Review Article

Role of exercise in osteoporosis prevention - Current concepts

Mozaffer Rahim Hingorjo[1], Sadiqa Syed[2], Masood A.Qureshi[3]

Department. of Physiology[1,2], Fatima Jinnah Dental College, Karachi, Department of Physiology[3], Dow International Medical College, Dow University of Health Sciences, Karachi.

Abstract

Osteoporosis is a metabolic disorder of the bones due to loss of both bone mineral and bone matrix in equal proportions resulting in a bone that is weak and unable to support the body. This becomes a problem in the elderly who are then at risk of frequent fractures increasing the morbidity and mortality. Measures taken early in life in the form of calcium and exercise go far in preventing the development of this disorder. The primary purpose of this narrative review is to evaluate the current literature and to provide insight into the role of exercise relating to osteoporosis. Emphasis is given to the importance of the specific types of exercises needed to increase bone strength and muscle power, keeping in view the age and general physical condition of the person.

Introduction

OSTEOPOROSIS is defined by the NIH Consensus Development Panel on Osteoporosis as "a skeletal disorder characterized by compromised bone strength predisposing a person to an increased risk of fracture."[1] The WHO Working Group has defined osteoporosis according to the measurement of bone mineral density (BMD) using dual-energy X-ray absorptiometry (DEXA). A T-score value of 2.5 standard deviation or more below the young adult mean is considered diagnostic for osteoporosis.[2]

Bone mineral density at any time in life depends upon the peak bone density achieved during the development and growth period (especially at the time of puberty) and the subsequent adult bone loss. Regular

physical activity done during childhood increases the peak bone mass to its maximum as the human skeleton before puberty is quite sensitive to mechanical stimulation elicited by physical activity. A study revealed that weight bearing exercise for six months increased bone parameters by 5.5 % approximately around puberty. This fell to a maximum of 1.9 % in late puberty.[3]

High volumes of exercise are not required to achieve notable osteogenic effect, rather just three hours of participation in sports is enough.[4] Girls who exercise athletically during years of peak bone acquisition have higher bone mass than their sedentary counterparts and this appears to have lasting benefits for lumbar spine and proximal femoral bone mass density later in life.[5] Exercise done during late adulthood increases the bone mass minimally if at all, its main purpose being to maintain the bone mass. During old age the bone loss is rapid. This loss starts at around the age of 40 in both sexes and is initially 0.3 - 0.5% of the peak bone mass per year, gradually increasing as the age progresses, though some women may have a very rapid loss after the menopause, up to 5 or 6%, resulting in a rapid reduction in bone mass. Exercise done at this age decreases the rate of bone loss as well as improves muscle strength thereby providing balance, preventing falls and subsequent fractures.[6] In view of the increase in life expectancy in our population and increased incidents of multiple fractures in middle aged and elderly subjects the effect of exercise on osteoporosis is reviewed.

Factors affecting Osteoporosis

Age related loss in bone mineral content occurs in both the compact and trabecular bones, however, the mass of trabecular bone does not change due to an overall enlargement of trabecular area as the age advances.[7]

Besides aging, several conditions can exaggerate the loss of mineral content which include nutritional, endocrinological, and exercise-related factors. The role for dietary calcium in influencing bone mineral content is well established especially in the first three decades of life, however, its intake decreases as a person grows older.[8]

In women, the most important determinant of bone mineral content is the presence of circulating estrogen. Any condition that reduces estrogen concentrations influences bone remodeling. After menopause the rate of trabecular mineral loss can increase up to 6% a year, with a greater loss in first 5 years. The rate of loss is large compared to the average loss before menopause of less than 1% a year. Hormone replacement therapy given at this time increases the BMD and affects bone remodeling but not as much as when it is combined with an exercise program.[9]

Classification of subjects according to BMD

The WHO Study Group[10] has classified osteoporosis according to BMD as follows:

A. Normal: BMD within 1 standard deviation (SD) of the young adult reference mean.
B. Osteopenia: Mild bone loss - BMD more than 1 SD below the young adult mean but less than 2.5 SD below this value.
C. Osteoporosis: BMD 2.5 SD or more below the young adult mean.
D. Severe osteoporosis (or established osteoporosis): BMD 2.5 SD or more below the young adult mean in addition to one or more fragility fractures.

