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Effects of Exercise Training With Weighted Vests on Bone Turnover and Isokinetic Strength in Postmenopausal Women

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The effects of 12 wk of exercise training using weighted vests on bone turnover and isokinetic strength were evaluated in postmenopausal women randomly assigned as exercisers (EX; $n = 9$) or controls (CON; $n = 7$). Training included 3 multimodal exercise sessions per wk wearing weighted vests. The vest load was progressively increased each wk to a maximum of 15% of body weight. Bone turnover was determined from resting levels of serum osteocalcin and NTx. Knee and ankle strength were measured at 60°/s and 180°/s using an isokinetic dynamometer. After 12 wk, NTx decreased by 14.5% ($P \leq .05$) in EX, with no significant changes in osteocalcin. EX also showed a 40% ($P \leq .05$) improvement in ankle plantar-flexion strength at 60°/s. Relative body fat significantly decreased and fat-free mass increased in EX. Exercise compliance was 80%. These findings support the use of progressive exercise training using weighted vests in postmenopausal women.

Key Words: cross-linked N-telopeptides, osteocalcin, peak torque, exercise compliance

Osteoporosis is a disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk. Bone homeostasis depends on a balanced biochemical and mechanical environment. Bone is continually being broken down by osteoclasts and formed by osteoblasts throughout life. Bone loss can occur when the rate of resorption exceeds that of formation. In addition, a high rate of bone turnover might be associated with an increased rate of bone loss in postmenopausal women (Eastell, 1998), which appears to adversely influence bone-mineral density and fracture risk (Melton, Khosla, Atkinson, O'Fallon, & Riggs, 1997).

Markers of bone turnover have been examined to provide a better understanding of the dynamic course of bone remodeling. Biochemical markers are derived from both cortical and trabecular bone (Watts, 1999). Although these markers are relatively new and have certain limitations, they are descriptive of the dynamic

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nature of bone (Creighton, Morgan, Boardley, & Brolinson, 2001). Furthermore, assessing bone turnover using serum or urinary biomarkers is advantageous over standard approaches, in that they are considered inexpensive, reflect turnover in the entire skeleton, allow repeated evaluations when necessary, and are highly sensitive (Delmas & Garnero, 1998; Eastell, 1998; Ingle, Fysh, Chapman, Claxton, & Eastell, 1998; Watts, 1999). Thus, their use is important in longitudinal intervention studies, in which acute changes in bone turnover might not be completely explicit and changes might occur over a short period of time (Watts). Among these markers of bone turnover, osteocalcin and cross-linked N-telopeptides of Type I collagen are bona fide markers of bone formation and resorption, respectively, and therefore provide a representation of metabolic changes in bone (Eastell et al., 2000). Biochemical markers of bone turnover can also provide useful clinical information about future changes in bone mass in postmenopausal women (Chaki et al., 2000; Iwamoto, Takeda, Sato, & Uzawa, 2004). They can also be useful in determining the osteogenic stimulus of various conditions of skeletal loading, that is, loading associated with different exercise programs; it has been demonstrated that the mechanism for the positive response of bone mass to moderate walking exercise in postmenopausal women with osteopenia or osteoporosis is the suppression of bone turnover and that a change in N-telopeptides as early as 3 months might be a useful predictor of the long-term response of bone mass to exercise (Yamazaki, Ichimura, Iwamoto, Takeda, & Toyama, 2004). Although in some studies weight-bearing exercise decreased serum osteocalcin (Dalsky et al., 1998), other studies have reported that combined aerobic and anaerobic exercise increased serum osteocalcin and that brisk walking did not significantly affect bone markers (Brooke-Wavell, Hardman, Tsuritani, & Yamada, 2001; Danz et al., 1998). Thus, the effect of exercise training on markers of bone turnover, especially serum, in postmenopausal women is not yet fully established.

