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CHAPTER 12

OSTEOPOROSIS

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EPIDEMIOLOGY AND PATHOPHYSIOLOGY

Osteoporosis is the most common disease that affects the skeleton. It is estimated that between 7 and 10 million women in the United States currently have osteoporosis (1), although the estimate varies based on which skeletal sites are measured to diagnose osteoporosis. In addition, although osteoporosis is thought of primarily as a disease of women, an estimated 2 million men in the United States have osteoporosis, and 3 million more may be at risk (2). Approximately 1.3 million osteoporotic fractures occur in the U.S. each year, and of these, half are spinal fractures and a quarter are hip fractures. Fractures of the hip and spine result in disability, decreased independence and quality of life, and increased risk of death (3). A 50-year-old woman has a lifetime fracture risk of 54%. Her risk of sustaining a spinal fracture is 32–35%, 16–18% for a hip fracture, and 15–17% for a wrist fracture. The majority of hip fractures occur as a consequence of traumatic falls, making falls the number one cause of accidental death in people over the age of 75. There are approximately 50,000 deaths each year as a result of complications from hip fracture. Although men are at a lower risk for sustaining a hip fracture than women, the mortality associated with hip fracture is higher in elderly men compared to women (4). The current cost of osteoporosis to the health-care system is estimated at \$10–15 billion per year (5, 6), with approximately 20% of that cost attributable to fractures in men. This cost is expected to rise to \$30 billion by the year 2020.

Definition and Classification

Osteoporosis, often called “brittle-bone disease,” is defined as a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue with a consequent increase in bone fragility and susceptibility to fracture (7). There are two categories of osteoporosis: primary osteoporosis and secondary osteoporosis (8). Primary osteoporosis is due to a disruption in the normal cycle of bone turnover. Postmenopausal osteoporosis (formerly known as Type I osteoporosis) is catego-

rized as primary osteoporosis. Other types of primary osteoporosis include senile osteoporosis (formerly known as Type II osteoporosis) and idiopathic osteoporosis (8). Secondary osteoporosis occurs when bone loss is a consequence of diseases such as Cushing’s disease, hyperthyroidism, and prolonged treatment with corticosteroids (8).

Bone Physiology

Bone tissue has three main functions. First, bones provide structural, mechanical, and protective support for soft tissues, serving as attachment points for skeletal muscle and acting as levers for locomotion. Second, the skeleton is responsible for maintaining calcium homeostasis, as well as serving as a storage site for phosphate, magnesium, potassium, and bicarbonate. Finally, the skeleton is the primary site of hemopoiesis (9).

There are two types of bone tissue, cortical bone and trabecular bone. Cortical bone, also known as compact bone, is found in the shafts of the long bones and comprises approximately 80% of the skeleton. Trabecular, or cancellous, bone constitutes the remaining 20% of the skeleton. Trabecular bone is arranged in a honeycomb pattern of trabeculae and is found in the flat bones, such as the pelvis and vertebral bodies, and in the ends of the long bones, such as the head and neck of the femur. Trabecular bone is more metabolically active than cortical bone and, therefore, is more sensitive to changes in biochemical, hormonal, and nutritional status. Because of this, trabecular bone is more susceptible to being lost and trabecular sites are typically where age-related losses in bone are first detected. It is for this reason that a majority of osteoporotic fractures occur in areas with a large proportion of trabecular bone: the lumbar spine, proximal hip (femoral neck and greater trochanter), and distal radius and ulna (10).

The adult skeleton is a dynamic organ that undergoes a constant process of resorption and deposition, referred to as remodeling. Remodeling serves to maintain the architecture and strength of the bone, maintain mineral homeostasis, and prevent fatigue damage. Remodeling is also important during periods of growth when the majority of

adult bone mass is laid down (11). Bone remodeling should be distinguished from bone modeling. Modeling and remodeling often occur simultaneously, and distinctions between them are not always apparent, but in general, bone modeling refers to alterations in the shape of the bone such as changes in length. Bone modeling usually ceases around the age of 18–20 when the skeleton stops growing. Remodeling occurs throughout the life span (11).

Bone resorption is carried out by osteoclasts, large multinucleated cells originating from stem cells in the bone marrow. Resorption involves the dissolving of bone mineral by proteolytic enzymes and organic acids released from the osteoclasts. The result is a cavity of approximately 60 μm within the surface of the bone. The deposition of new bone matrix in the cavity created by the osteoclasts is carried out by osteoblasts. Bone matrix is composed of collagen fibers and calcium salts known as hydroxyapatite.