Exercise prescribed for a younger person with a normal BMD would not be suitable for a frail elderly with osteoporosis, having an imminent risk of fracture. And the goals for one group may not be achievable in another group.

How exercise effects bone mass

The stimulus for bone to maintain its structural and functional strength is the load exerted upon it on account of gravity and mechanical stress applied by the muscles. It has been observed that weight bearing activity stimulates bone remodeling whereas lack of mechanical stimulation as seen in space travelers or in paralyzed limbs can lead to osteoporosis. To evaluate the role of exercise in osteoporosis it is important to understand how mechanical signals are converted into biochemical response. Osteocytes are the primary bone mechanosensors embedded within the bone matrix that sense mechanical signals via 'stress-generated fluid flow' inside the bone. This is evident by the increase of both intra-cellular and extra-cellular chemical mediators after skeletal strain such as the formation of cyclooxygenase-2 (COX-2) and release of prostaglandins.[11,12] However, the exact mechanism by which osteocytes and osteoblasts respond to fluid flow is not known.

Recently, it has been shown that the bones respond not only to increased magnitude of strain but to increased frequency of strain as well. This finding is particularly advantageous to frail population who are unable to do strenuous exercise due to the risk of fracture.[13,14]

What type of exercise should be advised?

Exercise strengthens muscles, increases flexibility, and improves coordination and balance. The importance of exercise in relation to bones is evident after disuse which results in a decrease in bone mineral density and thinning of cortical bone at the diaphysis. Bones being live tissue, respond to the stress placed by the environment. When that

stress is removed in the form of lack of physical activity, the bones loose their density. A paralyzed limb loses > 10% of bone mass in a year - equivalent to 20 years of bone loss.[15] How much exercise is needed to prevent this loss is yet to be determined as longitudinal studies are underway. Presently what is needed is to prescribe the type and amount of activity on an individual basis keeping in mind the goals to be achieved for that person. A person with normal BMD or osteopenia could be advised a more vigorous exercise programme in order to prevent the development of osteoporosis. These people because of their bone structure can withstand the stress applied during such exercises. On the other hand persons having osteoporosis already have fragile bones and should not be prescribed strenous exercises. Persons with established osteoporosis, i.e. those people who have severe osteoporosis and already have had a fracture have their activity restricted because of the fear of falling and over here the basic aim is to promote balance thereby preventing further falls.[16]

The beneficial effect of exercise on BMD is greatest among those who were previously sedentary as compared to very active individuals who will see less of an effect. To be effective, in terms of compliance and body fitness, all exercise programs should be started from a lower level of performance and build up progressively. An ideal programme should include activities that increase muscle strength, balance, flexibility and coordination.

Types of exercises

Two types of exercises are generally recommended for osteoporosis:

1. Weight-bearing exercises
2. Strength training or resistance exercises

Weight-bearing exercises are those in which the muscles and bones bear the weight of the person and work against gravity. This includes any exercise in which the arms, feet and legs are bearing the weight, such as walking, jogging, stair climbing, playing tennis, volleyball and similar sports, performing aerobics, tai chi and dancing. Persons having osteoporosis should start with a gentle exercise such as walking on level ground that has been shown to increases BMD[17] as other forms of exercises may increase their chances of fall.

Low impact aerobic exercises such as swimming and cycling do not have a significant effect on the bones as regards osteoporosis, however, due to their beneficial influence on the heart, they should be part of a regular fitness regimen.

