Title: **Preventing Osteoporosis the BEST Way**

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5 key words: postmenopausal women, strength training, calcium, iron, Bone Mineral Density

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Preventing Osteoporosis the BEST Way

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; 3) low bone mineral density is a characteristic of osteoporosis. The Bone Estrogen Strength Training (BEST) study results will demonstrate: 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 (in particular iron) interacted with hormone replacement therapy (HRT) use and influenced short term (1 year) and long term (4 years) bone mineral density changes in the BEST study participants.

SUMMARY STATEMENT

The first and four year results of the BEST study demonstrated that the loss of bone mineral density can be prevented in postmenopausal women with adequate resistance and weight-bearing exercise combined with adequate calcium intake.

BOTTOM LINE SUMMARY

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 BEST study demonstrated that BMD, particularly at the hip, can be increased with weight bearing and strength training resistance exercise done three days a week, in postmenopausal women who consume adequate calcium and dietary iron levels that met or exceeded the current Dietary Reference Intakes (DRI) (4,10). Over four years, the BEST study demonstrated that postmenopausal women maintained or increased their hip and lumbar spine BMD by continuing the exercise regime 3 times a week, combined with consuming an average of 1700 mg/day of calcium and consuming dietary iron at levels that met or exceeded the current DRI (5,11). For women who chose not to take hormone replacement therapy doing adequate exercise and taking adequate amounts of calcium and iron were even more important for maintaining and increasing BMD.

Preventing Osteoporosis the BEST Way

Osteoporosis is a disease in which bones become fragile due to 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 fractures. These debilitating fractures occur most often in the hip (femur neck, trochanter), lumbar spine (LS) and wrist. Women can lose up to 20 percent of their bone mass in the five to seven years following 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 over age 50 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 one and four year results from the Bone Estrogen Strength Training Study (BEST).

BEST Study Description – Year One

The most extensive study of its kind in the United States, the Bone Estrogen Strength Training (BEST) study began in 1995 to examine how strength-training exercise, combined with adequate calcium intake, would change bone mineral density in two groups of postmenopausal women. Prior to entering the study the subjects either were taking hormone replacement therapy (HRT) or were not taking 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. Bone mineral density (BMD) was assessed by dual energy x-ray absorptiometry (DXA) at the beginning of the study and after one year of study participation. All of the study participants took 800 milligrams of calcium citrate supplements (Citracal®) daily. Two hundred and sixty six women, ages 45 – 65 years old, completed the first year of the study.

Diet

Dietary intake was assessed throughout the first year from eight randomly assigned days of diet records (DR) collected at baseline, 6 months, and 12 months. Each recording period included one weekend day and 1-2 nonconsecutive weekdays (3, 4, 5). The participants completed an intensive 1½ hours of diet record training prior to 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 three days per week, on non-consecutive days, in community facilities under the supervision of on-site BEST study trainers. In the first year of the study, exercise sessions lasted 60-75 minutes and included weight-bearing activities for warm-up, strength training, cardio-weight-bearing circuit of moderate impact activities (e.g., walk/jog, skipping, hopping) at 70-80% of maximum heart rate, and 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 which were monitored regularly by on-site BEST study trainers.

INSERT FIGURE 1. "THE BEST WORKOUT" HERE

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.

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% (two days per week) and 80% (one day per week) of the one-repetition maximum (1-RM). The stretching and balance routine was designed to develop and maintain balance, prevent "forward head" or hunched-over posture and to correct for muscle imbalances. (6). The participant-to-trainer ratio was five-to-one in the first year of exercise.

One-Year Impacts on BMD

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

HRT:

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

No HRT:

- No HRT, calcium supplements, and **exercise** increased hip trochanteric BMD by ~1.0%.
- 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 one year whether they are using HRT or not. The increase in BMD was significant at more bone sites in the women using HRT, thus suggesting a greater benefit in increasing BMD with women taking HRT.

