords Bone turnover markers · Group-based exercise · Menopause · Osteopenia

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Introduction

Menopause is casually associated with the incidence of several chronic diseases, including osteoporosis, cardiovascular disease, and obesity [1]. It is anticipated that over 50 % of global osteoporotic hip fractures will occur in Asia by 2050 [2]. In Taiwan, the prevalence of osteoporosis in postmenopausal women (PMW) was found to be 18.5–21.0 % during the years 2005–2008 [3], when bone mineral density (BMD) T-scores of −2.5 or lower for women aged ≥60 years and ≥70 years were determined to be 50 and 63 %, respectively. Furthermore, the costs associated with osteoporosis-related fractures account for 11.4 % of the national health insurance claims in Taiwan [4].

According to the position stand on bone health and physical activity of the American College of Sports Medicine (ACSM), moderate-to-high intensity, weight-bearing endurance activities are recommended to help preserve or to increase bone mass in adults [5]. Compared to other types of endurance exercise (e.g., running or cycling), step aerobics (SA) is relatively easy to manage in terms of space and facility requirements. With respect to fitness levels, SA training programs can be easily adjusted to suit an individual's safety needs [6]. In addition, previous studies have demonstrated that low-cost, group-based physical activity interventions effectively enhance exercise adherence and promote greater personal satisfaction [7, 8]. The current understanding of the effects of SA exercises on bone health in PMW with low bone mass is rather limited. Exercise programs that incorporate SA (two to three times per week) have been shown to improve or to preserve the maintenance of BMD [9–11]. Chien et al. discovered that the femoral neck BMD of PMW increased by 6.8 % after the participants performed a 30-min treadmill-walking exercise at 70 % VO_2max followed by a 10-min stepping exercise (bench height of 20 cm) for 24 weeks, while the BMD of the control group decreased by 1.5 % [10]. Bravo et al. found that the spinal BMD, rather than the femoral BMD, was effectively maintained in PMW with low bone mass who participated in flexibility and weight-bearing exercises (walking, stepping, and aerobic dance) for 12 months (60 min each session, three times per week) [9, 11]. Welsh and Rutherford demonstrated that the femoral neck BMD in the study's exercise group was significantly improved (1.57 %) compared to that of the control group (−1.9 %) after a 12-month period (two to three times per week) of high-impact exercise (step and jumping) intervention [11].

Bone remodeling is a dynamic process. Osteoblasts (formation modeling) and osteoclasts (resorption modeling) are the two cell types responsible for bone metabolism, and interactions between the two types reflect the maintenance of the bone integrity. Bone remodeling involves sequential osteoclast-mediated bone resorption and osteoblast-mediated bone formation at the same location. The process of remodeling can be divided into five phases: activation, resorption, reversal, formation, and quiescence. However, the duration of a remodeling cycle is not evenly divided between resorption and formation. During the primary mineralization period, the initial incorporation of calcium and phosphate ions into the collagen matrix occurs rapidly over 2–3 weeks and accounts for roughly 70 % of the final mineral content. Osteoclasts typically resorb bone for 3–6 weeks (at a specific site), with the remainder of the cycle comprising bone formation; a complete mineralization process requires 5–9 weeks. Thus, a complete cycle of bone remodeling in humans takes 4–6 months (for details, please review [12]). Therefore, the duration of an intervention is critical in determining the chosen measured variables related to bone metabolism.

There is a close relationship between metabolic bone markers and BMD; for example, osteocalcin is significantly correlated with BMD in PMW with osteoporosis [13]. Among the metabolic bone markers, C-terminal telopeptide of type 1 collagen (CTX) is shown to be more sensitive and more specific to bone resorption than other conventional measurements, such as urinary hydroxyproline and urinary calcium excretion [14]. Besides, bone turnover markers can be indirectly used to detect or to monitor the early responses of the skeleton to weight-bearing exercise [15, 16]. Previously, the up- and downregulation of bone formation and resorption markers have been preliminarily used to detect bone metabolic activity in PMW after exercise intervention [17]. Poor functional fitness is also well-known to be associated with falls and fracture risk [18, 19]. In addition to densitometer and bone turnover makers, functional fitness can be another critical factor in bone health [20]. In other words, the benefits of exercise intervention on bone health can be alternatively indicated by a number of methods other than densitometry. We hypothesized that at the early stage of stimulation/exercise, the direction of bone turnover can be detected by a significant change in the bone metabolic markers, whereas the BMD did not show a significant change because a complete bone mineralization required a longer time to complete the bone remodeling cycle. Therefore, the major goal of the current study was to investigate the effects of short-term (10-week) SA exercise on serum bone turnover markers, BMD, and functional fitness components.