Women have been shown to fall more often than men (Wilkins, 1999), with the incidence of fracture in women being twice that of men, likely as a result of postmenopausal bone loss (Donaldson, Cook, & Thomson, 1990). Strength deficits in the hip, knee, and ankle increase the risk of falling (Lord, Ward, Williams, & Anstey, 1994). Several randomized clinical trials have demonstrated that regular physical activity can improve muscle strength in older women (Campbell et al., 1997; McCartney, Hicks, Martin, & Webber, 1995; Takeshima et al., 2002). Exercise training with weighted vests has been shown to improve both bone-mineral density and muscle strength in postmenopausal women (Jessup, Horne, Vishen & Wheeler, 2003; Shaw & Snow, 1998; Snow, Shaw, Winters, & Witzke, 2000). Shaw and Snow have also demonstrated that a 9-month regimen of lower body exercise using a weighted vest increased isokinetic strength in women age 50–75 years. It is unclear, however, whether similar gains can be demonstrated with a shorter multimodal exercise regimen, and the effects of such a program on bone turnover have not been investigated. In fact, Jessup et al., who found significant improvements in bone-mineral density after 32 weeks of exercise training with weighted vests in older women, specifically recommended that future research using weighted vests in this population should focus on examining changes in the biochemical markers of bone turnover.

The overall objective of this study was to determine whether 12 weeks of progressive exercise training using a weighted vest would be of sufficient duration to offset the rate of bone turnover observed postmenopause. To this end, a progressive multimodal exercise-training program using a weighted vest was designed, and the changes in serum markers of bone turnover and isokinetic strength were examined in postmenopausal women before and after 12 weeks of training. The intention was to design an exercise-training program of progressive resistance that would be easily adaptable and diverse enough to be appealing to a large number of postmenopausal women. The specific objectives included examining potential changes in resting values of serum markers of bone turnover, determining the magnitude of change in ankle and knee peak flexion and extension torque at speeds of 60°/s and 180°/s, and evaluating the compliance of this group of postmenopausal women to the multimodal exercise training. It was hypothesized that progressive exercise training with a weighted vest would elicit significant improvements in serum levels of bone biomarkers and ankle and knee strength.

Methodology

Participants

This study and all related procedures received ethical clearance from the Brock University Research Ethics Board. Eighteen women age 44–62 years initially agreed to participate in this study and gave informed consent after having been informed about its possible risks and benefits. Only postmenopausal women (no menses for more than 1 year) with no resistance-training background, asthma, cardiovascular disease, or musculoskeletal disorders and not on any medication affecting bone-mineral status, such as bisphosphanates and hormone-replacement therapy, were invited to participate. All the participants were nonsurgically menopausal. Participants were randomly assigned to one of two groups: exercise (EX) and control (CON). The intent was to recruit an equal number of participants per group; however, some women originally recruited did not agree to participate, and 2 of the 18 women who agreed to participate and were assigned to CON decided to withdraw from the study immediately after the original assessment for reasons unrelated to the study. By the beginning of the intervention program, 9 women made up the exercise group, and 7 women remained in the control group. There were no differences between the groups in terms of the number of years of postmenopausal status.

Exercise Protocol

Participants in EX participated in a 12-week, supervised, multimodal training program wearing weighted vests. The program consisted of three supervised 65-min sessions weekly in a class setting. Each of these sessions was structured in the following manner: 5 min of warm-up, 20 min of walking at 75% of age-predicted maximal heart rate, 15 min of lower body–strengthening exercises, 5 min of abdominal and back exercises, 15 min of balance exercises, and 5 min of cooldown and stretching. More specifically, the walking intensity, maintained at 75% of age-predicted maximal heart rate, was monitored continuously throughout the walking protocol by the program supervisor's using a Polar heart-rate monitor (3000 system). The strengthening exercises consisted of (a) three sets of

10 repetitions of lower leg exercises, including squats, lunges, leg lifts, and calf raises (toes inward/outward/forward); (b) abdominal and back work consisting of abdominal/oblique crunches and back extensions, with each participant completing 10 repetitions of each exercise; and (c) balance activity—15 min of balancing on a 20-in.-wide, 12°-angle wobble board (eyes open and closed), with two arms used for support against a wall, then with one arm only (eyes open and closed); standing on one leg; and tossing and catching a ball, with all positions being held for 10 s. Participants also completed a 5-min warm-up and cooldown, which included large locomotive movements, and static stretching of the major muscle groups that were held for 10–30 s.