One-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 bone (7, 8). After completing one year of the study, women who exercised increased whole body and regional (arms and legs) lean soft tissue (LST) measured by DXA. LST was positively correlated with skeletal muscle mass. 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.

One-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 associated significantly 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 DRI for calcium is 1,200 mg/day for women greater the 50 years of age (9). The Tolerable Upper Intake Level (UL) 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 51 years of age and older and 18 mg/ day for women 31 – 50 years old (9). The UL for iron is 45 mg/day (9).

At the start of the study, in a subsample of 242 women who had complete diet records, levels of dietary iron intake greater than 20 mg/day were associated with greater BMD at several bone sites among women with average calcium intakes of 800-1200 mg/day. In contrast, elevated iron intake was not associated with greater BMD among women with calcium intakes greater than 1200 mg/day or less than 800 mg/day (10). Thus, it appears that postmenopausal women with calcium intakes at or slightly below the

recommended 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 diet records, there were unique relationships among BMD, HRT use and average iron and calcium intakes. Women using HRT who consumed the lowest amount of calcium (900-1300 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 using HRT, BMD increased only in those with the highest calcium intake (1650-2600 mg/day) and the response was not influenced by the level of iron intake. It appears that HRT use influenced the complex relationships among 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 One Lessons Learned

The results from the first year of the BEST study indicate the most important component of an osteoporosis prevention program among post-menopausal women is resistance exercise and the effects appear to be dose-responsive. That is, those women who lifted the most weight over one year's time experienced the greatest improvement in BMD, especially at the hip site (5). While femoral trochanteric BMD improved after the first year of exercise and showed a significant relationship to weight lifted, lumbar spine BMD among exercisers exhibited no significant improvement compared to BMD among

the controls at the end of the first year of the study. The lumber spine BMD may require a longer exposure to consistent exercise before a change in BMD is observed.

The long-term effects of exercise on BMD are one of the most important and difficult questions yet to be answered. Since bone loss takes place over many years following menopause, it is important to know if sustained exercise can prevent bone loss. Unfortunately, few studies have encouraged women to continue to exercise after one or two 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. Many women engaged in additional exercise classes, which included aerobics, yoga, Pilates, and spinning during year two through year four to provide variety while continuing to do strength exercises**.**

INSERT FIGURES 2-7 HERE

Four -Year Impacts

Compliance and BMD

One hundred and sixty seven women completed four 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, and in the third and subsequent years, BEST study trainers were at the facilities once a month. After four 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 % $\pm$ 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 lean soft tissue were also significantly ($p<0.05$) associated with a higher exercise frequency. The benefit of exercise was found in both of the women who used HRT and those not using HRT. However, the combination of exercise and HRT was the most beneficial for BMD.

In general, the greatest increase in lean soft tissue 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 lean soft tissue from baseline in the first year. This effect was lost for years 2 through 4 ($p>0.7$), although the overall 4-year gain was significant for the total study period (5). The exception was for the lumbar spine BMD which continued to respond with an increase in BMD over four years of participation in the BEST study program.

Diet

Dietary intake was assessed at the end of the first year and annually through years 2-4 using the Arizona Food Frequency Questionnaire (AFFQ), modified to include southwestern foods (5). Supplemental calcium intake was assessed over four years from

tablet counts and quarterly self-reports. Vitamin D was not supplemented since 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 four years of the BEST study, who were not using 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, about 900 mg/day of calcium from dietary sources. Thus, it appears that a total calcium intake of at least 1700 mg/day may provide calcium at adequate levels to preserve BMD among postmenopausal women who do not use HRT and who follow the BEST exercise program. This is 500 mg/day more than the current level of Dietary Reference Intake for the adequate intake level of calcium for women over 50 years of age. 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 Four Lessons Learned

After four 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 lumbar spine BMD compared to the women who attended the least number of exercise sessions and lifted the least amount of weight. (5). 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.