Methods and materials

Participants

A total of 48 qualified PMW (age = 58.2 ± 3.4 years, BMI = 21.97 ± 2.48 kg/m^2, postmenopausal year = 7.50 ± 4.08 years) with low bone mass based on lumbar spine BMD (T-score = −2.00 ± 0.67) were recruited from Hualien County, Taiwan. Participants were excluded if they had taken certain medications, such as bisphosphonates, raloxifene, hormone replacement, or glucocorticoids, during the study period or within 12 months prior to the baseline, due to the potential effects of these agents on bone metabolism. In total, 46 PMW completed this experimental study. All participants were asked to complete Health Status and Activity of Daily Living questionnaires. The procedures and protocol used in this study were approved by the Institutional Review Boards at National Dung Hwa University and National Taiwan Sport University (Document No. 10019). A written informed consent was obtained from each participant.

Experimental design

In this intervention study, the participants were age-matched randomly assigned to an exercise group (EG, $n = 24$) or to a control group (CG, $n = 24$). Participants in the EG attended a 10-week SA exercise program designed especially for this study. All participants were instructed to maintain their normal dietary intake and lifestyles and were required to refrain from participating in any other routine physical activity or exercise during the study period. Measurements of body composition, functional fitness, and bone densitometry were conducted before and after the 10-week experimental period. The demographic characteristics of the participants in the EG and CG groups are presented in Table 1.

Exercise program

A GBSA exercise was designed and introduced in this study. The advantages of a GBSA include enhanced compliance to the exercise program and social support from peers [21]. The GBSA exercise, which was led by a certified SA instructor, featured a moderate-to-high intensity level and was conducted three times per week (Mondays, Wednesdays, and Fridays from 8:30 to 10:00 a.m.) for 10 weeks. The 90-min GBSA exercise session consisted of the following: (1) a 10–15 min warm-up session consisting of stretching exercises for the major muscles, (2) SA exercise to reach the target heart rate (HR) within the first 5–10 min and to maintain it for another 30–35 min, (3) a 10–15 min balance and cool-down session, and (4) a 10–15 min stretching and relaxation session. The SA choreography included the conventional basic step, the "V" step, the "L" step to both the right and left sides, alternating step knee-lift sequences, and alternating leg-curl, side-leg, and leg-back patterns. Arm movements, such as bicep curls and lateral raises at shoulder level and above the head, were incorporated simultaneously with the selected steps. During all the sessions, exercises were accompanied by appropriate music set at a tempo of 120–126 beats per min. The exercise intensity of the participants was monitored at 5-s intervals using a telemetry HR monitor (S810, Polar, Kempele, Finland). Participants were instructed to set the training target zone at the range of 75–85 % of their heart rate reserve and to monitor their HR to determine whether they had reached their target HR zone during the GBSA exercise. When the HR dropped below the target HR zone, participants expanded their movement or increased their step height to ensure that they reached their target HR. The height of the step was initially set at 10 cm and subsequently elevated when the training HR was no longer in the target zone. By the end of the training programs, the step height was elevated to 20–25 cm, at which the mean vertical impact force was reported to range from 1.54 to 1.87 × body weight [22, 23]. The average up- and down-step routine during each SA exercise (40–45 min) was 1280–1440 cycles. The training protocol was designed in accordance with the guidelines recommended by ACSM [24].