The loading of the vests was determined according to a previously determined loading schedule based on a percentage of the participants' body weight. In order to familiarize the participants with the weighted vest, they wore the vest with no weights during the first week. After the first week, the initial load of the vest was 3% of the participant's body weight; thereafter, the weight of the vest was increased by 4% of the participant's body weight every 3 weeks, to a maximum load of 15% of the participant's body weight.

Measurements

Baseline Measurements. The participants' height (cm) was assessed at study entry (T1), and body mass (kg) and relative body fat (%BF) were assessed at T1 and after 12 weeks of exercise training (T2). Each participant's fat-free mass (FFM) and %BF were determined using bioelectrical-impedance analysis (RJL Systems, Milford, CT) as previously described (Broeder, Burrhus, Svanevik, Volpe, & Wilmore, 1997; Stolarczyk et al., 1995). In order to standardize this procedure, and to avoid problems associated with dehydration, all participants were instructed to enter the laboratory euhydrated. Short- and long-term reproducibility of this method have been reported as $r = .99$ for measurements taken in the same participant within 1 week and as .98 for repeat measurements up to 1 month (Kyle et al., 2001).

Bone Turnover. Bone-formation activity was estimated by measuring the levels of osteocalcin (OC) in resting serum samples as previously suggested (Brooke-Wavell et al., 2001; Vincent & Braith, 2002), and bone resorption was estimated by measuring the resting serum levels of cross-linked N-telopeptides of Type I collagen (NTx), which have been established as a specific indicator of the current level of bone resorption (Eastell et al., 2000). The serum sampling in the measurement of NTx to monitor the effect of therapy has been previously supported (Eastell et al.). Because major changes in diet can alter NTx levels, the participants were asked to maintain the same dietary habits and nutritional intake over the course of the study. Moreover, although no detailed dietary assessment was done, according to the general demographic information the two groups appeared to have similar diets before and over the course of the study.

Resting blood specimens were collected at T1 and at T2. Intravenous blood samples were taken via venipuncture of the antecubital vein at the same time in the morning. Samples were immediately centrifuged for 15 min at 1,500 g, and the serum was separated, removed from the sample tube, placed in 2-ml microtubes, and stored at –80 °C until analysis. All analyses were performed in duplicate on the same assay plate by a blinded observer. Serum OC levels were assessed by ELISA using a commercially available immunoassay kit (EIA, Zymed, USA). The intra- and interassay coefficients of variation for the OC assay were 6.1% and 7.2%, respectively. Serum NTx levels were also assessed by ELISA using a commercially available assay (Osteomark NTx serum assay, Wampole Laboratories, USA) and expressed in nanomoles bone-collagen equivalents per liter (nM BCE/L). The intra- and interassay coefficients of variation for the NTx serum assay were 4.6% and 6.9%, respectively.

Isokinetic Strength. At T1 and T2, knee extension and flexion and ankle plantar and dorsiflexion were measured unilaterally in the left lower extremity at two speeds (60°/s and 180°/s) via an isokinetic dynamometer (Biodex Medical Systems, Shirley, NY). Each participant performed a practice session (three repetitions of knee extension and flexion and ankle plantar and dorsiflexion) at both speeds. After the practice, each participant performed a series of trials of three maximal, voluntary concentric contractions each at speeds of 60°/s and 180°/s to assess the strength of the knee extensors, knee flexors, ankle plantar flexors, and ankle dorsiflexors. These trials were always performed in the same order: knee flexion and extension first, followed by ankle plantar and dorsiflexion. The rest period between trials was 30 s. Peak torque was determined as the greatest single value of the three maximal efforts. Previous research has shown that peak torque is both an accurate and a highly reproducible measurement of isokinetic strength, with a reliability of $r = .99$ (Valovich, Drouin, Shultz, Perrin, & Gransneder, 2001).