Osteoporosis results when the rate of bone resorption exceeds that of deposition. During young adulthood, these two processes are balanced, and bone loss is minimal or bone mass is maintained. During perimenopause, women lose bone mass at a rate of approximately 1% per year. At menopause, when ovarian function ceases, estrogen deficiency ensues and results in rapid bone loss for up to 5 years after menopause (12, 13). There also appears to be some age-related bone loss (approximately 0.5–1.0% per year) experienced by both men and women (13, 14), although the exact age of onset of this loss is not known. Osteoblasts seem to be more greatly affected by aging than osteoclasts, and thus, bone formation decreases more than bone resorption, resulting in this age-related bone loss (15).

Risk Factors and Pathophysiology

There are several risk factors associated with osteoporosis, some of which are immutable and others that may be modifiable. Immutable risk factors include family history of osteoporosis, gender, advanced age, and race. Risk factors that might be modifiable, to some extent, include dietary factors, physical activity, body weight, smoking, gonadal hormone status, and use of certain medications (16).

As with many diseases, including cancer and cardiovascular disease, osteoporosis tends to be genetically related. Peak bone density and/or rate of bone loss are dependent on genetic components as well as shared environmental factors. Women are at greater risk than men for developing osteoporosis. This is mostly due to the postmenopausal loss of estrogen, but is partly due to the facts that women tend to be less physically active than men, have a smaller bone size, and most women also have inadequate calcium intakes. It appears Caucasians and Asians may be at greater risk for osteoporosis, but this is debatable (17).

Dietary factors that can influence the risk of osteoporosis include inadequate calcium and vitamin D intake and excessive consumption of caffeine and alcohol. Adequate

calcium intake is necessary for the attainment of peak bone mass as well as being effective in reducing postmenopausal bone loss. Vitamin D is required for calcium absorption from the gut and for the maintenance of bone calcium (18). Caffeine causes a short-term increase in urinary calcium loss and is associated with an increased risk of hip fracture in elderly women (19). Similarly, alcohol is associated with increased urinary loss of calcium, and excessive alcohol intake may reduce absorption of calcium from the intestine. Alcohol is also toxic to osteoblasts (20).

Body weight is directly correlated to bone density (21) and is the greatest determinant of bone density in adults (20). Smoking is associated with low bone mineral density (BMD), an increased risk of fracture (22), and is thought to interfere with estrogen metabolism (23). The gonadal hormones, particularly estrogen, are essential for maintaining bone mass. Estrogen directly affects bone turnover by binding to estrogen receptors on the osteoblasts. Estrogen also enhances calcium absorption from the intestines (18). Several medications, in particular the glucocorticoids, have adverse effects on the skeleton that include increased urinary excretion and decreased intestinal absorption of calcium, reduced levels of gonadal hormones, inhibition of osteoblast function, and increased bone resorption (18).

Several of these risk factors are interrelated. For example, peak bone mass is largely determined by genetic factors; however, failure to reach one's genetic potential is often the result of inadequate calcium intake and exercise (20). Also, risk of osteoporosis increases with advancing age, particularly after menopause in women, and an even greater risk is seen with early menopause, either natural or surgical. Postmenopausal bone loss is largely the result of estrogen deficiency, but hormone replacement therapy can dramatically attenuate postmenopausal bone loss.

CLINICAL EXERCISE PHYSIOLOGY

The primary purposes of acute exercise testing are typically to aid in the diagnoses of coronary artery disease (CAD) and/or to determine appropriate levels of exercise training. There are no specific studies regarding acute physiological responses to exercise in an osteoporotic population, but for those patients who can tolerate the exercise, there is no reason to believe their cardiovascular responses would be different from those individuals without osteoporosis. Osteoporosis can sometimes mask the presence of heart disease because it can prevent an individual from achieving the adequate heart rate and blood pressure necessary for accurate diagnoses. In addition, severe thoracic kyphosis can sometimes impair respiration and limit the test. Nonetheless, there are no specific recommendations from the American College of Sports Medicine that would suggest that osteoporosis is an absolute contraindication to exercise testing (24). If an exercise stress test is to be performed with an osteoporotic individual, one utilizing a cycle ergometer protocol would

probably be the best choice, since that would involve the least trauma and impact on the bones. However, caution must still be taken when utilizing a cycle ergometer. An upright posture should be maintained by the patient at all times, as any sort of spinal flexion is contraindicated in people with osteoporosis. Treadmill protocols can be utilized, but a walking protocol is recommended, and care must be taken to ensure the patient does not trip or fall.

