Journal of Gerontology: MEDICAL SCIENCES
2000, Vol. 55A, No. 9, M489–M491

Long-term Exercise Using Weighted Vests Prevents Hip Bone Loss in Postmenopausal Women

Christine M. Snow, Janet M. Shaw, Kerri M. Winters, and Kara A. Witzke

Bone Research Laboratory, Oregon State University, Corvallis, Oregon.

Background. Bone mineral density (BMD) is a primary risk factor for hip fracture. We studied the effect of long-term weighted vest plus jumping exercise on hip BMD in postmenopausal women as a strategy for reducing hip fracture risk.

Methods. Eighteen postmenopausal women (age = 64.1 ± 1.6 years at baseline, 69.9 ± 1.6 years at post-testing) who had participated in a 9-month exercise intervention volunteered for the long-term trial. Nine of the original group engaged in weighted vest plus jumping exercise three times per week for 32 weeks of the year over a period of 5 years. Nine of the original controls were active but not enrolled in the exercise program. BMD of the proximal femur was assessed by dual energy x-ray absorptiometry at baseline and after 5 years.

Results. At baseline, groups were similar for age, weight, height, years past menopause, and BMD of the femoral neck, trochanter, and total hip. At follow-up, differences in BMD at all regions of the hip were higher in exercisers than controls. For exercisers, changes in BMD were +1.54% ± 2.37%, −0.24% ± 1.02%, and −0.82% ± 1.04% (means + *SE*) at the femoral neck, trochanter, and total hip, respectively; controls decreased at all sites (−4.43% ± 0.93%, −3.43% ± 1.09%, and −3.80% ± 1.03%, respectively).

Conclusions. A 5-year program of weighted vest plus jumping exercise maintains hip BMD by preventing significant bone loss in older postmenopausal women. Furthermore, this particular program appears to promote long-term adherence and compliance, as evidenced by the commitment of the exercisers for more than 5 years.

HIP fractures represent a national health problem of crisis proportions in this country. There are approximately 300,000 hip fractures annually in the United States, and these carry an economic cost of over $9 billion. Moreover, their numbers are expected to double by the year 2040 (1). Furthermore, the psychological burden of hip fracture can be devastating. In a recent study, Salkeld and colleagues (2) reported that 80% of women would rather die than be institutionalized as a result of hip fracture.

Falls and reduced bone mineral density (BMD) are two primary risk factors for hip fracture (3). Exercise has been suggested as a particularly effective intervention for reducing hip fractures, in that it may both decrease falls and increase BMD. In an earlier study (4), we reported that 9 months of weighted vest exercise reduced fall risk in postmenopausal women by improving neuromuscular measures of muscle strength and power and dynamic balance. However, we did not observe an increase in hip BMD in that study. Because participants in the earlier study were motivated to continue exercising, we had the opportunity to follow bone changes for 5 additional years. Thus, our aim in the present study was to evaluate the long-term effects of weighted vest exercise on hip BMD in postmenopausal women.

Methods

Subjects

From an original 40 subjects in our previous study (4), 18 women volunteered for testing. Of these, nine participated in 5 years of weighted vest exercise and nine were active (5.7 ± 1.7 hr/wk of weight bearing activity) but not engaged in weighted vest or jumping activity. None of the women smoked or took medications known to alter bone metabolism, except estrogen. Two exercisers and three controls had been on estrogen for more than 6 years, and thus their skeletal status was stable. At baseline, BMD, age, weight, height, and years past menopause were similar between groups (Table 1).

Measurements

Bone mineral density (g/cm^2) of the right proximal femur (femoral neck, trochanter, and total hip) was determined by dual-energy x-ray absorptiometry (DXA; Hologic QDR-1000/W, Waltham, MA). The in-house coefficient of variation (CV) is 1.0% for regions of the hip. At the 5-year follow-up, participants completed the Block Food Frequency Questionnaire (5), an assessment of calcium (mg) and vitamin D (IU) intake over the previous year. Results revealed no differences in these nutrients between groups at baseline (4) or at 5 years (exercisers, 1096 ± 140 mg/d and 219 + 34 IU/d; controls, 1249 ± 318 mg/d and 283 ± 84 IU/d).