Calibration of the dynamometer was verified before each testing session using standard weights placed on the lever arm. To minimize upper body motion while measuring knee strength, participants were positioned in an upright, seated 90° position, secured at the thigh, pelvis, and torso using straps, and they held their arms in a folded position across the chest. The head of the lateral femoral condyle was used as a bony marker to match the axis of rotation of the dynamometer to the axis of rotation of the knee joint. Once a participant was in position, the following measurements were made to reproduce the positioning during subsequent testing sessions: seat height, dynamometer-head height, and lever-arm length. Gravity was corrected through assessment of the torque exerted on the dynamometer with the leg relaxed in the extended position. Plantar flexion and dorsiflexion of the ankle were assessed with the participant in a supine position, legs and thighs supported by the table, and secured to the table with straps at the hips, across the knee, and at the forefoot and midfoot. The foot was positioned such that the ankle-joint axis of rotation was aligned with the dynamometer axis of rotation; this was done by referencing a 90° angle formed by a line connecting the lateral femoral condyle to the lateral malleolus and a line parallel to the sole of the foot. After setup, the measurement of ankle strength followed the same procedures as outlined for the knee-extension and -flexion assessment. Verbal encouragement was used to provide motivation for participants to perform maximal effort during muscle contractions. In an attempt to standardize conditions during testing, encouragement was provided by the same person on all occasions.

Compliance. Participants in the EX group were instructed to complete an exercise training log after every training session. A check mark was used to signify that the participant had completed the five components of each training session (as previously outlined). Several lines for comments were available for participants to document any unusual symptoms during the session or reasons for not completing the training session. Compliance was calculated by summing all participants' completed training sessions, dividing by the available number of classes for the 12 weeks (34 in total), and multiplying by the total number of participants (*n* = 9; Vellas, Wayne, Romero, Baumgartner, & Garry, 1997).

Statistical Analysis

An independent-samples *t* test was used to determine the differences between the two groups (CON and EX) for participants' characteristics at T1. A two-way analysis of variance (ANOVA) with repeated measures was used to investigate the between-group (CON and EX) and within-group (pretest and posttest) effects and any group-by-time interactions. When appropriate, Bonferroni post hoc tests were used to evaluate differences between the within-group measures. An alpha level of $P \leq .05$ was the criterion for significance. All data are expressed as *M* ± *SD*. All statistical analyses were conducted using the Statistics Package for Social Sciences (SPSS 11.5 for Windows, SPSS Inc., Chicago).

Results

At study entry, there were no significant between-group differences in participants' physical characteristics and number of years postmenopause. The exercise compliance rate was 79.7%. The two-way ANOVA showed significant group-by-time interaction in %BF and FFM. The post hoc test revealed that after 12 weeks, significant changes were observed in %BF ($P < .05$) and FFM in the EX group (Table 1).

