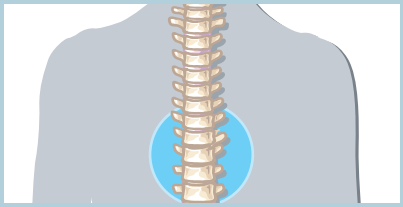
abstract



Physical activity/exercise can provide an important tool for both the prevention and treatment of osteoporosis. Physical stress transmits load to the bone and can improve or maintain its structural competence and strength. Participation in weight-bearing activities during adolescence is an effective method to achieve an ample peak bone mass and to reduce the risk for the later development of osteoporosis. Postmenopause, the ideal exercise to stimulate bone mineral density would involve progressive, resistive-type training involving overloading of some nature.

Key words: *functional loading, weight-bearing activities, resistance training, peak bone mass, bone mineral density*

Physical Activity for the Prevention and Treatment of Osteoporosis

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Introduction

Osteoporosis—derived from the Greek words *osteon*, meaning bone, and *poros*, meaning small hole—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. Osteoporosis is more common among women over the age of 50 as a result of hypoestrogenemia, but it also affects men and can occur in individuals of any age. In addition, many chronic illnesses (e.g., asthma, inflammatory myopathies, and duchenne muscular dystrophy) involve treatment with corticosteroids, which are also known to cause elevated bone resorption and reduced bone formation, resulting in lower bone mass. The social and medical consequences related to osteoporosis include an increased risk of fracture and a reduced quality of life. Individuals with osteoporosis are likely to experience fractures with forces no greater than those applied by routine daily activity. It is estimated that there has been a four-fold increase in hip fractures worldwide since 1990.[1] Osteoporosis can also result in disfigurement, lowered self-esteem, reduction or loss of mobility, and decreased independence.

As there is no cure for osteoporosis, physical activity/exercise has been suggested as a particularly effective strategy in averting the inevitable repercussions of this disease. Regular physical activity has been shown to improve or maintain the structural competence of bone. It is well established that physical activity transmits load to the bone via two mechanisms—direct impact from weight-bearing exercise and the pull that is produced by the muscle contraction. These forces lead to alterations in bone shape and, to a large degree, determine bone strength.[2]

Physical Activity and Osteoporosis Prevention

Childhood through to late adolescence is a significant period in bone formation, with about 50% of the peak bone mass (PBM) being acquired during this period. Peak bone mass is defined as the amount of bony tissue present at the end of skeletal maturation. Because a low peak bone mass is a significant risk factor for osteoporosis and associated fractures,[3] the achievement of an ample peak bone mass during childhood and adolescence is an effective method to reduce the risk for the later development of osteoporosis. Debate continues as to the age at which peak bone mass is attained, with estimates ranging widely in cross-sectional data from late adolescence[4] to the third[5] and into the fourth[6] decades of life. Some studies show that significant loss of trabecular bone may also occur immediately after the acquisition of PBM, even before menopause, at some sites (e.g., proximal femur).[6,7] Given that the incidence of fracture in North America is about twice as great for women as it is for men, women must use all available means to achieve the highest possible peak bone mass. Since, for most sites of the skeleton, peak bone mass is established by late adolescence,[7] this period of life provides the singular best opportunity to employ strategies aimed at optimizing and maintaining premenopausal bone mineral status and, thus, reducing the risk of developing osteoporosis.

Although genetics accounts for

Table 1: Intervention Studies Published in the Last Ten Years Using Different Exercise Programs in Postmenopausal Women

