Preventing Osteoporosis the Bone Estrogen Strength Training Way

by Linda B. Houtkooper, Ph.D., R.D., FACSM, Vanessa A. Stanford, M.S., R.D., CSCS, Lauve L. Metcalfe, M.S., FAWHP, Timothy G. Lohman, Ph.D., and Scott B. Going, Ph.D.

Learning Objectives

The purposes of this article are to demonstrate that (1) osteoporosis is a debilitating disease that leads to fragile bones and bone fractures, (2) osteoporosis cannot be cured but can be prevented, and (3) low bone mineral density is a characteristic of osteoporosis. The Bone Estrogen Strength Training study results will demonstrate the following:

1. *Bone mineral density can be maintained or increased in postmenopausal women using a regime of adequate resistance and weight-bearing exercise training combined with adequate calcium intake in the short term (1 year) and the long term (4 years).*
2. *In addition to calcium, other nutrients (particularly iron) interacted with hormone replacement therapy use and influenced short-term (1 year) and long-term (4 years) bone mineral density changes in the Bone Estrogen Strength Training study participants.*

Key words: *Postmenopausal Women, Strength Training, Calcium, Iron, Bone Mineral Density*

Osteoporosis is a disease in which bones become fragile because of loss of mineral content and protein structure. The 1993 Osteoporosis Consensus Development Conference defined osteoporosis as "a metabolic bone disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk." If not prevented, osteoporosis can progress silently and painlessly until a bone becomes fractured. These debilitating fractures occur most often in the hip (femoral neck and trochanter), lumbar spine (LS), and wrist. Women can lose up to 20% of their bone mass in the 5 to 7 years after menopause, making them more susceptible to osteoporosis (1). The Surgeon General's Report on Bone Health and Osteoporosis (2) warns that one in two women and one in four men aged older than 50 years will have an osteoporosis-related fracture in her or his remaining lifetime. Effective osteoporosis prevention strategies include adequate resistance and weight-bearing exercise in combination with adequate calcium intake (4). This article describes the 1-year and 4-year results from the Bone Estrogen Strength Training (BEST) Study.

BEST Study Description—Year 1

The most extensive study of its kind in the United States, the BEST study began in 1995 to examine how strength-training exercise, combined with adequate calcium intake, would change bone mineral density (BMD) in two groups of postmenopausal women. Before entering the study, the subjects either were or were not undergoing hormone replacement therapy (HRT) (3). Sedentary (<120 minutes of physical activity per week) postmenopausal women were recruited to participate in the study and were randomized to either the control group or the exercise group. These women had never lifted weights on a regular basis before joining the study. The BMD was assessed using dual energy X-ray absorptiometry (DXA) at the beginning of the study and after 1 year of study participation. All of the study participants took 800 mg of calcium citrate supplements (Citracal®) daily. Two hundred sixty-six women, aged 45 to 65 years, completed the first year of the study.

Diet

Dietary intake was assessed throughout the first year from eight randomly assigned days of diet records (DRs) collected at baseline and at 6 and 12 months. Each recording period included 1 weekend day and 1 to 2 nonconsecutive weekdays (3, 4, 5). The participants completed an intensive hour-and-a-half DR training before each recording period. Supplemental calcium intake was assessed from tablet counts during the first year.

Exercise

Participants in the control group maintained their sedentary lifestyle, and participants in the exercise group performed supervised weight-bearing and resistance exercises 30 days per week on nonconsecutive days in community facilities under the supervision of on-site BEST study trainers. In the first

year of the study, exercise sessions lasted 60 to 75 minutes and included weight-bearing activities for warm-up, strength-training, and cardio weight-bearing circuit of moderate impact activities (*e.g.,* walking/jogging, skipping, and hopping) at 70% to 80% of maximum heart rate; stair climbing on step boxes while wearing weighted vests; and small muscle exercises that included stretching and balance exercises. Exercise attendance; strength-training loads, sets, and repetitions; steps with weighted vests; and minutes of aerobic activity were recorded in exercise logs that were monitored regularly by on-site BEST study trainers (Fig. 1).