INSERT FIGURE 8. HERE

One of the major issues of long-term exercise intervention studies is participant retention. One hundred and seventy-seven of the 266 women who finished the first year of the study went on to complete four years of participation, and since 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 eight years of exercise 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 over four years, postmenopausal women maintained or increased their hip and lumbar spine BMD by participating in a program of weight-bearing and strength training resistance exercise for three days a week, combined with consuming an average of 1700 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 take 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. 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.

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Recommended Reading:

Lohman, T., Going, S., Houtkooper, L., et al. The BEST exercise program for osteoporosis prevention, Tucson: Desert Southwest Fitness, 2004. (For more information go to: http://www.cpanarizona.org/)

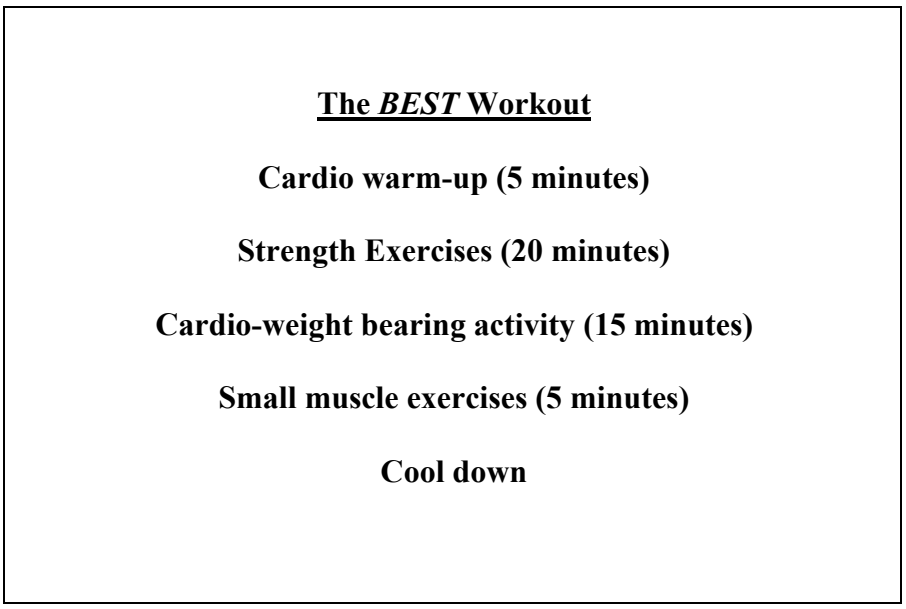

Figure 1. The BEST workout

Figure 2

Figure 3

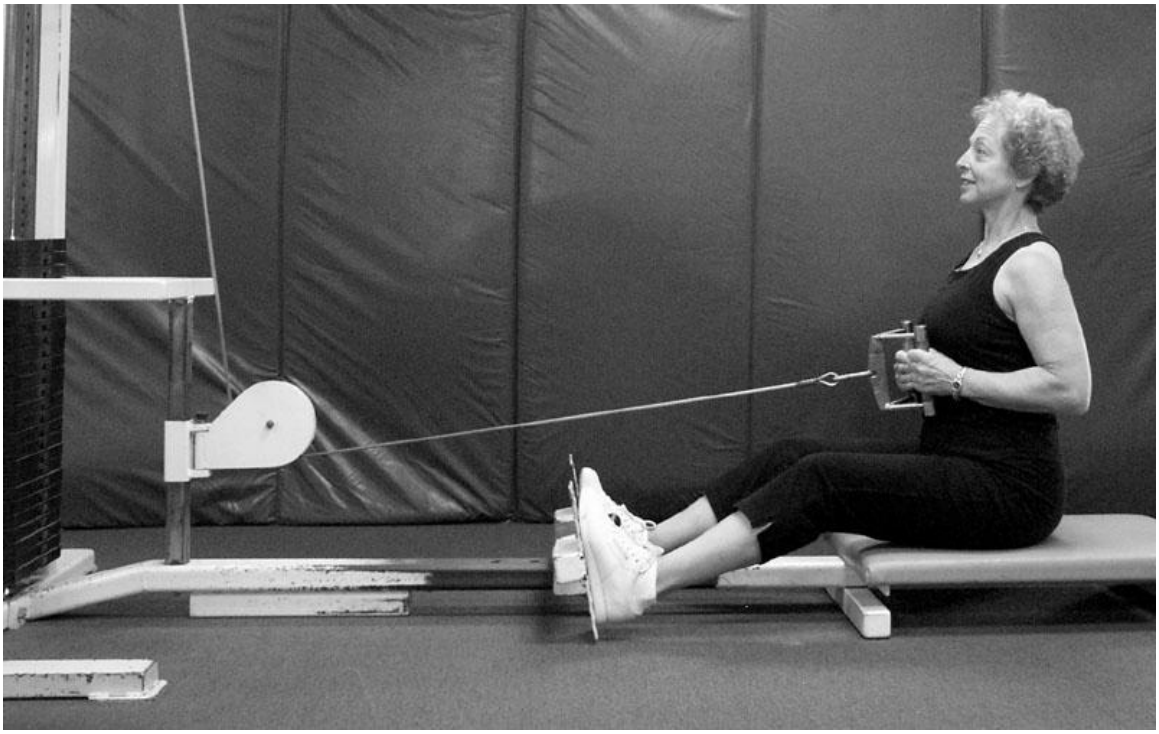

Figure 4

Figure 5

Figure 6

Figure 7

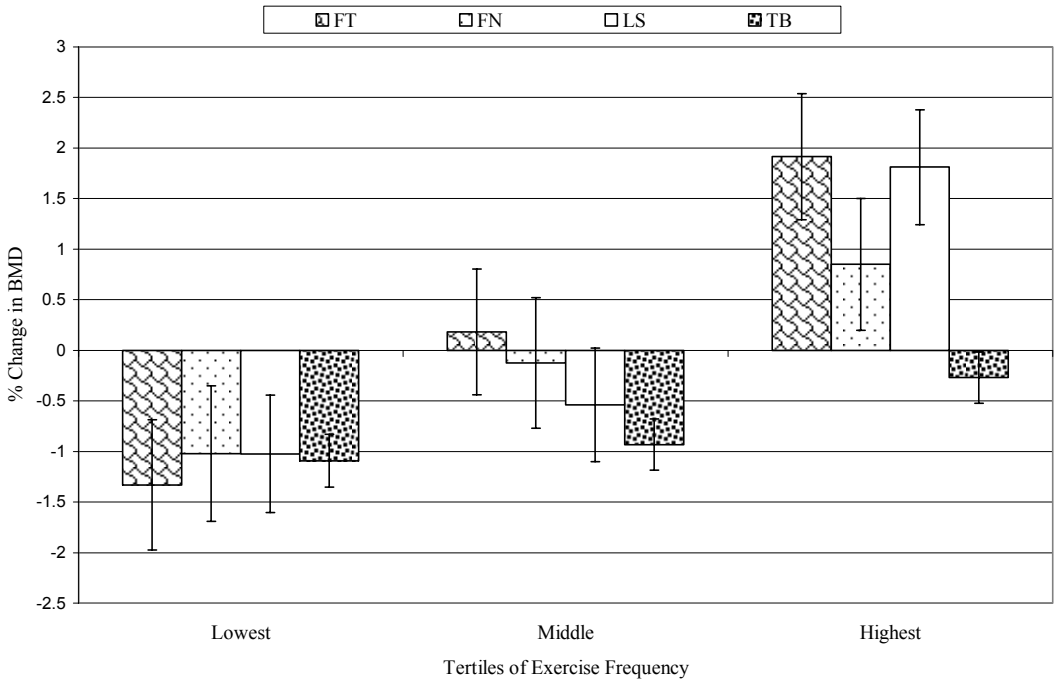

Figure 8. Four-year percentage change in BMD by tertiles of frequency of exercise (n = 167) (FT femur trochanter, FN femur neck, LS lumbar spine, TB total body) (With permission of Springer Science and Business Media) (5)