Training Program

The training program included lower body resistance and jumping exercises performed 3 days per week (MWF). Details of the program are provided elsewhere (4). Years 2–5 emphasized maintenance with respect to the lower body exercises utilizing the weighted vests, included more jumps per class than year 1, and encouraged use of the weighted vest while jumping. During the 5-year period, compliance averaged 83.6% ± 2.4%, jumps per session averaged 51.7 ± 7.5, and weight of vests averaged 11.3 pounds (Table 2).

Table 1. Values for Exercisers and Controls at Baseline and 5 Years

	Exercisers (n = 9)		Controls (n = 9)	
	Baseline	Year 5	Baseline	Year 5
Age (y)	66.4 ± 1.7	72.4 ± 1.7	61.8 ± 2.5	67.4 ± 2.5
Height (cm)	162.82 ± 1.91	161.74 ± 1.84	162.54 ± 1.80	161.93 ± 1.78
Weight (kg)	67.73 ± 2.77	66.15 ± 2.06	61.33 ± 2.87	60.61 ± 3.05
Past menopause (y)	20.1 ± 2.2	25.3 ± 2.2	15.7 ± 2.1	22.8 ± 2.3
BMD (g/cm^2)				
Femoral neck*	0.633 ± 0.026	0.641 ± 0.025	0.688 ± 0.019	0.657 ± 0.018
Trochanter **	0.583 ± 0.021	0.581 ± 0.020	0.645 ± 0.025	0.622 ± 0.023
Total Hip**	0.750 ± 0.032	0.744 ± 0.032	0.803 ± 0.023	0.772 ± 0.021

Notes: There were no significant differences between groups at baseline for any variables. In repeated measures analysis of variance, bone mineral density (BMD) at all regions of the hip (femoral neck, trochanter, and total) was significantly different between groups. Data are presented as means ± *SE*.

*p = .026, change in exercisers > change in controls; **p = .05, change in exercisers > change in controls.

Statistical Analysis

Descriptive statistics were performed on baseline and 5-year data. Analysis of variance (ANOVA) was used to evaluate baseline differences between exercise and control groups. BMD differences at the femoral neck, trochanter, and total hip between groups were analyzed by repeated measures ANOVA. One-sample t tests were also run to determine if percent changes in BMD were significantly different from zero. The SPSS 9.0 statistical software package (SPSS, Inc., Chicago, IL) was used for data analysis with a two-tailed significance criterion set at $p = .05$.

Results

In repeated measures ANOVA, changes for exercisers were significantly different from changes in controls for BMD at the femoral neck, trochanter, and total hip (Table 1). Furthermore, at all sites, controls exhibited significant decreases in BMD when compared to zero (Figure 1). When plotted individually for femoral neck, only three of the exercisers lost BMD, whereas all nine of the control women had decreased BMD at this site.

Discussion

Our aim was to evaluate the effect of long-term participation in weighted vest plus jump training. We report that after 5 years of participation in our exercise program, bone mineral density at the femoral neck, trochanter, and total hip was maintained in exercisers, whereas in controls, BMD decreased by 3.2%–4.4% at these regions of the hip.

This study has several strengths. To our knowledge, ours is the first study to evaluate the effects of more than 5 years of exercise participation on bone mass in older women. The duration of most exercise programs designed to improve BMD in older women is no more than 18 months. Another strength is that participants were highly motivated; thus compliance was extremely high (>83%), and we had no attrition. A primary criticism of exercise interventions for osteoporosis prevention is that most lack the resources and/or group dynamic to motivate participants over the length of time required to observe clinically relevant outcomes. Our program promoted motivation in participants by creating an environment of individual encouragement and support, and by showing visible results in individual participants. Another strength was that calcium and vitamin D were similar between groups and thus did not represent confounding variables. Finally, no new injuries were precipitated by the impact from jumping or by the length of exercise participation.

Our study also had limitations. First, not all women were estrogen deplete. However, of the five women who were on estrogen (two in the exercise group and three in the control group), all had been on the therapy for over 1 year prior to baseline testing and were thus considered stable with respect to their skeletal status. This was confirmed by plotting individual responses in exercise and control groups according to estrogen status. A second limitation was that subjects were not randomized into exercise or control groups. Instead, subjects self-selected at the onset to either continue to exercise or not. Finally, since equipment was not available, we did not measure long-term neuromuscular adaptations as we had in our original report. An assessment of variables associated with fall risk would have provided a more balanced measure of fracture risk.