Estimation of total energy expenditure

A 7-day physical activity recall questionnaire [25] was used to estimate each participant's energy expenditure during regular, daily lifestyle activities. A well-trained interviewer

Table 1 Demographic characteristics of participants

Variables	EG ($n = 24$)	CG ($n = 22$)	P value
Age (years)	57.5 ± 3.5	58.8 ± 3.2	0.195
Height (cm)	155.0 ± 4.5	155.8 ± 3.6	0.496
Weight (kg)	52.0 ± 6.4	54.2 ± 5.8	0.230
BMI (kg/m^2)	21.69 ± 2.94	22.27 ± 1.89	0.425
Age of first period (year)	13.8 ± 1.8	14.3 ± 1.2	0.241
Menopause age (year)	50.2 ± 3.2	49.3 ± 2.7	0.184
Attendance rate (%)	96.73 ± 0.94	N/A	
Bone health status			
Lumbar spine BMD (T-score)	−2.15 ± 0.67	−1.85 ± 0.64	0.108
osteopenia	70.8 % ($n = 17$)	81.8 % ($n = 18$)	
osteoporosis	29.1 % ($n = 7$)	18.2 % ($n = 4$)	

Note: Values are presented as mean and SD administered the 7-day recall physical activity questionnaires and interviewed the participants.

Functional fitness test

For PMW (aged 50–65 years), normal functional fitness is defined as having the physical ability to perform activities safely and independently [26]. Thus, the measurement of functional fitness components in the current study included the back scratch, chair stand, sit-and-reach, 8-foot up-and-go, arm curl, and 2-minute step test. For the details of the functional fitness testing, please refer to the Senior Fitness Test Manual [27].

Serum biochemical markers assays

To minimize circadian variations, all overnight fasting blood samples were obtained in the morning between the hours of 7:00 a.m. and 9:00 a.m., 2 days before and 2 days after the 10-week intervention period. Blood samples were allowed to stand at room temperature (20–30 min) for clotting and were centrifuged under 4 °C at 1500 rpm for 30 min. Subsequently, serum samples were aliquoted and stored at −80 °C for further serum biochemical markers assay. Serum levels of total cholesterol, triglycerides (TG), and high-density lipoprotein (HDL) cholesterol were determined using commercially available enzymatic assay kits (Wako Pure Chemical, Osaka, Japan). Serum osteocalcin and CTX levels were used for estimating bone formation and bone resorption activities. Enzyme-linked immunosorbent assay (ELISA) kits were used to determine serum osteocalcin and CTX (Immunodiagnostic Systems Inc., Scottsdale, AZ, USA). The intra-assay coefficients of variation for osteocalcin and CTX were 2.0 and 5.0 %, respectively.

Bone densitometry and body composition

Total and regional body compositions were assessed using dual-energy X-ray absorptiometry (DXA; Hologic Series Discovery QDR, Software Physician's Viewer, APEX System Software Version 3.1.2, Bedford, MA, USA). Measurements, including total body fat percentage, BMD, bone mineral content (BMC) of the whole body, and total hip, were obtained before and after the 10-week GBSA intervention. Lumbar spine was scanned at the pre-test as one of the criteria for participant recruitment; T-score < −1.0. All analyses were performed by a trained technician. Scanning instructions and procedures were standardized for all participants. The accuracy of the densitometer was calibrated using the manufacturer's spine phantom with a known hydroxyapatite density [28].

Statistical analysis

Data were analyzed using an SPSS software package (version 18.0). All data were checked for normality and homogeneity of variance before the statistical analysis was carried out. The results of all data were presented as means ±standard deviation (SD). A mixed-model repeated measures procedure was used to analyze the differences between the groups and the changes over time. The percentage change within an individual was calculated as follows:

$$\text{Percentage change } (\%) = 100\%\text{x } [(\text{post-test})\text{-}(\text{pre-test})]/(\text{pre-test})$$

An independent t test ($\alpha = 0.05$) was used to analyze the baseline measurements and percentage changes in various indices between members of the EG and CG. All statistical differences of $P < 0.05$ were considered significant.

Results

There was no significant difference in participants' characteristic between the EG and the CG. Two participants of the CG dropped out for personal reasons. No adverse events occurred during the 10-week experimental period. The attendance rates of the participants in EG who completed the GBSA exercise were high (96.7 ± 0.9 %). The estimated energy expenditure of the EG was increased about 41 % during the intervention period. The percentage change in the estimated energy expenditure of the EG was significantly higher than that of the CG ($P < 0.001$) (Table 2).