Cardio warm-up (5 minutes)

Strength exercises (20 minutes)

Cardio weight-bearing activity (15 minutes)

Small muscle exercises (5 minutes)

Cool down

Figure 1. The BEST workout.

Strength training was done using free weights and machines. Eight exercises focused on major muscle groups with attachments on or near BMD measurement sites. These exercises included the seated leg press, lat pull down, weighted march, seated row, back extension, one-arm military press (right and left), squats (initially, wall squats and, later, Smith or hack squats), and the rotary torso machine.

The subjects completed two sets of six to eight repetitions (four to six repetitions for the military press to decrease injury to the shoulder) at 70% (2 days per week) and 80% (1 day per week) of the one-repetition maximum. The stretching and balance routine was designed to develop and maintain balance, to prevent "forward head" or hunched-over posture and to correct for muscle imbalances (6). The participant-trainer ratio was 5:1 during the first year of exercise.

1-Year Impacts on BMD

The first year results demonstrated that the exercise group participants significantly improved BMD (4).

For subjects undergoing HRT:

- The HRT, calcium supplements, and exercise increased the hip femoral neck and trochanteric BMD by approximately 1% to 2%.
- The HRT, calcium supplements, and no exercise had a negligible change in their BMD.

For subjects not undergoing HRT:

- No HRT, calcium supplements, and exercise increased hip trochanteric BMD by approximately 1%.
- No HRT, calcium supplements, and no exercise significantly decreased their BMD.

The results demonstrated that BMD can be improved or maintained at the hip femoral neck and trochanter regions in postmenopausal women who do weight-bearing activity combined with strength-training exercises for 1 year whether they are using HRT. The increase in BMD was significant at more bone sites in women using HRT, thus suggesting a greater benefit in increasing BMD for women taking HRT.

1-Year Impacts on Soft Tissue

In addition to the BMD effects, the BEST intervention had significant positive effects on soft tissue composition, which includes all of the body components except the bone (7, 8). After completing 1 year of the study, women who exercised increased whole body and regional (arms and legs) lean soft tissue (LST) measured using DXA. The LST was positively correlated with skeletal muscle mass. The HRT did not enhance the effects of exercise on LST, although it did protect women who did not exercise from losing LST. Women who exercised and used HRT also lost fat mass. Although the changes in LST and fat mass were small, they are nonetheless important. Postmenopausal women are at risk for muscle loss and fat gain, which together contribute to impaired physical performance and increasing risk of metabolic dysregulation. The gains in LST and muscle strength elicited by the BEST exercise program and loss of body fat would be expected to counter these effects.

1-Year Impact of Nutrients

The participants' dietary intake of calcium, iron, magnesium, phosphorus, zinc, and vitamin D was positively associated with BMD at the beginning and end of the first year of the study. Because iron is consistently and significantly associated with BMD in all bone sites studied, this article focuses on the unique associations among calcium, iron, and HRT. Adequate calcium intake has long been associated with maintaining and increasing BMD (5). The current dietary reference intake (DRI) for calcium is 1,200 mg/day for women aged 50 years and older (9). The Tolerable Upper Intake Level for calcium is 2,500 mg/day (9). Iron intake also is associated with BMD (10). The DRI for iron is 8 mg/day for women aged 51 years and older and 18 mg/day for women aged 31 to 50 years (9). The Tolerable Upper Intake Level for iron is 45 mg/day (9).

At the start of the study, in a subsample of 242 women who had complete DRs, levels of dietary iron intake of greater than 20 mg/day were associated with greater BMD at several bone sites among women with average calcium intakes of 800 to 1,200 mg/day. In contrast, elevated iron intake was not associated with greater BMD among women with calcium intakes of greater than 1,200 mg/day or less than 800 mg/day (10). Thus, it seems that postmenopausal women with calcium intakes at or slightly below the recommended calcium intakes and with higher than recommended levels of iron intake had higher BMD levels.

