

# Osteoporosis and Exercise:

## A Review

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### Abstract

**Background:** Osteoporosis is a widespread bone disorder which primarily effects post-menopausal women, with annual costs of six billion dollars. Several studies have looked at the potential value of exercise as an inexpensive and widely available treatment.

**Methods:** Using Medline, English-language articles published after 1989 in major medical journals and containing the key words "exercise" and "osteoporosis" were obtained. Selected prospective studies which included twenty or more subjects were reviewed with special attention to the exercise portion of the protocol. Studies felt to be historically important were also reviewed.

**Results:** Quality of studies, design types and exercise intervention varied greatly. Detailed exercise protocols, high compliance rates and low drop-out rates appeared to favorably effect results.

**Conclusion:** As a whole, the literature suggests that exercise induced improvement in bone mineral density in select individuals. Based on the review the author suggests an ideal program.

**Key Words:** Exercise, osteoporosis, bone mineral density, review.

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OSTEOPOROSIS IS CHARACTERIZED by abnormally low bone mass and micro-architectural deterioration of bone tissue, leading to an increase in bone fragility and a consequent increase in fracture risk (1). The costs of the complications of osteoporosis are estimated at six billion dollars in 1992 (2). Moreover, as the population life expectancy increases, the problem of osteoporosis is likely to grow.

The major complication of osteoporosis is fracture. Fractures are most common in the femur and spine, and their incidence increases exponentially in the later years of life (3). Each standard deviation decrease in femoral neck bone mineral density (BMD) increases the age-adjusted risk of hip fracture 2.6 times (5). BMD accounts for 80–90% of the variance in the strength of the proximal femur (5). BMD assess-

ment can be performed by various methods. Conventional radiographs are considered unreliable. The first quantitative methods developed were single photodensitometry and photon absorptiometry. They measure primarily cortical bone of the appendicular skeleton. More recent techniques can quantify bone mineral content in the spine, the site of early osteoporosis. Dual photon absorptiometry (DPA) and dual x-ray absorptiometry (DXA) measure an integral of compact and cancellous bone of the axial or entire skeleton. Quantitative computed tomography (QCT) measures pure trabecular bone. Most recent investigations favor DXA because of the shortened exam time and greater accuracy compared to DPA, and lower radiation exposure compared to QCT (6).

Bone mineral density may be a modifiable risk factor for fracture, through exercise. This was suggested by early longitudinal studies among cross country runners (7, 8). The first major study to investigate the role of exercise was reported by Lane et al. (9). They compared the BMD of forty-one members of the "50 Plus Runners Association" with age-matched controls

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and found that the runners had about 40% greater BMD. In 1989, Michel et al. (10) expanded this study group to include more females and focus on the amount and types of exercise performed (running, dancing and brisk walking). A strong correlation was found between BMD and up to 300 minutes of exercise per week, but the five women who exercised more than 300 minutes experienced no additional benefit.

In 1989, a similar study by Kirk et al. (11) used a smaller sample size but closely matched controls (T4, FSH,  $VO_2$ max, Vitamin D levels). The researchers found no improvement in vertebral BMD in postmenopausal subjects, only in the premenopausal group (not previously reported). There are significant methodological differences between these studies, making comparison difficult. But they were historically important and served as a springboard to a large number of more recent investigations. For example, a 1996 longitudinal study by Orwoll et al. (12) of more than seven thousand ambulatory women found that general activity level and muscle strength (and, importantly, increased body weight) were associated with increased BMD. Since then, there have been prospective randomized trials which have tested the potential value of exercise in improving BMD.

The goal of this article is to provide the reader with a critical review of important recent exercise intervention trials. Earlier studies have been reviewed elsewhere (13). The physiatrist frequently deals with detailed exercise prescriptions and issues of patient compliance. Some studies involve comparison of multiple intervention (e.g., estrogen, calcium). Special attention will be paid to the exercise portion of the methodology and the stated or likely patient compliance, in order to assist the reader in making realistic conclusions about the types and intensity of exercise required. Specific recommendations and a review of the present understanding of how exercise may affect BMD will follow.