Strength training or Resistance exercises are activities in which the body is moved through its range of motion against some kind of resistance. The resistance can be in the form of free weights, machines, tubing, or one's own body weight. Lifting weights, push-ups, and squats apply resistance against the bones by contracting the muscles and pulling upon the tendons. This has a direct effect upon bone formation and remodeling which is site specific and associated with high BMD in young and older individuals.[18,19] Strengthening the muscles helps in daily tasks such as walking, standing from a sitting posture and helping improve balance thus preventing falls.[20] Postural exercises that strengthen the back muscles prevent against the development of compression fractures of the spine.[21]

Persons with established osteoporosis have a fear of fall due to their lack of balance and coordination in their limbs and thus become more and more dependent on others. In this group, the above exercises will put a further strain on the bones and can lead to more fractures. The aim therefore should be for a targeted exercise programme that would improve their balance and increase muscle power. Exercises like yoga and tai chi are low impact weight bearing exercises involving slow, controlled movements that improve balance, muscle strength and help in alleviating the fear of falling.[22]

In old age, pain is a prominent factor, restricting activity of any kind. Hydrotherapy consists of exercises performed in warm water. The temperature of the water reduces the pain thus allowing patients to move their limbs. In addition, buoyancy relieves the body of its weight and allows certain movements that would not have been possible otherwise.[23]

Whole body vibrations is a new form of exercise consisting of vibrations of low amplitude and high frequency applied to the whole body while the subject is in a comfortable position. It has been shown to be a better alternative than walking in improving both bone mineral density and balance of elderly frail subjects.[14]

How much exercise is recommended?

A consensus on the optimal dimensions of exercise (type, frequency, duration and intensity) recommended for a person has still not reached as it would also depend on the age of the person and their bone health.[24] However, an exercise programme that includes both weight bearing and resistance exercises done for 30 - 40 minutes daily, three to four times each week appears to achieve the purpose of increasing bone mass. Although the recommended intensity of training is between 70 and 80% of the functional capacity or maximal strength but this has yet to be decided.[25] Extreme levels of exercise such as marathon running may in fact cause osteoporosis besides having other deleterious

effects on the health. Of course each person has to tailor the exercises according to his or her own capabilities, keeping in mind that some exercise is better than no exercise at all. It should be realized, however, that any skeletal benefit acquired during exercise will not be maintained if the person returns to his previous sedentary lifestyle.[26]

Conclusion

Osteoporosis is a public health issue that leads to increased morbidity and mortality. This is especially important in relation to post-menopausal women and the elderly. Lack of awareness about the disease process and its causative factors play a primary role in the progression of osteoporosis. In the present era of flood of information through television channels and media, and latest computer technology, the people have opted for a sedentary lifestyle in which case the importance of exercise cannot be overemphasized. Cross-sectional and interventional studies have shown a positive correlation between exercise and BMD, with high impact exercises having the greatest effect. Furthermore, the increase in bone mineral density is maximum when exercise is done at a younger age. Elderly population loses their bone mass rapidly and exercise slows down this process, as well as increasing muscle strength and coordination thus decreasing their chances of fall. New forms of exercises such as whole body vibration improve BMD and balance and may be a better alternative to walking in the elderly. In addition to exercise, a proper intake of calcium and if needed, hormone replacement therapy for women, play a cumulative role in preventing the development of osteoporosis. Apart from having an effect on the bones, exercise is beneficial for the cardio-respiratory system, improves diabetic control, reduces weight of a person and alleviates the mood, thus improving the quality of life and level of daily functioning. As it does not cost anything and if done properly, is free from side effects, exercise should be prescribed at all levels of bone health.