We found that jumping (impact) plus resistance exercise significantly reduced hip bone loss in postmenopausal women. The few reports of impact and resistance exercise effects on hip BMD in postmenopausal women give mixed results. Studies of interventions involving impact alone (heel drops and jumping) (6,7) have yielded results indicating no change at the hip, whereas studies of high intensity

Table 2. Yearly Compliance, Number of Jumps per Session, and Weight in Vests for Postmenopausal Women Over a 5-Year Period of Weighted Vest Excercise

	Year 1	Year 2	Year 3	Year 4	Year 5
Compliance (%)	76.61 ± 3.42	87.17 ± 2.95	85.59 ± 3.59	85.69 ± 4.57	82.74 ± 3.29
Jumps/session	44 ± 3	53 ± 4	44 ± 8	57 ± 13	60 ± 14
Weight in vests (lbs)	14 ± 2	13 ± 4	15 ± 2	7 ± 3	7 ± 3

Notes: Values are presented as means ± *SE*. Compliance was computed as number of sessions attended ÷ by number of sessions held × 100.

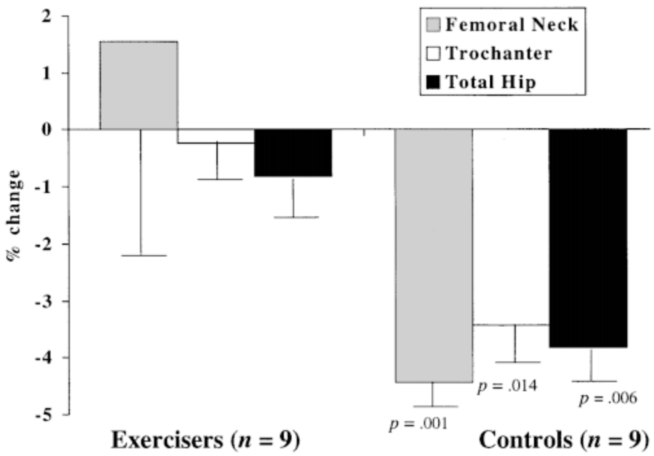

Figure 1. Percent changes in bone mineral density (BMD) at the femoral neck, trochanter, and total hip in exercisers and controls after 5 years. Changes for exercisers were 1.54% ± 2.37% (CI = −3.9% to 7.0%) at the femoral neck, −0.24% ± 1.02% (CI = −2.6% to 2.1%) at the trochanter, and −0.82% ± 1.04% (CI = −3.2% to 1.6%) at the total hip, whereas controls changed −4.43% ± 0.93% (CI = −6.6% to −2.3%) at the femoral neck, −3.43% ± 1.09% (CI = −5.9% to −0.92%) at the trochanter, and −3.80% ± 1.03% (CI = −6.2% to −1.4%) at the total hip. Decreases in controls are significantly different from zero (unpaired *t* tests). Data are presented as means + SE.

resistance training have reported positive responses (8,9). Bassey and Ramsdale (6) found no effect of impact exercise (heel drops) on BMD in postmenopausal women after 12 months, probably due to the low ground reaction forces generated in heel drops (1.5 times body weight). Recently, Bassey and colleagues (7) compared the effects of jumping on hip BMD in pre- and postmenopausal women. Although premenopausal women increased trochanteric BMD after 6 months, there was no effect on hip BMD after 12 months in postmenopausal women regardless of estrogen status and despite the higher ground reaction forces compared to heel drops (4 vs 1.5 times body weight). Similar to Bassey and colleagues (7), in our first report (4), we did not observe a response in hip BMD after 9 months. Thus, a longer intervention period of impact exercise appears necessary for a response at the hip in older individuals.