Dalsky et al. (14) reported the first prospective study of the effect of exercise on BMD. Her group used DPA to compare lumbar spine mineral content in 17 exercise volunteers and 18 sedentary controls whose average age was 62. Exercise consisted of three sessions per week of walking, jogging and, eventually, stair climbing, for a total of 50–60 minutes at 70–90% of maximal oxygen capacity. Additionally, each participant performed 15–20 minutes of rowing or cycling. BMD was measured at nine months, and for some subjects at twenty-two months. BMD increased 5.2% at nine months and 6.1% at twenty-two

months, compared to an expected decline of 1.4% in controls. Those who stopped exercising at nine months had their BMD decline to only 1.1% below their baseline after twenty-two months. Although these gains in BMD are among the most substantial reported to date, these subjects were admittedly not randomized in this study, but rather had volunteered to exercise. Indeed, two subjects initially in the exercise group were converted to controls when their initial exercise attendance was poor.

In 1991, Notelovitz et al. (15) published a prospective randomized study of the effects of variable resistance (Nautilus®) exercise on BMD, again using DPA. Twenty subjects who had undergone surgical menopause and were using hormonal replacement therapy (HRT) were randomized into two groups: exercise and sedentary controls. The exercise group worked on a one-to-one basis with an “exercise trainer” three times per week for 15–20 minutes for one year. They participated in at least 70% of their sessions. BMD gains were substantial for the radial mid-shaft (4%), spine (8%) and total body (2%). Of note, subjects were younger in this study (average age 43) than most postmenopausal subjects, because they had undergone surgical menopause. Also the exact onset and duration of HRT are not given, which may discredit the results.

The first large prospective study on this topic was by Prince et al. (16). This two-year study compared sedentary controls, exercise subjects, exercise plus calcium, and exercise plus HRT. The mean age of the subjects was 56. Forty postmenopausal subjects were in each group, all with BMD one standard deviation below the fracture threshold at the distal radius, as determined by CT scanning. The rate of bone loss was similar for the exercise group and the sedentary controls. Calcium slowed bone loss, while the HRT group gained bone mass. This important study concluded that HRT should be used in the treatment of osteoporosis. As a study of the role of exercise, however, it should be viewed with caution, since exercise consisted of only one hour of supervised low impact aerobics per week. Compliance was less than 50%. Moreover, the wrist site was poorly chosen as an area likely to be effected by a traditional low impact exercise program.

In 1994, Nelson et al. (17) were the first to use dual x-ray absorptiometry to perform a randomized, prospective control trial of the effects of high intensity strength training. The average age of her subjects was 61. Under close supervision by a physical trainer (two subjects per trainer), 45 minutes of exercise were performed on pneumatic

resistance machines twice a week for one year at 80% of one repetition maximum (1RM) (80% of the maximal weight that could be lifted once on a given machine). The values for 1RMs were reestablished every four weeks. Exercise was directed at the major proximal muscle groups and an exact protocol is described (three sets of 8 repetitions, with each repetition lasting 6–9 seconds and two minutes between sets). Attendance was 87%. Significant gains in BMD were noted at the femoral neck and lumbar spine. Muscle mass, strength and balance also significantly improved.

In 1995, Pruitt et al. (18) compared high and low intensity resistance training (80% vs. 40% of 1RM with the same total work) in a group of older postmenopausal subjects whose average age was 68. The protocol described was quite similar to Nelson's discussed above and is well outlined by the authors. However, no significant changes in BMD were found. As the number of subjects per trainer is not detailed, it appears that they were trained as a group. Many subjects dropped out of this study. Strength gains, although statistically significant, seem surprisingly small after one year of training (10–66%). For example, the increase in lateral pull-down strength found in Nelson's group was 76% while the change was only 41% in this study. The authors also note that their subjects' baseline BMD was unusually high and felt that this may have prevented further gains. It may also be that the older age of the subjects or the lower level of supervision made the exercise routine less rigorous.