Chronic responses to exercise in the osteoporotic population and in postmenopausal women have been studied (25–30). The primary purpose of prescribing exercise for these populations is to increase, or at least maintain, BMD and to increase overall fitness and balance to aid in fall prevention. In this regard, the majority of studies have shown positive results. A number of studies with postmenopausal women have shown that exercise can increase bone density or prevent further bone loss when compared to nonexercising controls (27–29, 31, 32). However, these studies have also pointed out that exercise without concomitant estrogen replacement will generally result in further bone loss. There have been some studies that have shown that exercise alone will increase bone mass in postmenopausal women (27, 33), although the increases were greater when estrogen and exercise were used in combination.

Although research has been primarily directed toward the adult population, a recent review of the literature highlights the importance of exercise in establishing optimal levels of bone mineral during the growing years when bone modeling accompanies growth (34). Retrospective studies of children generally report a positive association between BMD and weight-bearing, but not non-weight-bearing, activities (35–37). Further, the timing of exercise intervention during childhood has been demonstrated to affect bone mineral status in adulthood. Female tennis and squash players who started their playing careers before or at menarche were found to have a two- to three-fold greater dominant arm BMC than those who had started playing more than 15 years after menarche (38). This point is further illustrated by examining two separate studies on athletes. Courteix et al. (39) and Taaffe et al. (40) each examined BMD in gymnasts and controls. In the first study, gymnasts were prepubertal with an average age of 10.4 years and had been training for only 3 years. In the second study, gymnasts were 19.3 years of age and had been training for 12 years. Despite the 9 years of difference in training time of the gymnasts in the two studies, the percentage difference in BMD between gymnasts and controls was the same for both studies. Results from these studies would suggest that the optimal time to begin exercise training to increase BMD is before puberty.

There are a number of recent intervention studies in children and adolescents that point out the potential for exercise to increase bone mass (41–44). Participation in athletics also has the potential for increasing bone mineral density. A number of studies, both cross-sectional and

longitudinal, have found positive effects for bone health from the training associated with sports participation (45–49). However, sufficient evidence does not exist to suggest that one type of exercise or athletic activity is better than another with regard to osteogenic effect. It does appear that those sports or exercises that involve a high degree of impact (gymnastics or volleyball) are more beneficial to bone than those without impact loading (swimming or cycling) (40, 45, 50).

PHARMACOLOGY

The majority of women diagnosed with osteoporosis, and postmenopausal women in general, take some form of calcium and vitamin D supplements. Other common drugs available, that have FDA approval for treatment or prevention of osteoporosis, include estrogen alone or in combination with progesterone, bisphosphates, calcitonin, and selective estrogen receptor modulators (SERMs). Other less common agents include isoflavones (natural and synthetic), sodium fluoride, and parathyroid hormone (see Table 12.1 for a complete list). Isoflavones are plant-derived compounds that have a chemical structure similar to estrogen and thus have physiological effects that may also be similar to estrogen. The effects of any of these drugs or nutrients on acute or chronic exercise responses have not been extensively studied. However, there is no clear reason why any of these agents would affect exercise responses, with the possible exception of estrogen. Estrogen (and its cousins the isoflavones) has acute vasodilator action and thus may alter responses to exercise during a treadmill test. Although this effect has been seen in studies using larger doses of estrogen (51), it has not been demonstrated with doses normally used in estrogen-replacement therapy (52).

PHYSICAL EXAMINATION

The physical assessment of the client with osteoporosis should include a detailed medical history, including information about all medications and supplements used by the client. A pain history also provides useful information along with a careful assessment of height and observation of posture.

Pain Assessment

Although osteoporosis frequently presents with no pain until a fracture has occurred (16), pain history is an important part of the physical examination of the client with osteoporosis. The most common fractures that occur in individuals with osteoporosis are hip, wrist, and vertebral fractures. Fractures of the hip and wrist are easily identified on x-rays and usually occur as a result of a fall. Vertebral fractures, however, often cannot be visualized on x-rays and frequently occur during routine daily activities such as lifting a grocery bag or sneezing. Sharp and per-

sistent back pain may be the only physical finding to suggest vertebral fracture (16). Although a bone scan may be performed to confirm the fracture, the nature of the pain experienced and the circumstances leading up to the pain are often considered sufficient to make the diagnosis of vertebral fracture. History of any previous fractures should also be noted, along with the mechanics and circumstances leading up to these fractures.