At the end of the first year of study participation, in the subsample of 228 women, who had complete DRs, there were unique relationships among BMD, HRT use, and average iron and calcium intakes. Women undergoing HRT who consumed the lowest amount of calcium (900 to 1,300 mg/day) had an increase in BMD as iron intake increased from a low intake of 7 mg/day to a higher intake of 32 mg/day. In women not undergoing HRT, BMD increased only in those with the highest calcium intake (1,650 to 2,600 mg/day), and the response was not influenced by the level of iron intake. It seems that HRT use influenced the complex relationships of iron, calcium intake, and BMD in postmenopausal women (11).

These findings from the first year of the BEST study suggested a possible interaction in the relationships among the intakes of calcium and iron, HRT use, and BMD. The mechanisms that link HRT, iron, and calcium in the metabolism of bone are still unclear.

Year 1—Lessons Learned

The results from the first year of the BEST study indicate that the most important component of an osteoporosis prevention program among postmenopausal women is resistance exercise, and the effects seem to be dose responsive. That is, those women who lifted the most weight for 1 year experienced the greatest improvement in BMD, especially at the hip site (5). Although femoral trochanteric BMD improved after the first year of exercise and showed a significant relationship to the amount of weight lifted, LS BMD among exercisers exhibited no significant improvement compared with BMD among the control group at the end of the first year of the study. The lumbar spine BMD may require a longer exposure to consistent exercise before a change in BMD is observed.

Figure 2. Seated Leg Press (6). (Reprinted with permission from DSWFitness.)

Figure 3. Lat pull down (6). (Reprinted with permission from DSWFitness.)

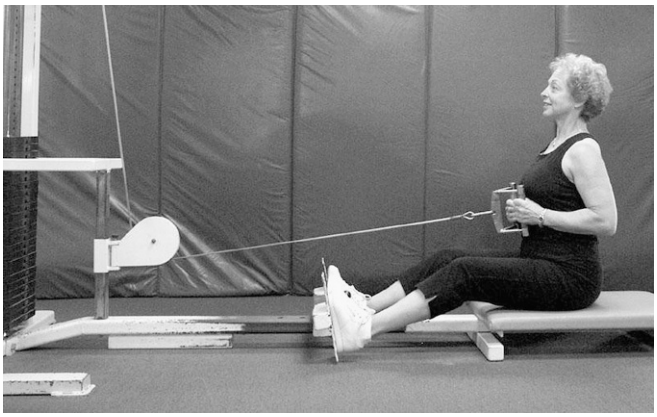

Figure 4. Seated Row (6). (Reprinted with permission from DSWFitness.)

The long-term effects of exercise on BMD are one of the most important and difficult questions yet to be answered. Because bone loss takes place for many years after menopause, it is important to know if sustained exercise can prevent bone loss. Unfortunately, few studies have encouraged women to continue to exercise after 1 or 2 years, and none have examined long-term results in relation to exercise compliance. In our research, we found that two sets of each exercise were sufficient for increasing BMD and that the progression of lifting heavier weights over time was essential for increasing BMD (4, 5, 12).

To encourage our participants to continue the BEST exercise program after the first year of the study, we shortened the BEST workout to a 45-minute exercise session that could be performed three times per week and reduced the number of strength-training exercises to six: leg press, wall squat/Smith squat, one-arm dumbbell press, cable row, lat pull down, and back extension (Figs. 2–7). Many women engaged in additional exercise classes, which included aerobics, yoga, Pilates, and spinning during years 2 to 4 to provide variety while continuing to do strength exercises.

4-Year Impacts

Compliance and BMD

A total of 167 women completed 4 years of participation in the BEST study. After completing the first year of the study, all participants were encouraged to continue to exercise on their own and to have yearly DXA assessments conducted by the study. Supervision was reduced in the facilities during the second year; in the third and subsequent years, BEST study trainers were at the facilities once a month. After 4 years, the participants' exercise frequency varied from none to 94% of the prescribed exercise sessions. The women who remained active maintained or improved BMD at the hip (femoral neck and trochanter) and the LS (5). Women who exercised the most consistently (highest tertile for exercise frequency, 70.3 ± 12.6% attendance at exercise sessions) experienced significantly ($P < 0.05$) greater benefits on BMD at all bone sites than women who exercised less often. Larger increases in LST also were significantly ($P < 0.05$) associated with a higher exercise frequency. The benefit of exercise was found in both sets of women who underwent HRT and those who did not undergo HRT. However, the combination of exercise and HRT was the most beneficial for BMD.