Body composition, lipid profile, and functional fitness components

Table 3 shows the results of body composition, lipid profile, and functional fitness components at pre- and post-10-week GBSA training among the PMW with low bone mass. The results indicated that there were no significant changes in body weight, BMI, and lipid profiles in either group after the intervention period. However, there was a significant interaction between the exercise program and the time on body fat percentage, $F_{(1,44)} = 5.38$, $P < 0.025$. The body fat percentage of the EG was significantly reduced at the end of the 10-week GBSA training, while that of the CG was significantly increased. In terms of the functional fitness components, there was a significant interaction between

Table 2 The estimated energy expenditure of the participants

Variables	EG (n = 24)	CG (n = 22)	P value
	Pre-intervention		
Total energy (kcal/day)	1122 ± 276	1198 ± 243	0.700
Energy per body weight (kcal/kg/day)	21.7 ± 4.6	21.9 ± 4.7	0.317
	Intervention period		
Total energy (kcal/day)	1575 ± 345[a]	1193 ± 242[b]	<0.001
Energy per body weight (kcal/kg/day)	30.5 ± 6.2[a]	21.8 ± 4.7[b]	<0.001

Note: Values are presented as mean and SD

[a] Significant difference between pre-test and post-test values within group

[b] Significant difference between CG and EG

the exercise program and the time on all measured functional fitness components other than the back scratch. These include a significant improvement in the chair stand, arm curl, 8-foot up-and-go, sit-and-reach, and 2-minute step in the EG ($P < 0.05$), whereas the changes in the CG were not significant (Table 3).

Table 3 Body composition, lipid profile, and functional fitness for the pre- and post-tests

Variables	Group	Pre-test	Post-test	Percentage change within group (%)	Wilks' Lamda (Λ) (group × time) P value
			Body composition		
Weight (kg)	EG	52.0 ± 6.4	51.6 ± 6.6	−0.7 ± 1.5	0.094
	CG	54.2 ± 5.8	54.3 ± 5.8	0.2 ± 1.8	
BMI (kg/m^2)	EG	21.69 ± 2.94	21.62 ± 3.00	−0.3 ± 2.6	0.681
	CG	22.27 ± 1.89	22.27 ± 1.85	0.1 ± 2.1	
Total body fat (%)	EG	34.60 ± 5.65	33.98 ± 5.71[a]	−0.3 ± 10.7	0.025
	CG	34.31 ± 3.75	35.05 ± 3.32[a]	2.4 ± 4.8	
			Lipid profile		
Total cholesterol (mg/dl)	EG	215 ± 39	206 ± 45	−3.9 ± 15.9	0.361
	CG	220 ± 29	218 ± 25	−0.2 ± 9.0	
TG (mg/dl)	EG	121 ± 48	115 ± 59	0.9 ± 45.8	0.864
	CG	108 ± 47	105 ± 62	−2.9 ± 26.2	
HDL (mg/dl)	EG	64 ± 11	62 ± 12	−1.7 ± 10.7	0.483
	CG	63 ± 12	60 ± 11	−3.5 ± 12.4	
LDL (mg/dl)	EG	113 ± 27	110 ± 28	−1.8 ± 10.8	0.805
	CG	120 ± 21	116 ± 18	−3.3 ± 9.6	
			Functional fitness components		
Chair stand (reps)	EG	19.1 ± 4.8	28.1 ± 5.8[a]	53.4 ± 37.2[b]	<0.001
	CG	21.8 ± 4.7	23.6 ± 4.8	9.5 ± 17.9	
Sit-and-reach (cm)	EG	26.6 ± 9.4	36.2 ± 8.6[a]	30.7 ± 23.8	0.022
	CG	30.5 ± 8.6	30.7 ± 8.2	4.2 ± 25.4	
Back scratch (cm)	EG	0.1 ± 5.2	1.5 ± 7.1	−16.8 ± 23.8	0.092
	CG	4.2 ± 6.2	3.4 ± 5.9	−4.5 ± 39.2	
8-ft up-and-go (sec)	EG	5.08 ± 0.79	4.77 ± 0.59[a]	−5.1 ± 11.0	0.037
	CG	4.96 ± 0.51	5.02 ± 0.63	1.6 ± 11.7	
Arm curl (reps)	EG	16.3 ± 4.8	23.3 ± 6.0[a]	46.8 ± 30.4[b]	<0.001
	CG	19.8 ± 4.2	22.0 ± 2.9	15.2 ± 25.2	
2-min step (reps)	EG	88.1 ± 15.2	115.4 ± 17.1[a]	35.2 ± 32.1[b]	<0.001
	CG	80.6 ± 12.2	86.3 ± 13.2	2.8 ± 10.6	