The next two important recent contributions to the osteoporosis and exercise literature involve studies of weight-bearing exercises such as walking, jogging, or aerobics, as opposed to the resistance-training protocols cited above.

In 1995, Kohrt et al. (19) published a one-year interventional trial comparing the combined and separate effects of HRT and weight-bearing exercises in 32 subjects with an average age of 66. Exercise consisted of 2 months of low intensity exercises followed by 9 months of more vigorous exercise (jogging or stair climbing) for 45 minutes between three and five times per week at 65–85% of maximal heart rate (confirmed weekly by heart rate monitoring). The program was individualized, with new goals set weekly. In the last 4 weeks of the study, participants were still averaging 3.3 sessions per week. Exercise or HRT alone caused a significant improvement in BMD of the lumbar spine, hip and femur. HRT plus exercise had an additive effect at the lumbar spine and synergistic effect on total BMD. Because of the small sample size, subjects were not randomized, but

assigned to treatment groups on a matching basis for body weight.

Prince et al. (20) published another article on osteoporosis and exercise in 1995. They compared the effects of calcium and exercise on BMD during a two-year interventional trial. BMD was measured via DXA in the lumbar spine, at three sites at the hip and two tibial sites near the ankle. The average age of subjects was 63. One gram of calcium supplement in either tablet or powdered milk form was found to be beneficial in preventing bone loss at the intertrochanteric hip site and ultradistal tibia. The calcium and exercise group had less bone loss only at the femoral neck site when compared to calcium alone in either form. Again, the actual amount of exercise performed by subjects in this study needs to be carefully scrutinized. Subjects were "asked to perform" three additional hours of weight-bearing exercise per week (two of which could be self-reported walking). No information is given as to the level of supervision or modification of goals during the two-year period. Compliance was only 39%.

As is generally the case with a relatively new area of research, larger, more detailed studies would be of benefit in reaching more definite conclusions. It is worth observing, however, that all of the published work that showed a strong benefit from exercise reported at least two of the following elements: a highly detailed exercise regimen (including type, frequency, intensity and duration), frequent revision and advancement of the exercise goals, close supervision of the subjects, low drop-out rates, high compliance rates, and highly motivated subjects. Significant improvements have been noted with both resistance-type training, and aerobic training, although resistance protocols generally appear to be more effective. A few studies have followed patients for more than one or two years to assess long-term benefits and compliance. These studies have shown a trend toward reversion to pre-exercise levels with discontinuation of exercise (14, 21).

Optimal mechanical strain to enhance bone remodeling has only been tested in animal models. A series of studies by Lanyon and Rubin in isolated turkey or rooster ulna osteotomy preparations have been the most comprehensive (22–24). Changes in bone mass were more responsive to strain magnitude than load cycles. It may be, therefore, that the development of muscular fatigue is an important precondition or stimulus to bone remodeling.

Based on this review, the author feels that the ideal exercise to stimulate BMD would involve progressive resistive training using several slow

repetitions at 70–80% of the one repetition maximum until the muscles feel fatigued. The exercise should be performed at least three times per week for 30 minutes and continued for one year. The 1RM should be adjusted monthly and all of the proximal large muscle groups should be exercised. Walking alone is probably not enough stimulus for BMD changes. The reader is cautioned that this program may be too strenuous and potentially dangerous for elderly patients with concomitant medical problems. Also, patients with a history of vertebral compression fracture should avoid lumbar flexion exercises because of the suspected risk of further fractures (25).

The author believes that, for the well-chosen and motivated individual, exercise is of benefit in improving bone mineral density. It is equally important to remember that there are other clearly well-documented benefits to any exercise program in all postmenopausal subjects, regardless of the potential for BMD change. Exercise has recently been documented to prevent falls and fractures (26). Aerobic exercise performed regularly will diminish the risk of heart disease (27). Finally and most important, patients with osteoporosis who exercise regularly have an improved quality of life (28, 29).

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