Authors	Program	Participants	Site Measured	Results
Kohrt et al., 1995[22]	12 months of weight-bearing exercises	32 postmenopausal women, aged 66 years	L2–L4, FN, TH	Significant improvements in the BMD of the lumbar spine, hip, and femur[22]
Hartard et al., 1996[19]	Six months of strength training	16 women, aged 63.6 years, in the training group and 15 women, aged 67.4 years, in the control group	L2–L4, FN	No significant changes in BMD at both sites for the exercisers; significant loss of bone mineral density in the controls[19]
Kerr et al., 1996[17]	12 months of progressive resistance training	56 postmenopausal women	TR, ITH, WT, RF	BMD significantly greater at all hip sites (controls -0.1% to -0.8%, exercisers +1.5% to +5.2%) and at the radial site (controls -1.4%, exercisers +2.4%)[17]
Bravo et al., 1997[23]	12 months of weight-bearing, water based exercises	77 osteopenic women, 50–70 years of age	FN	No changes in femoral neck BMD; improved flexibility, agility, muscle strength, endurance, cardiorespiratory fitness, and psychological parameters[23]
Ebrahim et al., 1997[24]	24 months of self-paced brisk walking or upper limb exercises	165 women with history of upper limb fracture in the last two years	L2–L4	Lumbar BMD increased (+0.017 g/cm2) in both walking and upper limb groups[24]
Snow et al., 2000[18]	Five years of jumping exercises with weighted vests	18 healthy women, aged 64.1 years	FN, TR, TH	Increased femoral neck BMD in the exercisers; higher BMD at all regions in the exercisers when compared to controls[18]
Maddalozzo et al., 2000[25]	High intensity free-weight training	Older men and women	TR	Increased BMD in men (1.9%) but not in women[25]
Walker et al., 2000[20]	Five years of weight-bearing aerobic activities of moderate intensity and free weight resistance exercises both in the hospital and at home	89 postmenopausal osteoporotic women, aged 63.2 years	L2–L4, FN	Lumbar BMD increased +4.4% in the hospital group and +3.4% in the home group; for the femoral neck BMD increased +1.1% in the hospital group and –0.9% in the home group; reduction in the number of fractures and no significant loss of height[20]
Yamazaki et al., 2004[21]	12 months of moderate walking	50 osteopenic/osteoporotic women, aged 49–75 years	L2–L4	Lumbar BMD was sustained; suppression of bone turnover as indicated by decreased urinary NTX-1 levels[21]

BMD - bone mineral density; FN - femoral neck; TB - total body; TH - total hip; TR - trochanter; ITH - intertrochanteric hip; WT - Ward's triangle; RF - radial forearm

approximately 75% of the variation in bone mass, certain modifiable lifestyle factors have a strong influence on the remaining variation in PBM. Physical activity and exercise have been proposed as simple and effective means of improving bone mass and maintaining its structural integrity throughout life, and seems to be one of the most important modifiable variables affecting bone.[8–10] The value of physical activity as a tool for the prevention of osteoporosis lies in its potential to reduce bone loss, improve muscle strength, prevent falls, and reduce bone fractures.[1] The greater mechanical loads on the bones of physically active individuals are thought to result in an increase in bone strength.[2] As mentioned above, the loads applied to bone as a result of physical activity include the direct impact down the long axis of the bone during weight-bearing activities and the torsional force on the bone as the muscles contract. While it is well established that the decreased mechanical loading from physical inactivity (as in bed rest and spaceflight) results in bone resorption and a profound decline in bone mass,[11] the observed improvements in bone mass resulting from increased physical activity are less conclusive. In other words, changes in bone mass occur more rapidly with unloading than with increased loading. Given that it may not be possible to increase bone mineral density following the acquisition of peak bone mass, it is clear that regular physical activity is essential to the effective maintenance of bone mass and decreasing the rate of age-associated bone loss.[12]

Education is a major component in any prevention strategy. Research has demonstrated that women's willingness to adopt healthy behaviours, including physical activity/exercise, depends on the level of knowledge of osteoporosis and its antecedents.[13] Unfortunately, there appears to be a general lack of knowledge concerning osteoporosis risk factors, particularly on the topics of calcium intake and physical activity, and the perception of low risk for developing osteoporosis among college women persists.[14] Predictors of behaviour in terms of exercise habits and calcium intake were best explained by barriers to exercise and exercise self-efficacy. It is, therefore, apparent that any preventative strategy aimed at reducing the chances for developing osteoporosis must begin through education and that this education must begin before women reach menopause. An accurate knowledge of osteoporosis and its risk factors should help young women identify their relative risk of developing the disease, thereby encouraging them to reduce the risk by taking preventative action.