Note: Values are presented as mean and SD

TG triglycerides, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein

[a] Significant difference between pre-test and post-test values within group;

[b] Significant difference between CG and EG

Bone densitometry and serum bone metabolic markers

Table 4 shows the results of the bone densitometric measurements, both the EG and the CG participants showed no significant changes in BMD after the 10-week of GBSA exercise. The results showed there was no significant changes in osteocalcin levels after the 10-week of GBSA exercise. Similarly, there was also no significant exercise program by time interaction for CTX (Table 5); however, the percent change for CTX was different between the groups (EG = −13.1 ± 24.4 vs. CG = 11.0 ± 51.5 %, $P < 0.05$) while there was no significant difference in the changes of osteocalcin between EG and CG (EG = 53.3 ± 114.8 vs. CG = 19.8 ± 63.1 %, $P > 0.05$).

Discussion

In this study, we analyzed the effects of GBSA on BMD, bone turnover markers, and the functional fitness of PMW with low bone mass. Our findings highlight the fact that a relatively short-term (10-week) intervention period of GBSA exercise resulted in significant positive effects on overall functional fitness components by serving as a protective factor for falls and fracture risks. With respect to bone turnover markers, the 10-week GBSA elicited a trend of downregulating bone resorption activity; this may benefit for bone formation and bone health.

GBSA efficiency

The duration of the training period and the ground reaction force seem to be critical factors in maximizing the benefit of exercise on the BMD of PMW. Studies using training periods over 6 months consistently revealed increases in BMD [5, 29, 30]. Theoretically, the duration of the human bone-remodeling cycle takes about 4–6 months, and the durations of resorption and formation are not evenly divided. The osteoclastic resorption activity (at a specific site) accounted for 3–6 weeks, followed by osteoblast-mediated bone formation, which accounted for 5–9 weeks. Hence, a 10-week exercise program is more feasible than a long-term exercise program (e.g., 20–30 weeks) to investigate bone turnover markers rather than bone mineral accumulation. Therefore, the 10-week GBSA exercise used in the current study showed no significant alterations in BMD accretion; this finding is consistent with the typical period of time required for a complete bone-remodeling cycle, while the following secondary mineralization and maturation of mineral crystals occur over a much longer time frame [12]. However, based on the concept of bone metabolism, bone health can be estimated via biochemical markers of bone turnover other than densitometric indices. The determinants of bone quality include its microarchitecture, degree of mineralization, accumulated microdamage, and collagen cross-link formation [31]. Cross-linking is a major post-translational modification of collagen [32].

The results of previous studies on bone turnover and exercise have been inconsistent [33, 34]. In a study of mice, exercise caused a quick reduction in bone turnover, as there were significant negative effects on serum CTX. Similar results were demonstrated by Klentrou et al.'s study. After 12 weeks of exercise, the serum of bone resorption, N-telopeptide of type I collagen (NTx), decreased by 14.5 % in the EG, while there were no significant changes in the osteocalcin levels of PMW

Table 4 Bone densitometry for the pre- and post-tests

Variables	Group	Pre-test	Post-test	Percent change within group (%)	Wilks' Lamda (Λ) (group × time) *P* value
Total BMC (g)	EG	1456 ± 201	1477 ± 211	1.4 ± 4.7	0.111
	CG	1563 ± 213	1557 ± 210	−0.4 ± 1.7	
Total BA (cm^2)	EG	1588 ± 120	1603 ± 120	1.0 ± 2.2	0.138
	CG	1646 ± 134	1646 ± 128	0.1 ± 1.9	
Total BMD (g/cm^2)	EG	0.91 ± 0.08	0.92 ± 0.09	0.4 ± 3.8	0.402
	CG	0.95 ± 0.08	0.94 ± 0.08	−0.4 ± 1.6	
Total hip BMC (g)	EG	20.72 ± 2.96	21.85 ± 3.34	6.2 ± 15.5	0.291
	CG	22.58 ± 3.81	23.08 ± 3.93	2.2 ± 4.7	
Total hip BA (cm^2)	EG	28.76 ± 3.00	29.56 ± 3.27	3.1 ± 9.9	0.676
	CG	29.58 ± 2.45	30.14 ± 2.39	2.0 ± 3.0	
Total hip BMD (g/cm^2)	EG	0.72 ± 0.07	0.74 ± 0.08	3.0 ± 7.5	0.074
	CG	0.76 ± 0.09	0.76 ± 0.08	−0.1 ± 3.1	