In general, the greatest increase in LST and BMD occurred in the first year of the BEST study regardless of HRT use. Among women in the highest tertile of exercise frequency, there was a significant ($P < 0.001$) increase in LST from baseline during the first year. This effect was lost for years 2 to 4 ($P > 0.7$), although the overall 4-year gain was significant for the total study period (5). The exception was for the LS BMD that continued to respond with an increase in BMD for 4 years of participation in the BEST study program.

Diet

Dietary intake was assessed at the end of the first year and annually through years 2 to 4 using the Arizona Food Frequency Questionnaire, an optically scannable food frequency questionnaire based on the Block Model and modified to include southwestern foods (5). Supplemental calcium intake was assessed for 4 years from tablet counts and quarterly self-reports. Vitamin D was not supplemented

Figure 5. Back Extension (6). (Reprinted with permission from DSWFitness.)

Figure 6. One-arm shoulder press (6). (Reprinted with permission from DSWFitness.)

because the study took place in Tucson, Arizona where sunshine is abundant; thus, it is expected that supplemental vitamin D is not needed.

The women completing 4 years of the BEST study, who were not undergoing HRT and who took at least 800 mg/day of supplemental calcium, had greater improvements in BMD than those taking less supplemental calcium. These women also consumed, on average, approximately 900 mg/day of calcium from dietary sources. Thus, it seems that a total calcium intake of at least 1,700 mg/day may provide calcium at adequate levels to preserve BMD among postmenopausal women who do not undergo HRT and who follow the BEST exercise program. This is 500 mg/day more than the current level of DRI for the adequate intake level of calcium for women aged older than 50 years. The effect of calcium intake on BMD was independent of the exercise effects, emphasizing that both exercise and calcium intake are important contributors to the prevention of osteoporosis (5).

Year 4—Lessons Learned

After 4 years of participating in the BEST exercise program, women who attended the most exercise sessions and lifted the greatest amount of weight showed the largest gains in LS BMD compared with the women who attended the least number of exercise sessions and lifted the least amount of weight (5). After 4 years, however, increases in LS BMD that were related to exercise frequency became apparent. There was a 2.5% difference in LS BMD between the women who lifted the greatest amount of total weight and those who lifted the least amount of weight (Fig. 8).

One of the major issues of long-term exercise intervention studies is participant retention. Of the 266 women who finished the first year of the study, 177 went on to complete 4 years of participation; since the completion of the fourth year of the study, we collected data annually for 4 additional years. We will analyze these data from women who completed 8 years of exercise

Figure 7. Squat (6). (Reprinted with permission from DSWFitness.)