Assessment of Stature

Loss of height that may range from 1 inch to as much as 4 or 5 inches is an important physical finding because a loss of height occurs with each spinal compression fracture sustained by the individual with osteoporosis. In a compression fracture of the vertebra, the bone within the vertebral body collapses, resulting in a loss of height of the vertebra. An individual can sustain multiple fractures to the same vertebra or fractures to multiple vertebra that can result in several inches of lost height. These compression fractures may be accompanied by severe pain or minimal pain that may be ignored by the individual. In any case, loss of height is always a significant finding and should be monitored closely. The use of a stature board allows precise measurement of height and is useful in monitoring changes.

Postural Assessment

Spinal compression fractures often occur specifically in the anterior portion of the vertebral body. When the anterior portion of the vertebral body collapses, the loss in anterior vertebral height results in a wedge-shaped vertebra (hence the name, wedge fracture). Wedge fractures cause a change in the overall curvature of the spine that is seen as an increased thoracic kyphosis, sometimes referred to as "dowager's hump." As the thoracic kyphosis progresses, the head is thrust forward and the ribs approach the pelvic bones, resulting in further loss of height. Additionally, as the kyphosis progresses, there is less room for lung expansion. If the kyphosis is severe enough, respiration will be affected. Degree of forward head, thoracic kyphosis, and lumbar lordosis should be noted in the postural assessment. Additionally, there are simple tools that can be used to obtain objective measurements of thoracic kyphosis and lumbar lordosis. A surveyor's flexicurve provides a simple, inexpensive method of assessing thoracic kyphosis and lumbar lordosis (53). The flexicurve is a plastic "ruler" that bends in one plane and holds its shape. It can be molded to a subject's spine, then lifted and laid on a ruled sheet to be traced. Objective measurements can then be obtained from the tracing. Accuracy and precision of the flexicurve, however, are somewhat limited.

MEDICAL AND SURGICAL TREATMENTS

All of the current drugs with an FDA approval for osteoporosis are considered antiresorptive drugs. They halt the loss of bone, or even increase bone mass, by inhibit-

ing bone resorption, while bone formation remains the same. The majority of the drugs available are presented in Table 12.1. It must be pointed out, however, that all drug therapies approved by the FDA for treatment or prevention of osteoporosis are approved for use in postmenopausal women only. Estrogen replacement therapy (ERT) has been used for several years in the treatment and prevention of osteoporosis in postmenopausal women. Studies have shown that estrogen therapy can halt the loss of and often increase bone mass, but its effect on fracture risk is less well established (54–58). Estrogen use is contraindicated in women who are pregnant, have any history or suspected history of breast cancer, or have thrombo-

Table 12.1. Medical Therapies Available in the Treatment or Prevention of Osteoporosis

DRUG CLASS	NAME OF DRUG	BRAND NAME
Estrogens ¹	Estrone Sulfate	Ogen [®]
	Conjugated Estrogen	Premarin [®]
	Transdermal Estrogen	Estraderm [®]
	Estropipate	Ortho-Est [®]
	Esterified Estrogen	Estratab [®]
	Conjugated Estrogen + Medroxyprogesterone Acetate ²	Premphase [®]
		PremPro [®]
Calcitonin ³	Synthetic Salmon Calcitonin	Activella [®]
		MiaCalcin [®]
Bisphosphonates	Alendronate ⁴	Fosamax [®]
	Risedronate ⁴	Actonel [®]
	Etidronate ⁵	Didronel [®]
	Ibandronate ⁶	
	Zoledronate	
	Tiludronate ⁶	
	Pamidronate	Aredia [®]
SERMs	Raloxifene ⁷	Evista [®]
	Tamoxifene	Nolvadex [®]
	Droloxifene ⁶	
	Levormeloxifene	
Others	Isoflavones (natural flavonoids)	
	Tibolone or Ipriflavone (synthetic flavonoids)	
	Calcitriol ⁸	
	Sodium Fluoride ⁹	
	Parathyroid Hormone ⁷	

¹All estrogens have FDA approval for prevention of osteoporosis, but only Premarin[®] is approved for treatment.

²Premphase[®], PremPro[®] and Activella[®] are estrogen and progesterone taken in combination; Premphase and PremPro are FDA approved for treatment of osteoporosis; Activella is approved for prevention.

³Both calcitonins are approved for prevention, but only MiaCalcin[®] is approved for treatment of osteoporosis.

⁴Alendronate and risedronate have FDA approval for both prevention and treatment of osteoporosis.

⁵Etidronate has FDA approval but not with an osteoporosis indication.

⁶In clinical trials for treatment or prevention of osteoporosis.