The results for the serum markers of bone turnover are presented in Table 2. There were no significant differences between groups at study entry for OC and NTx (Table 2). Neither group showed a significant change in OC levels from T1 to T2 (group-by-time $P > .05$). A significant ($P < .05$) group-by-time interaction

Table 1 Participants' Physical Characteristics, *M* ± *SD*

	Controls (*n* = 7)		Exercisers (*n* = 9)	
	T1	**T2**	**T1**	**T2**
Age (years)	53.4 ± 5.6	N/A	52.7 ± 4.1	N/A
Years postmenopause	4.6 ± 2.9	N/A	4.6 ± 2.5	N/A
Height (cm)	161.2 ± 6.0	N/A	165.3 ± 5.6	N/A
Weight (kg)	74.5 ± 10.5	74.0 ± 10.4	71.5 ± 7.2	72.3 ± 7.4
Relative body fat (%)	40.9 ± 5.7	40.6 ± 5.6	37.4 ± 7.4	35.6 ± 6.3*
Fat mass (kg)	30.9 ± 8.3	30.5 ± 8.3	27.2 ± 6.9	26.0 ± 6.4
Fat-free mass (kg)	43.5 ± 2.6	43.5 ± 2.5	44.7 ± 3.9	46.3 ± 3.6*

Note. T1 = preintervention; T2 = 12 weeks postintervention. No significant differences were detected between groups at T1.

*$P \leq .05$ from pre to post.

Table 2 Values of Markers of Bone Turnover, *M* ± *SD*

	Controls (*n* = 7)		Exercisers (*n* = 9)	
	T1	T2	T1	T2
Serum osteocalcin (ng/ml)	32.2 ± 5.9	31.4 ± 4.7	35.5 ± 9.0	35.2 ± 8.9
Serum cross-linked N-telopeptides of Type I collagen (nM BCE/L)	14.2 ± 6.3	14.5 ± 7.3	13.1 ± 4.5*	11.2 ± 3.1*

Note. T1 = preintervention; T2 = 12 weeks postintervention.

*$P \leq .05$ between T1 and T2 values.

was found for NTx. The post hoc analysis revealed that NTx was significantly ($P < .05$) decreased from T1 to T2 (by 14.5%) in the EX group, with no changes being observed in the CON group (Table 2).

There were no significant between-group differences at T1 for any of the strength measures. Peak-torque values and percentage changes for isokinetic knee and ankle flexion and extension are shown in Table 3. There was no significant group-by-time interaction in isokinetic strength except for plantar-flexion strength at 60°/s. More specifically, the EX group showed a significant ($P < .05$) improvement (40%) in mean ankle plantar-flexion strength (60°/s) from T1 to T2 compared with the CON group. None of the other seven strength measurements showed a significant increase after 12 weeks of exercise training (Table 3).

Discussion

The intention of this study was to design a multimodal exercise-training program of progressive resistance that would be easily adaptable to home and community settings and diverse enough to be appealing to a large number of postmenopausal women. The results of this trial can be summarized into three major points. First, serum NTx decreased significantly after the 12 weeks of progressive, multimodal exercise training while serum OC remained unchanged in the exercising postmenopausal women. Second, the EX group showed significantly greater improvements in %BF, FFM, and ankle plantar-flexor strength (60°/s) than did the CON. Third, this exercise-training program using multiple modes of exercise with a weighted vest had an 80% exercise-compliance rate in this group of postmenopausal women. Generalization of these findings, however, must be undertaken with caution because of the small sample size.

The present study fulfilled the recommendations of previous studies using weighted vests in older women. More specifically, our results supplement the findings by Jessup et al. (2003), who examined the effects of a 32-week exercise regimen with weighted vests on bone-mineral density and muscle strength in women age 69.2 ± 3.5 years. The 9 women in the exercise group in their study had significant improvements in bone density of the femoral neck. The authors suggested, however, that because several biochemical markers of bone turnover are sensitive to changes in bone metabolism after menopause and exercise-induced increases in bone-mineral density, measuring these markers might strengthen their findings. The most encouraging of these findings is the attenuation of bone resorption after 12