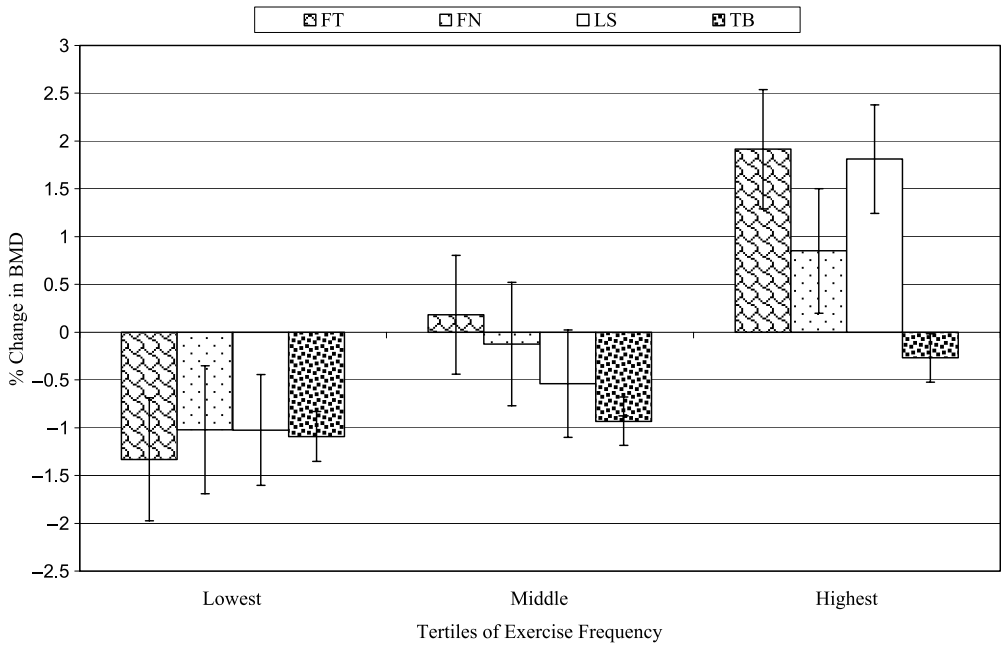

Figure 8. Four-year percentage change in BMD by tertiles of frequency of exercise (n = 167). (FN indicates femur neck; FT, femur trochanter; LS, lumbar spine; TB, total body) (5). (Reprinted with permission from Springer Science and Business Media.)

participation to further assess the long-term benefits of exercise on their BMD.

Conclusion/Application

In conclusion, low BMD is a risk factor for osteoporotic fractures; increasing BMD or maintaining BMD levels can decrease the risk for osteoporosis. The BEST study demonstrated that for 4 years, postmenopausal women maintained or increased their hip and LS BMD by participating in a program of weight-bearing and strength-training resistance exercise for 3 days a week, combined with consuming an average of 1,700 mg/day of calcium and a dietary iron intake that met or exceeded the current DRI. Having adequate exercise, calcium and iron intake was even more important for maintaining and increasing BMD in women who chose not to undergo HRT.

Health-care professionals may implement the BEST Exercise program by using the step-by-step educational book entitled *The BEST Exercise Program for Osteoporosis Prevention* (6). This book describes the 45-minute exercise session including the strength-training exercises that were found to have the most positive effect on bone density, training protocols, specific programming, motivational strategies, nutrition, and screening recommendations. The BEST study research has shown that individuals who consistently were able to increase the volume of weight lifted had the greatest effect on BMD. This BEST Exercise Program book also provides additional client handout information and recommendations to prevent osteoporosis.

Linda B. Houtkooper, Ph.D., R.D., FACSM, is a professor and head of the Department of Nutritional Sciences in the College of Agriculture and Life Sciences at the University of Arizona. She is the director of Nutrition and Education for the Center for Physical Activity and Nutrition at the University of Arizona. She is a coprincipal investigator for the BEST study and one of the authors of The BEST Exercise Program for Osteoporosis Prevention.

Vanessa A. Stanford, M.S., R.D., CSCS, is a senior research specialist in the College of Agriculture and Life Sciences in the Department of Nutritional Sciences at the University of Arizona. She is the coordinator of the Nutritional Assessment Lab and one of the authors of The BEST Exercise Program for Osteoporosis Prevention.

Lauve L. Metcalfe, M.S., FAWHP, is the director of Program Development and Community Outreach for the Center of Physical Activity and Nutrition. Ms. Metcalfe is a coprincipal investigator for the BEST study and directed the exercise and social support portion of the intervention. She also is one of the authors of The BEST Exercise Program for Osteoporosis Prevention.

Timothy G. Lohman, Ph.D., is a professor in the Department of Physiology in the College of Medicine at the University of Arizona. He is the director of the Center for Physical Activity and Nutrition and is the Principal Investigator of the BEST study. He also is one of the authors of The BEST Exercise Program for Osteoporosis Prevention.

Scott B. Going, Ph.D., is an associate professor in the College of Agriculture and Life Sciences, Department of Nutrition at the University of Arizona. He is the director of Research Development for the Center for Physical Activity and Nutrition. He is a coprincipal investigator for the BEST study and one of the authors of The BEST Exercise Program for Osteoporosis Prevention.