⁷FDA approved for prevention and treatment of osteoporosis.

⁸Calcitriol is a vitamin D metabolite with FDA approval, but not for osteoporosis.

⁹Approval pending for an osteoporosis indication.

embolic disorders. Side effects include breakthrough bleeding, breast tenderness, thrombophlebitis, and cramps. As many as 70% of women will discontinue estrogen therapy within a year (59). Dosages vary for estrogen depending on the exact type used but range from 0.3 to 2.5 mg, with 0.625 mg probably the most commonly prescribed for osteoporosis.

Calcitonin is a hormone used for calcium regulation by the body. Salmon calcitonin, either in an injectable or nasal spray preparation, has proved effective in both increasing low bone mass and decreasing fracture risk in postmenopausal women (60–63). Side effects are rare but may include headaches or flushing. The most common dosages are 200 IU for the nasal spray preparation and 100 IU for the injectable form.

Bisphosphonates are one of the newer classes of drugs now being used in the prevention and treatment of osteoporosis. They are probably the most powerful of the antiresorptive drugs available. Several different bisphosphonates have been shown to be effective in reducing bone loss and decreasing fracture risk in postmenopausal women (64–69). Recent studies have also indicated that combining estrogen and bisphosphonates may be better than either treatment alone (70). Gastrointestinal problems may occur with improper administration of the drug (71), and contraindications to bisphosphonate use include esophageal stricture, difficulty swallowing, active esophageal ulcer, esophagitis, or renal insufficiency or failure (71). Bisphosphonates are typically given in either 5 or 10 mg doses.

Selective estrogen receptor modulators (SERMs) are another antiresorptive agent under investigation for use in osteoporosis. Raloxifene has FDA approval for use in prevention of osteoporosis, but there are very little data on other SERMs with regard to their effects on low bone mass. The advantages of SERMs include favorable effects on bone and lipids, much like estrogen, but they do not have the stimulatory effect on breast or endometrial tissue seen with estrogen (72). The increases in BMD that are shown when taking raloxifene or other SERMs are generally less than seen with estrogen (73, 74), and unlike ERT, SERMs appear to have no beneficial effect on HDL cholesterol (73, 74). However, for the woman with a history of breast cancer, SERMs would be a good alternative to ERT. Raloxifene is commonly prescribed in 60 mg tablets, and side effects include hot flashes and leg cramps.

The effectiveness of calcium and/or vitamin D supplementation on increasing bone density in postmenopausal women is unclear. Some studies have shown increases in BMD (75, 76), while others have shown no effect (77, 78). The number of years past menopause may play a role in the effectiveness of calcium and/or vitamin D (79). An important thing to consider with regard to calcium and vitamin D is that the vast majority of studies investigating other therapeutic modalities for osteoporosis (bisphosphonates, estrogen, exercise) have given calcium and/or vitamin D supplementation to the treatment groups.

Thus, the effectiveness of these therapies may be reduced without the inclusion of calcium or vitamin D supplementation.

Surgery is often necessary to repair the fractures that occur as a result of osteoporosis. However, surgical interventions aimed at preventing or treating the disease itself are virtually unavailable. The one possible exception is the use of acrylic bone cements. This is a minimally invasive procedure in which some form of polymethylmethacrylate bone cement is injected into the fractured vertebrae (80). Pain relief in patients has been reported to be as high as 75% (81). In addition, *in vitro* studies have demonstrated increased strength in vertebrae augmented with bone cement (82). Although this procedure shows promise, there have not been any good randomized studies on its effectiveness or any possible long-term consequences.

Falls are one of the major causes of fracture, and thus, fall prevention is important in the health management of the patient with osteoporosis. To help offset the chance of fracture if a fall does occur, the use of hip protectors has some possibilities (83).

DIAGNOSTIC TECHNIQUES

Diagnosis of osteoporosis involves the measurement of BMD. Several methods for measuring BMD have been used in the past, including radiogammetry, single-photon absorptiometry, and dual-photon absorptiometry. However, these techniques lacked the precision and accuracy necessary for broad clinical use. Dual-energy x-ray absorptiometry (DXA) is considered the gold standard for assessing bone mineral density. Quantitative computed tomography (QCT) and ultrasound are also used for the measurement of bone.