References

1. Osteoporosis prevention, diagnosis and therapy. NIH Consensus Statement 2000; 17: 1-45.
2. NIH Consensus Department Panel on Osteoporosis Prevention, Diagnosis and Therapy. Osteoporosis prevention, diagnosis, and therapy. JAMA 2001; 285: 785-95.
3. Hind K, Burrows M. Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials. Bone 2007; 40: 14-27.
4. Vicente-Rodriguez G. How does exercise affect bone development during growth? Sports Med 2006; 36: 561-9.
5. Rideout CA, McKay HA, Barr SI. Self-reported lifetime physical activity and areal bone mineral density in healthy postmenopausal women: the importance of teenage activity. Calcif Tissue Int 2006; 79: 214-22.
6. Kemmler W, Engelke K, von Stengel S, Weineck J, Lauber D, Kalender WA. Long-term four-year exercise has a positive effect on menopausal risk factors: the Erlangen Fitness Osteoporosis Prevention Study. J Strength Cond Res 2007; 21: 232-9.
7. Gatti D, Rossini M, Zamberlan N, Braga V, Fracassi E, Adami S. Effect of aging on trabecular and compact bone components of proximal and ultradistal radius. Osteoporos Int 1996; 6: 355-60.
8. Coaccioli S, Ponteqqia M, Ponteggia F, Fatati G, Di Gianvito A, Puxeddu A. Osteoporosis prevention: a reasoned examination of food habits and physical activities in a schoolchildren population in central Italy. Clin Ter 2006; 157: 489-94.
9. Milliken LA, Going SB, Houtkooper LB, Flint-Wagner HG, Fiqueroa A, Metcalfe LL, et al. Effects of exercise training on bone remodeling, insulin-like growth factors, and bone mineral density in postmenopausal women with and without hormone replacement therapy. Calcif Tissue Int 2003; 72: 478-84.
10. WHO Study Group on assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: Report of a WHO Study Group. WHO Technical Report Series 843; 1994.
11. Riddle RC, Taylor AF, Genetos DC, Donahue HJ. MAP kinase and calcium signaling mediate fluid flow-induced human mesenchymal stem cell proliferation. Am J Physiol Cell Physiol 2006; 290: 776-84.
12. Ponik SM, Pavalko FM. Formation of focal adhesions on fibronectin promotes fluid shear stress induction of COX-2 and PGE2 release in MC3T3-E1 osteoblasts. J Appl Physiol 2004; 97: 135-42.
13. Beck BR, Kent K, Holloway L, Marcus R. Novel, high-frequency, low-strain mechanical loading for premenopausal women with low bone mass: early findings. J Bone Miner Metab 2006; 24: 505-7.
14. Gusi N, Raimundo A, Leal A. Low-frequency vibratory exercise reduces the risk of bone fracture more than walking: a randomized controlled trial. BMC Musculoskelet Disord 2006; 7: 92.
15. Beaupre GS, Lew HL. Bone-density changes after stroke. Am J Phys Med Rehabil 2006; 85: 464-72.
16. Madureira MM, Takayama L, Gallinaro AL, Caparbo VF, Costa RA, Pereira RM. Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. Osteoporos Int 2007; 18: 419-25.
17. Palombaro KM. Effects of walking-only interventions on bone mineral density at various skeletal sites: a meta-analysis. J Geriatr Phys Ther 2005; 28: 102-7.
18. Ryan AS, Treuth MS, Rubin MA, Miller JP, Nicklas BJ, Landis DM, et al. Effects of strength training on bone mineral density: hormonal and bone turnover relationships. J Appl Physiol 1994; 77: 1678-84.
19. Kerr D, Ackland T, Maslen B, Morton A, Prince R. Resistance training over 2 years increases bone mass in calcium-replete postmenopausal women. J Bone Miner Res 2001; 16: 175-81.
20. Sequin R, Nelson ME. The benefits of strength training for older adults. Am J Prev Med 2003; 25: 141-9.
21. Chien MY, Yang RS, Tsauo JY. Home-based trunk-strengthening exercise for osteoporotic and osteopenic postmenopausal women without fracture - a pilot study. Clin Rehabil 2005; 19: 28-36.
22. Maciaszek J, Osinski W, Szeklicki R, Stemplewski R. Effect of Tai Chi on body balance: randomized controlled trial in men with osteopenia or osteoporosis. Am J Chin Med 2007; 35: 1-9.
23. Devereux K, Robertson D, Briffa NK. Effects of a water-based program on women 65 years and over: a randomized controlled trial. Aust J Physiother 2005; 51: 102-8.
24. Shipp KM. Exercise for people with osteoporosis: translating the science into clinical practice. Curr Osteoporos Rep 2006; 4: 129-33.
25. Chien MY, Wu YT, Hsu AT, Yang RS, Lai JS. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. Calcif Tissue Int 2000; 67: 443-8.
26. Winters KM, Snow CM. Detraining reverses positive effects of exercise on the musculoskeletal system in premenopausal women. J Bone Miner Res 2000; 15: 2495-503.