Note: Values are presented as mean and SD

BMD bone mineral density, *BMC* bone mineral content, *BA* bone area

Table 5 Bone turnover rate for the pre- and post-tests

Variables	Group	Pre-test	Post-test	Percent change within group (%)	Wilks' Lamda (Λ) (group × time) *P* value
Osteocalcin (nmol/l)	EG	15.11 ± 8.16	17.85 ± 7.99	53.3 ± 114.8	0.558
	CG	21.58 ± 7.97	22.86 ± 7.44	19.8 ± 63.1	
CTX (nmol/l)	EG	0.69 ± 0.26	0.57 ± 0.19	−13.1 ± 24.4[a]	0.118
	CG	0.89 ± 0.48	0.94 ± 0.64	11.0 ± 51.5	
Osteocalcin / CTX ratio	EG	24.39 ± 13.93	32.79 ± 13.88	100.4 ± 226.3	0.070
	CG	30.25 ± 18.64	29.91 ± 13.72	19.5 ± 70.8	

Note: Values are presented as mean and SD

[a] Significant difference between CG and EG

[34]. Similarly, in the current study, the changes in the serum CTX levels were significantly different between groups after a 10-week GBSA exercise; the EG showed a trend in downregulating bone resorption activity, which was reflected by a reduction of CTX. This is positively benefited to bone formation.

One previous study demonstrated that a 24-week SA exercise program improved BMD [10]. However, the current study showed no significant alteration in BMD, and the marker of bone resorption, the serum CTX level, was in a declining trend after the 10-week GBSA exercise, suggesting that short-term GBSA exercise may likely be effective in preventing bone loss and in enhancing bone formation. Similar results were also obtained by Roghani et al. [17], who found increases in bone-specific alkaline phosphatase and decreases in NTx after a 6-week, moderate-intensity (50–60 % HRR) aerobic (walking on a treadmill) exercise in PMW with osteoporosis. However, the findings of Phoosuwan et al. [35] were inconsistent with those of Roghani et al. The study showed reductions in both NTx and bone-specific alkaline phosphatase after a 12-week, weight-bearing yoga training program. These mixed downregulations of bone turnover might be due to disparities in exercise mode and intensity. Nevertheless, various short-term programs of exercise consistently demonstrated benefits in reducing bone resorption activity. Study by Zhao also indicated that the femoral neck BMD was negatively correlated with the CTX level in healthy adults aged 52–71 years [36]. We speculate that the trend of decreased CTX levels after the 10-week GBSA would increase the BMD if the duration of the exercise intervention is extended.

The implications of enhanced functional fitness on bone health

In the current study, the progressive GBSA exercise at an intensity of 75–85 % HRR was chosen to prevent the possibility of injuries. The moderate-to-high intensity of weight-bearing exercise training has been shown to benefit hip bone mass and bone turnover [37]. In terms of healthcare and wellness, poor physical functionality is well-known to be associated with falls and fracture risk [18, 19, 38]. The prevalence of falls among the elderly is closely associated with weaknesses of the lower extremities, imbalance, or poor gait; therefore, the functional fitness measurements in this study should not be treated as subsidiary data. As osteogenic response saturates during prolonged loading and more physical activity sessions, improvement of functional fitness would indirectly increase the mechanical loads imposed by daily physical activity and habitual muscle contractions. These can positively influence the size and internal structure of the bone [39]. In Taiwan, approximately 30 % of people over 65 years of age fall each year. Moreover, PMW suffer a higher rate of fall-related fractures, which are closely associated with impairments in balance and muscular strength, combined with osteopenia or osteoporosis [40]. Falls are responsible for about 90 % of the bone fractures occurring in older women during the years 2005–2008 [3], and osteoporosis-related fractures caused a burden of 11.4 % of Taiwan's national health insurance claims [4]. An intervention study of group-based exercise programs revealed that participants experienced a reduced the rate of falls and risks of falling [41]. The 10-week GBSA exercise implemented in the current study also significantly improved functional fitness components, such as the strength of both lower extremities (chair stand) and of the upper body (arm curl), agility/dynamic balance (8-foot up-and-go), and cardiovascular endurance (2-minute step), which serve as protective factors for falls and related fractures. In other words, a short-term GBSA exercise is beneficial and has the potential to reduce the risk of falling before it ultimately benefits bone mass accretion and enhances bone strength.