Dual-energy x-ray absorptiometry is the most commonly used technology for measuring BMD and is the primary technique used to diagnose osteoporosis. DXA uses low-dose x-ray to emit photons at two different energy levels. BMD is calculated based on the amount of energy attenuated by the body. DXA measurements are reported in g/cm^2 , so are not a true density, but rather an area density. DXA is capable of differentiating between bone and soft tissue and therefore can also be used to measure regional and total body composition. The advantages of DXA, as compared to other methods, include the capability of measuring small changes in BMD over time, measuring with a low precision error of 0.5–2.0%, requiring short exam times (5–10 minutes), and providing low radiation exposure.

Quantitative computed tomography has two advantages over DXA in that it provides a three-dimensional anatomical localization for direct measurement of true bone density and QCT is also capable of differentiating between trabecular and cortical bone and is used to examine the anatomy of trabecular regions within the spine. This makes QCT quite attractive in certain research appli-

cations. However, QCT is less practical than DXA for routine screening for osteoporosis due to expense, higher radiation exposure, and less precision, and thus QCT is rarely used in diagnosing osteoporosis.

Another emerging technology for assessing bone health is quantitative ultrasound (QUS). Ultrasound does not measure bone density, but rather measures two parameters called speed of sound (SOS) and broadband ultrasound attenuation (BUA) that are related to the structural properties of bone. Some manufacturers will then use BUA and/or SOS to derive other indices or even estimate bone mineral density. However, since the use of QUS is relatively new in the field of bone health, not all manufacturers use the same technology. Speed of sound measured on one device may be a different type of measurement on an ultrasound unit from another manufacturer. Nevertheless, studies have shown that QUS measures have the ability to distinguish fracture patients from controls (84), as well as predict future fracture (85, 86). The advantages for ultrasound devices are that they are small, portable, and use no ionizing radiation.

Bone mineral density is reported not only in g/cm^2 (DXA) or g/cm^3 (QCT), but also in terms of standard deviations, or z-scores. The likelihood of sustaining a fracture increases 1.5- to 3-fold for each standard deviation decrease in BMD (87, 88). The World Health Organization Consensus Development Conference has developed diagnostic criteria for osteoporosis based on this relationship (89). Normal BMD is less than 1.0 standard deviation below the mean for young adults. A BMD that is between 1.0 and 2.5 standard deviations below the young adult mean is considered low bone mass, or osteopenia. Osteoporosis is defined as BMD more than 2.5 standard deviations below the young adult mean and is considered "severe" if accompanied by one or more fractures. Although these criteria were originally developed for diagnosis of osteoporosis at the proximal femur in postmenopausal women, they are commonly used for men and women of all ages and are applied to the lumbar spine and distal radius and ulna.

EXERCISE/FITNESS/FUNCTIONAL TESTING

Exercise recommendations for individuals with osteoporosis or those who are at risk for developing osteoporosis generally include an aerobic, weight-bearing exercise program (such as walking) and a resistive exercise program to promote bone health. Non-weight-bearing exercises (such as swimming or water aerobics) do not seem to provide the osteogenic effect seen with weight-bearing exercise, but their use might be recommended for those individuals who cannot tolerate the higher impact associated with weight-bearing exercise. Additionally, if an individual has osteoporosis, that individual is at increased risk of fracturing a bone. Because falls are associated with most hip and wrist fractures, and are a leading

cause of injury in older adults, a falls-intervention program should be instituted in all older adults who are diagnosed with osteoporosis. The following exercise testing should be conducted in order to provide each individual with a safe, effective training program.

Aerobic Fitness Testing

Graded exercise testing is recommended for individuals who are considered to be at risk for heart disease according to American College of Sports Medicine guidelines (24). The results of the graded exercise test can be used to determine the appropriate intensity for the walking or jogging exercise included within the training program. When graded exercise testing is not deemed necessary or is contraindicated, age-predicted maximal heart rate is used to determine training intensity based on a target heart rate (24).

Muscle Strength Testing

Muscle strength testing is used to determine training intensity of the resistance exercise program. Determination of the 1-repetition maximum (RM) is generally used for strength assessment in healthy persons, but use of the 1-RM is discouraged in the client with osteoporosis because of the increased possibility of fracture. Assessment of the 10-repetition maximum is recommended for strength assessment in the osteoporotic client.

Because deficits in lower-extremity muscle strength are associated with an increased incidence of falls (90, 91), maximal isometric muscle strength assessment can be used to identify muscle strength deficits as part of the overall evaluation of fall risk. Hand-held dynamometry is sometimes used because it provides an easy, objective measurement of isometric strength and a useful indication of overall muscle strength. It can also be used for monitoring change in muscle strength in response to an exercise program; however, its use is not advised in hypertensive individuals. The use of a normative muscle strength database is recommended to help identify strength impairments.