Although our program did not involve traditional resistance exercise, the use of weighted vests built the knee and hip strength necessary to support jumping activity. There have been two reports of an exercise effect at the hip from resistance training in nonestrogen replaced postmenopausal women, but the responses have varied by region. Nelson and colleagues (8) observed a maintenance in femoral neck BMD after 1 year of high intensity resistance training, whereas Kerr and colleagues (9) reported a small increase in trochanteric BMD. Given these results, one could speculate that the resistance training alone in our study caused the observed maintenance in BMD. However, we did not observe a bone response to resistance training in our earlier 9-month study (4). Thus, we believe the higher rate of loading associated with jumping is an important component of our program.

To our knowledge, there have been no reports of an exercise effect on all regions of the hip as we report here. Given that fractures of the femoral neck and trochanter regions comprise 80%–90% of all hip fractures, preventing bone loss in these regions may protect from both types of fracture (10). Furthermore, total hip BMD is a robust predictor of hip fracture risk and has become the reference site for diagnosing osteoporosis at the hip (11). We demonstrate that weighted vest exercise prevents bone loss in all of these regions of the hip and the effect is similar to or even exceeds that of estrogen (12).

Our data support participation in long-term exercise using weighted vests as a strategy for reducing hip fracture risk, a finding that should be confirmed in additional long-term prospective trials. Furthermore, this program is safe and practical and promotes both adherence and compliance in older women.

Acknowledgments

This study was supported by the AARP Andrus Foundation, by funds from the Clinical Program of the Bone Research Laboratory, and an AAUW Dissertation Fellowship (JMS). The authors thank Shantel Stark for her expertise in manuscript preparation and Wilson C. Hayes, PhD, for editorial assistance. Finally, we extend our gratitude to the women in this study for their willingness to engage in follow-up testing over such a long time period.

Address correspondence to Christine M. Snow, PhD, Director, Bone Research Laboratory, Women's Building 13, Oregon State University, Corvallis, OR 97331. E-mail: christine.snow@orst.edu

References

1. Cooper C, Fogelman K, Melton LJ II. Bisphosphonates and vertebral fracture: an epidemiological perspective. *Osteoporos Int*. 1991;2:1–4.
2. Salkeld G, Cameron ID, Cumming RG, Easter S, Seymour J, Kurrle SE, Quine S. Quality of life related to fear of falling and hip fracture in older women: a time trade-off study. *Br Med J*. 2000;320(7231):341–346.
3. Hayes WC, Meyers ER, Morris JN, Gerhardt TN, Yett HS, Lipsitz LA. Impact near the hip dominates fracture risk in elderly nursing home residents who fall. *Calcif Tissue Int*. 1993;52:192–198.
4. Shaw J, Snow C. Weighted vest exercise improves indices of fall risk in older women. *J Gerontol Med Sci*. 1998;53:M53–M58.
5. Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. *Am J Epidemiol*. 1986;124:453–469.
6. Bassey EJ, Ramsdale SJ. Weight-bearing exercise and ground reaction forces: a 12-month randomized controlled trial of effects on bone mineral density in healthy postmenopausal women. *Bone*. 1995;16(4):469–476.
7. Bassey EJ, Rothwell MC, Littlewood JJ, Pye DW. Pre- and postmenopausal women have different bone mineral density responses to the same high-impact exercise. *J Bone Miner Res*. 1998;13:1805–1813.
8. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures: a randomized controlled trial. *JAMA*. 1994;272:1909–1914.
9. Kerr D, Morton A, Dick I, Prince R. Exercise effects on bone mass in postmenopausal women are site-specific and load-dependent. *J Bone Miner Res*. 1996;11:218–225.
10. Greenspan SL, Myers ER, Maitland LA, Kido TH, Krasnow MB, Hayes WC. Trochanteric bone mineral density is associated with type of hip fracture in the elderly. *J Bone Miner Res*. 1994;9(12):1889–1894.
11. Looker AC, Wahner HW, Dunn WL, et al. Updated data on proximal femur bone mineral levels of U.S. adults. *Osteoporos Int*. 1998;8(5): 468–489.
12. Grady D, Rubin SM, Petitti DB, Fox CS, Black D, Ettinger B, Ernster VL, Cummings SR. Hormone therapy to prevent disease and prolong life in postmenopausal women. *Ann Intern Med*. 1992;117(12):1016–1037.

Received March 22, 2000
Accepted March 29, 2000
Decision Editor: John E. Morley, MB, BCh