Recommended Readings

Lohman, T., S. Going, L. Houtkooper, et al. *The BEST Exercise Program for Osteoporosis Prevention.* Tucson, AZ: Desert Southwest Fitness, 2004. (For more information go to: *http://www.cpanarizona.org/.*)

References

1. National Osteoporosis Foundations: Fast Facts on Osteoporosis. Available at *http://www.nof.org/osteoporosis/diseasefacts.htm.* Accessed March 17, 2006.
2. U.S. Department of Health and Human Services. Bone health and osteoporosis: a report of the surgeon general, October 14, 2004. Available at *http://www.surgeongeneral.gov/library/bonehealth/content.html.* Accessed March 13, 2006.
3. Metcalfe, L., T. Lohman, S. Going, et al. Postmenopausal women and exercise for the prevention of osteoporosis: the Bone, Estrogen, and Strength Training (BEST) study. *ACSM's Health & Fitness Journal*® 5(3):6–14, 2001.
4. Going, S., T. Lohman, L. Houtkooper, et al. Effects of exercise on bone mineral density in calcium-replete postmenopausal women with and without hormone replacement therapy. *Osteoporosis International* 14: 637–643, 2003.
5. Cussler, E., S. Going, L. Houtkooper, et al. Exercise frequency and calcium intake predict 4-year bone changes in postmenopausal women. *Osteoporosis International* 16:2129–2141, 2005.
6. Lohman, T., S. Going, L. Houtkooper, et al. *The BEST Exercise Program for Osteoporosis Prevention.* Tucson, AZ: Desert Southwest Fitness, 2004, p. 53–108.
7. Teixeira, P.J., S.B. Going, L.B. Houtkooper, et al. Resistance training in postmenopausal women with and without hormone therapy. *Medicine & Science in Sports & Exercise*® 35(4):555–562, 2003.
8. Figueroa, A., S.B. Going, L.A. Milliken, et al. Effects of exercise training and hormone replacement therapy on lean and fat mass in postmenopausal women. *Journals of Gerontology A—Biological Sciences and Medical Sciences* 58(3):M266–M270, 2003.
9. Trumbo, P., S. Schlicker, A. Yates, et al. Dietary Reference Intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *Journal of the American Dietetic Association* 102(11):1621–1630, 2002.
10. Harris, M., L. Houtkooper, V. Stanford, et al. Dietary iron is associated with bone mineral density in healthy postmenopausal women. *Journal of Nutrition* 133:3598–3602, 2003.
11. Maurer, J., M. Harris, V. Stanford, et al. Dietary iron positively influences bone mineral density in postmenopausal women on hormone replacement therapy. *Journal of Nutrition* 135:863–869, 2005.
12. Kerr, D., A. Morton, R. Prince. Exercise effects on bone mass in postmenopausal women are site-specific and load-dependent. *Journal of Bone Mineral Research* 11:218–255, 1996.

Condensed Version and Bottom Line

Osteoporosis is a debilitating disease which cannot be cured but can be prevented in postmenopausal women with adequate exercise combined with adequate mineral intake. Low bone mineral density (BMD) is a characteristic of osteoporosis. Increasing BMD or maintaining BMD levels can decrease the risk for osteoporosis. In the first year, the Bone Estrogen Strength Training study demonstrated that BMD, particularly at the hip, can be increased with weight bearing and strength-training resistance exercise done 3 days a week in postmenopausal women who consume adequate calcium and dietary iron levels that met or exceeded the current Dietary Reference Intakes. For 4 years, the Bone Estrogen Strength Training study demonstrated that postmenopausal women maintained or increased their hip and lumbar spine BMD by continuing the exercise regime three times a week, combined with consuming an average of 1,700 mg/day of calcium and consuming dietary iron at levels that met or exceeded the current Dietary Reference Intakes. For women who chose not to undergo hormone replacement therapy, doing adequate exercise and taking adequate amounts of calcium and iron were even more important for maintaining and increasing BMD.