Table 3 **Participant Peak-Torque Values, *M* ± *SD***

	Controls (*n* = 7)			Exercisers (*n* = 9)		
	T1	T2	% Change	T1	T2	% Change
Ankle						
plantar flexion 60°/s	47.3 ± 19.5	51.3 ± 17.0	16.0 ± 9.8	37.8 ± 8.4	52.2 ± 14.0	40.2 ± 13.1*
dorsiflexion 60°/s	12.3 ± 2.8	13.2 ± 3.8	8.4 ± 8.6	12.4 ± 3.3	13.0 ± 2.2	9.4 ± 8.5
plantar flexion 180°/s	30.9 ± 8.3	29.8 ± 10.0	–3.7 ± 9.9	27.9 ± 7.0	30.6 ± 9.5	9.8 ± 8.2
dorsiflexion 180°/s	10.9 ± 6.0	12.9 ± 7.8	29.9 ± 34.4	10.6 ± 3.1	10.3 ± 4.2	5.9 ± 14.8
Knee						
extension 60°/s	93.4 ± 23.1	83.2 ± 18.9	–8.6 ± 8.9	102.8 ± 34.9	102.0 ± 36.0	1.5 ± 9.7
flexion 60°/s	62.1 ± 15.5	59.0 ± 12.0	–0.9 ± 10.3	81.1 ± 24.4	74.9 ± 23.9	–5.3 ± 9.1
extension 180°/s	54.3 ± 19.6	46.5 ± 18.1	–14.4 ± 7.8	61.9 ± 21.7	61.2 ± 22.2	9.3 ± 18.4
flexion 180°/s	50.0 ± 15.4	39.2 ± 13.8	–19.9 ± 10.3	56.7 ± 19.9	55.2 ± 18.0	3.7 ± 12.1

Note. T1 = preintervention; T2 = 12 weeks postintervention.

*$P \leq .05$ group-by-time interaction for repeated-measures ANOVA.

weeks of progressive, multimodal exercise training in this group of postmenopausal women. This result conforms to the literature concerning exercise and bone mass. The beneficial effects of regular weight-bearing exercise on the retention of bone mass in postmenopausal women have been well documented (Dalsky et al., 1998; Vincent & Braith, 2002; Walker, Klentrou, Chow, & Plyley, 2000). These activities appear to have an osteogenic effect through the application of force to bone, resulting in the development of mechanical strain (Zanker & Cooke, 2004). The cellular mechanisms involved in this effect are less evident. According to the existing theoretical framework, the development of postmenopausal osteoporosis is the result of increased osteoclast resorption resulting from estrogen deficiency and a reduced physical activity level in postmenopausal women (Ruimerman, van Rietbergen, Hilbers, & Huiskes, 2005). The EX group in the present study had a significant decrease in serum NTx, indicating a decrease in osteoclast resorption. Thus, although serum OC did not significantly increase in the EX group after the 12 weeks of progressive weight training, the program was beneficial in reducing the effect of the primary mechanism for bone loss in postmenopausal women, namely, bone resorption.

Previous investigations have shown significant increases in OC, up to 40%, after 6 months of exercise training in elderly men and women (Vincent & Braith, 2002). In general, it has been found that both high- and low-intensity resistance training can change the biochemical ratios of bone turnover, favoring increased bone formation (Vincent & Braith). This discrepancy might be explained by the experimental differences between the two studies. The study by Vincent and Braith included results for both men and women, and the duration of the exercise program was twice that of the current study. Furthermore, the results of the current study on postmenopausal women agree with those of a recent study by Yamazaki et al. (2004), who reported that urinary levels of NTx rapidly decreased after 12 weeks of walking exercise in postmenopausal women with osteopenia or osteoporosis. The intention of the present study was to strengthen the findings of Yamazaki et al. by measuring serum levels of bone-formation and bone-resorption markers. One must interpret these results with caution, however, because the absence of dietary control is a major limitation of the current study. According to their general demographic information, the two groups appeared to have similar diets before and over the course of the study, but future research projects should control for calcium and vitamin D intakes.