Balance Testing

A deficit in balance has also been shown to be a predictor of falls (90), and is therefore, a critical component in the evaluation of fall risk. The ability to stand on one leg is a simple clinical test frequently used to assess balance function. Although force platform systems can provide more information about the nature of the balance impairment, single stance time has been shown to distinguish fallers from nonfallers among the elderly (92, 93).

Gait speed and tandem gait ability have been reported to be independent predictors of hip fracture risk (94). While these factors are a function of both balance and muscular fitness, they are not properly tested for by either balance or muscular strength testing and therefore should be independently assessed. Testing for other fall-related

factors such as visual acuity and cognitive ability should also be considered.

Flexibility Testing

General flexibility tests such as the sit-and-reach and shoulder elevation tests are not performed in clients with osteoporosis. Primarily, flexibility of muscles that have the potential to adversely affect posture should be assessed. Decreases in length of muscles that cross more than one joint have the greatest potential to cause problems in posture (for example, hamstrings and hip flexors). Insufficient length in the hamstrings or hip flexors will produce a posterior pelvic tilt or anterior pelvic tilt, respectively. Such postural alterations affect how weight is borne through the bones in the spine and lower extremities. Other muscles that frequently lose flexibility and can lead to postural problems include the pectoral muscles and the gastrocnemius muscles. Flexibility is assessed by measuring joint range of motion (ROM) when the muscle is fully elongated over each joint crossed by that muscle. For example, flexibility of the gastrocnemius muscle is assessed by measuring dorsiflexion of the ankle when the knee is kept fully extended.

Contraindications for Exercise

Impact exercises that impart high loads to the skeleton, such as jumping, running, or jogging, are contraindicated for people with osteoporosis (95). These exercises cause high compressive forces in the spine and lower extremities, and can cause fractures in weakened bones. Impact exercises such as two-footed jumping, however, have been shown to be effective for increasing bone mineral density in nonosteoporotic women and can be used to help prevent osteoporosis in a nonosteoporotic population (96).

People with osteoporosis should not perform exercises that require bending forward at the waist or excessive twisting at the waist. Bending and twisting motions at the waist produce very high compressive forces over an area of the spinal bones that is most susceptible to fracture. For this reason, exercises such as toe touches, sit-ups, or rowing machines, as well as activities such as golf, tennis, or bowling, should be avoided by people with osteoporosis (16). Resistive exercises are not contraindicated for people with osteoporosis, but resistance should be used cautiously when the osteoporosis is severe.

EXERCISE PRESCRIPTION AND PROGRAMMING

Although studies have shown that several forms of exercise training have the potential to increase BMD, the optimal training program for skeletal integrity has yet to be defined. Based on current experimental knowledge, it has been proposed that an osteogenic exercise regimen should have load-bearing activities at high magnitude (force) with few repetitions, create versatile strain distributions throughout the bone structure (load the bone in di-

rections to which it is unaccustomed), and be long term and progressive in nature (50, 97). Resistance training (weight lifting) probably offers the best opportunity to meet these criteria on an individual basis, requires little skill, and has the added advantage of being highly adaptable to changes in both magnitude and strain distribution. In addition, strength and muscle size increases have been demonstrated following resistance training, even in the elderly (98).

There are no known studies that have specifically examined cardiovascular adaptations in osteoporotic patients, but older adults can increase their fitness levels 10–30% with prolonged endurance training (99). A good number of older women with osteoporosis will not be on estrogen replacement therapy (59) and thus will be receiving none of the cardiovascular benefits associated with ERT (100). Since exercise endurance training can decrease cardiovascular disease risk factors such as high blood pressure and cholesterol, it is recommended for the osteoporotic woman.

Thus, resistance training combined with cardiovascular training (bicycling or walking) is the best recommendation for an exercise program for the patient with osteoporosis. Not only will such a program increase overall fitness and perhaps bone mineral density, it will aid greatly in reducing the risk of falling (99, 101, 102), which is one of the primary causes of fracture in osteoporosis.

Although osteoporosis occurs in young amenorrheic women, it is still a disease that primarily occurs in older women. Currently, the American College of Sports Medicine recommends that anyone over the age of 50 who wants to begin a vigorous exercise program should have a medically supervised stress test (24). However, for osteoporotic older women who simply want to begin a walking and/or resistance training program, this recommendation may be both impractical and unnecessary. Careful screening should be undertaken to identify which individuals need further evaluation by a physician (103).