Other advantages of a step aerobics exercise program

Research indicates that a group-based exercise program is able to create social interaction in the exercise atmosphere [42] and to gain support from peers, which enhances an individual's engagement in physical activity [21]. Characterized by rhythmical movements on a step, GBSA is performed to cadenced musical arrangements and is easy to learn. The intensity of

GBSA can be adjusted easily and does not require special equipment, thereby accommodating the needs of an aging population [6]. Numerous studies have indicated that GBSA training can be a low-cost intervention and an effective strategy for improving functional fitness, sleep quality, and cardiovascular health, as well as for enhancing exercise adherence and promoting greater satisfaction, quality of life, and physical function in healthy older women [6–8]. Compared to resistance training and running on a treadmill, SA exercises more easily meet requirements in terms of facilities, space, and training protocols. Moreover, the protocols and intensity of SA exercise programs can be simply modified to suit the target group. Especially for senior participants, factors such as step height and step cadence can be easily adjusted to suit the individual's ability. In our study, the participants were members of senior citizen education programs sponsored by the Ministry of Education in Taiwan. As suggested in previous studies, health-knowledge enhancement and strong social support are important determinants that are known to be helpful in achieving compliance and participation [42]. The attendance and compliance of the participants in this study were also potentially enhanced by the "schoolmate" relationship. The population of individuals over 65 years old in Taiwan approximated 12.0 % in 2014 [43], and the burden of yearly healthcare-related costs continues to rise, especially the fees associated with acute medical care. In order to reduce the national expenditures for medical care, the Taiwanese government has implemented various policies, such as senior-targeted programs in the education system, to improve senior citizens' functional physical fitness and independency and to reduce fall risk. These senior citizen education programs, which are conducted in universities, play a comprehensive role in fostering social interaction and in providing health-related knowledge as well as high-quality personnel and resources. The current findings suggest that group-based exercise programs are a useful tool for promoting general health and functional fitness in the senior population.

Limitations

Our study had some limits that need to be mentioned. First, the present study did not determine the calcium status of the participants, a factor which may influence bone metabolism. During the experimental period, we instructed the participants to maintain their normal dietary intake and daily activity but did not monitor their calcium dietary intake. Additionally, this was a short-term intervention study that focused mainly on the changes of bone metabolic markers; outcomes within a time frame close to the complete bone remodeling cycle were not examined. After the 10-week GBSA exercise, there was a reduction in the marker of bone resorption, which benefits bone formation; however, there were no significant changes in BMD accretion. In future studies, experiments should be extended to a time frame similar to that of the complete bone remodeling cycle and thus potentially gain more information on bone status. Others markers, such as sclerostin, which is a protein secreted by osteocytes that acts as an inhibitor of bone formation [44], could be examined in the future. This may provide stronger evidence to support the positive effects of GBSA on bone health and formation.

Conclusions

The current study has demonstrated that a short-term (10-week) GBSA exercise may benefit bone metabolism and general health by down-regulating bone resorption activity and significantly improving functional fitness in PMW with osteopenia or osteoporosis. The GBSA exercise used in this study could be considered a model for creating a group-based exercise activity for senior citizen education programs, particularly for those used by the PMW population. Future studies to compare the efficiency of group-based exercise and individual training programs with regard to multiple issues, such as compliance, cost-effectiveness of the program, and the benefits to quality of life and well-being, would be valuable.

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Compliance with ethical standards

Conflicts of interest None.

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