Although our 12-week intervention did not result in significant weight loss, %BF was significantly ($P < .05$) decreased and FFM was significantly increased in the EX group. In a previous study of longer duration, Jessup et al. (2003) reported significant weight loss after 32 weeks of exercise training with weighted vests in older women. As those authors pointed out, an increase in caloric expenditure associated with increased physical activity often results in body-composition changes. This is actually a potential additional exercise benefit for this population. In fact, closely monitoring dietary intakes might have helped explain the changes seen in body composition after the 12 weeks of exercise training in our population of women, but diet was not assessed in this study.

There was a significant increase (40%) in ankle strength in the EX group, but there were no other significant increases observed in isokinetic strength after 12 weeks of training in this group of women. The increase in ankle strength was tempered by the fact that the CON values for this measurement also increased (16%), but not significantly. Accordingly, Jessup et al. (2003) also found that the increase in muscle strength after 32 weeks of using the weighted vests for training was not statistically significant. The only other study to examine the effect of weighted-vest strength training on leg strength, leg power, and lateral stability (Shaw & Snow, 1998) evaluated 22 exercising women (vs. 22 controls) between the ages of 50 and 75 years. Participants trained using a weighted-vest exercise program three times per week for 9 months. The authors reported significant increases in lower body muscle strength ranging from 16% to 33% while, similar to the findings of the current study, ankle dorsiflexion was not increased (Shaw & Snow). Significant increases were reported for hip-abduction, knee-extension, and ankle plantar-flexion strength (Shaw & Snow). The current study resulted in similar strength gains in ankle plantar flexion with only 12 weeks of training, which would suggest that exercise programs of shorter durations can elicit significant improvements in strength similar to those resulting from longer duration training programs.

Because in the current study we were unable to show significant improvements in all measures of isokinetic strength with exercise, it is apparent that the effectiveness of a weighted-vest training program depends on additional factors such as training frequency, volume (sets-repetitions-loading schedule), and mode (resistance machines vs. free weights). Shaw and Snow (1998) used an initial loading of 5% of body weight and increased the load by 1–2% every 2 weeks until the load reached 10% of body weight; beyond the 10% load, the increases were more conservative. After this, the load was "periodized" in a cyclical manner (Shaw & Snow). The load achieved at the end of the program, 16–20% of body weight, was slightly higher than the one used in the current investigation and was sufficient to produce significant improvements in hip-abduction, knee-extension, and ankle plantar-flexion strength; however, similar to the current study, ankle dorsiflexion was not increased even after 9 months of training. Perhaps higher loads (>15% body weight) are needed to elicit greater improvements in strength, but they would entail an increased likelihood of musculoskeletal injury and a higher chance of dropout. None of the participants in the study by Shaw and Snow reported any musculoskeletal issues before study entry, but during the course of training, several participants complained of knee and/or shin pain that seemed to coincide with increases in the load of the weighted vests. On the other hand, none of the participants in the current study had any musculoskeletal complaints or injuries before study entry or during the study.

In summary, the current study aimed at developing a program that could be used in the home or community and was composed of exercises that did not require the use of specialized machines or free weights. The high compliance rate might have been attributable, in part, to the weighted-vest exercise-training paradigm. Other studies using weighted vests have also shown high compliance rates of 80–90% either with or without involving an exercise program (Greendale et al., 2000; Shaw & Snow, 1998). The 12-week progressive, multimodal exercise-training program resulted in an attenuation of bone resorption, as estimated by serum NTx, in this sample of postmenopausal women. The same exercise training elicited significant improvements in ankle plantar-flexion strength at 60°/s and body composition. No significant changes were observed, however, in the other seven strength measurements. These findings suggest that bone turnover and lower extremity strength can be improved with the proper training stimulus and program duration, but further research is needed to examine the effect of varying training frequency, exercise load and study duration and different methods of weight training on bone turnover and isokinetic strength. This would enable the determination of the optimal balance of these factors and provide recommendations for clinicians and fitness instructors to prescribe exercises to stabilize bone mass in postmenopausal women.

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