Exercise Prescription and Osteoporosis Management

Regular physical activity can reduce fractures, not only by increasing bone mass but by decreasing falls though increased muscle strength, improved balance, and maintaining body mass. Clinical trials have used a variety of exercise programs to demonstrate the effectiveness of exercise as an intervention strategy for reducing osteoporotic fractures. Various forms of aerobic and resistance activities of differing intensity and duration have been examined in postmenopausal women in relation to bone health. Higher impact activities have been shown to be more beneficial for bone health in women when compared to nonimpact types of activity, such as swimming. It has been reported that weight-bearing activities produce a mechanical loading which, combined with the force of gravity, creates electrical charges in the bone that stimulate bone formation. Thus, activities such as walking, jogging, weight lifting, hiking, stair climbing, aerobics, and dancing are among some of the most beneficial activities. Interestingly, these types of weight-bearing activity have been reported to have a favourable influence on weight-bearing as well as non–weight-bearing bone in postmenopausal women.[15] Strength-training programs have also been found to have a positive effect on regional bone density in postmenopausal women.[16,17] Kerr *et al.* have shown that the most significant gains in bone mass can be achieved from a program that employs a relatively heavy load with fewer repetitions.[17] Further, long-term exercise programs using weighted vests have been found to prevent significant bone loss in older postmenopausal women.[18]

Many of these studies, however, involve only healthy postmenopausal women. There are few studies that have looked at the ability of women diagnosed with osteoporosis to improve bone mineral density and reduce fractures through an exercise-training program. A controlled trial involving postmenopausal women who had an established bone loss of at least 30% has demonstrated that bone mineral density did not change in the strength-training group, but fell significantly in the control group, indicating that the physical activity was beneficial in preventing the continued loss of bone.[19] If one examines the results of all prospective trials of exercise, and averages the results of the bone mineral density measurements, the mean net increase is one percent per year. Table 1 summarizes the findings of exercise intervention studies in postmenopausal conducted over the last 10 years.

Although the general belief is that any prescribed exercise regimen involving osteoporosis patients is best done under the provider's supervision, this may not be a prerequisite in osteoporosis management. Walker *et al.* examined neck and lumbar BMD scores of 89 postmenopausal women (60–68 years of age).[20] Subjects were prescribed an exercise regimen that was either completed at home or in a supervised hospital setting. The program consisted of 20 minutes of low-load strength training and 30 minutes of aerobic activities (walking and dance) at 70–80% of maximum heart rate, twice a week. The authors concluded that it is possible to stabilize height and BMD at the lumbar region with the prescribed exercise program and reported a decreased incidence of fractures over a five-year period, regardless of whether the activity was done at home or in the hospital.[20] Similar findings were reported by Yamazaki *et al.* both for lumbar bone mineral density and biochemical markers of bone turnover (urinary NTX-1

levels, serum BAP, OC, and bone ALP levels).[21] Their examination of 50 postmenopausal women (ages 49–75 years) with osteopenia/osteoporosis included an exercise group who walked (50% VO2max) for one hour, four days a week, over a one-year period. It was found that lumbar bone mineral density was sustained via suppression of bone turnover, as indicated by decreased urinary NTX-1 levels. While the effect on the lumbar bone mineral density change was modest, the authors were able to conclude that exercise has an antiresorptive effect on bone in this population.[21]

In addition to the variety of exercise modalities and intensities implemented in the various studies, the literature also reveals a large variation in intervention duration, with both long duration (12 months or longer) and short (six months or less) programs. While it is generally agreed that it takes at least 12 months to detect any significant changes in bone mineral density, research has shown that the mechanism for the exercise-induced positive response of lumbar bone mineral density in postmenopausal women with osteopenia/osteoporosis is the suppression of bone turnover, and that a change as early as three months in N-telopeptides may be useful to predict the long-term response of increasing lumbar bone mineral density with exercise.[21]

Overall, the ideal exercise to stimulate bone mineral density would involve long-term, progressive, resistive-type training, using several slow repetitions involving overloading of some nature. Weight-bearing activities are recommended while a progressive program using a weighted vest would also be beneficial.

Conclusion

In summary, this review of the literature on osteoporosis and exercise indicates that exercise can be beneficial in the treatment and prevention of osteoporosis. The ideal exercise to stimulate bone mineral density would involve long-term, progressive, resistive-type training, using several slow repetitions involving overloading of some nature. If walking is the preferred activity, then it is suggested that a progressive program using a weighted vest would provide the overload stimulus necessary to stimulate bone. While the optimal dose-response between exercise and bone mass has yet to be established, and although there is still only minimal information on the amount of daily physical activity required to achieve optimal bone mass and strength, many of the reported studies show that physical activity is beneficial with respect to bone health, and that functional loading through regular exercise can exert a positive influence on bone mass in aging humans. ◆

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