There are recommendations, specific to the patient with osteoporosis, to consider when developing an exercise program. Impact activities such as running, jumping, or high-impact aerobics should be avoided with osteoporotic patients due to their risk of a fracture with little or no trauma. Another activity that absolutely must not be done by people with osteoporosis is spinal flexion, including things such as sit-ups or toe touches (104). Spinal flexion drastically increases the forces on the spine, increasing the likelihood of a fracture (105). Other activities to avoid are those that increase the chance of falling such as trampolines, step aerobics, skating (ice or in-line), or exercising on slippery floors (95).

From the other perspective, there are certain exercises that are quite beneficial for the osteoporotic patient. These include exercises designed to help with balance and agility in order to reduce falls. For instance, exercises that strengthen the quadriceps are helpful. However, squats

with free weights should be avoided because of the excess load that might be applied to the spine as well as the potential for spinal flexion during the squat lift. A specific exercise that helps build hip and low back strength as well as improve balance is standing on one foot for 5 to 15 seconds. Initially, the patient should be encouraged to place his/her hands on a counter for support until he/she develops the strength and/or balance needed to perform the exercise without danger of falling. The osteoporotic patient should also be encouraged to do spine extension (but NOT spinal flexion) exercises (104). Spine extension exercises can be performed in a chair and can help strengthen the back muscles, which can help reduce the development of a dowager's hump and possibly reduce the risk of vertebral fracture (106). However, these and all exercises done by patients with osteoporosis should be performed with slow and controlled movements, avoiding jerky, rapid movements. More complete information can be found on these and other exercises for the osteoporotic patient (95, 107).

As stated, the physiological responses to exercise in an osteoporotic population have not been specifically investigated, but they should not be substantially different from an age-matched person without osteoporosis. Similarly, the goals of an exercise program for a person with or without osteoporosis should also be the same. For someone just beginning an exercise program, those goals should include an increase in cardiovascular fitness, increased muscular strength, and an increase (or at least no decrease) in bone mineral density. Heart disease remains the number one killer of both women and men by a wide margin. So, the goal of everyone should be to increase their physical activity to reduce the risk of heart disease, and in that regard, physical activity may be a better recommendation than hormone replacement therapy for women (108). The 1996 Surgeon General's report on health and physical activity recommends approximately 30 minutes of moderate physical activity accumulated on most if not all days of the week (109). This would be a worthwhile goal for anyone, including those with osteoporosis. However, if the person with osteoporosis is just beginning an exercise program, the duration of exercise might need to be shortened initially to allow time for adjustment to the exercise. As the person's fitness level increases, the duration of exercise can be increased. For an osteoporotic person, or for that matter any man or woman just beginning an exercise program, a walking program should provide the needed benefits along with being a safe mode of exercise.

Weight training appears to offer the most benefits for increases in muscular strength and bone density. Current recommendations suggest a single set of 15 repetitions of 8–10 exercises performed at least 2 days per week (110). Again, this is a worthwhile goal for the person with osteoporosis, but a less strenuous program may be needed initially, with care taken to avoid the exercises mentioned

above that are dangerous. In addition, some resistance training exercises have a tendency to cause spinal flexion, especially exercises for the upper and lower extremities, so it is important that during resistance training all exercise be done with an upright posture.

A program to increase flexibility can also benefit the osteoporotic patient since decreased flexibility can cause problems with posture. Muscles that cross more than one joint such as the hamstring are particularly important. However, many of the commonly prescribed exercises for increasing flexibility, especially of the hamstring, involve spinal flexion and must be avoided. There is little consensus on the optimal training program for increasing flexibility, but good suggestions are available from many sources (95, 111).

Thus, exercise may be beneficial for both increasing bone density to help prevent osteoporosis and as a therapeutic modality for those patients in whom osteoporosis is already present. However, caution must be observed in the type of exercise program to be used and the specific exercises performed. Patients with severe osteoporosis who are just beginning an exercise program should be supervised until it is determined that they can properly perform the exercises without danger to themselves.

EDUCATION AND COUNSELING

Activity/Exercise

Following instructions in an appropriate exercise program is important, and in order to encourage compliance with the recommended exercise program, these two points should be emphasized:

- Gains made in bone density will only be maintained as long as the exercise is continued (28).
- Approximately 9 months to 1 year are required to detect a significant change in bone mass (11).

Safety Hazards in the Home

Falls are a frequent cause of fracture, and thus, fall prevention is important to the osteoporotic patient. The reasons falls occur are varied, but identified risk factors include environmental hazards, muscle weakness, poor balance, and medication-related side effects (112, 113). Eliminating as many of these risk factors as possible can greatly reduce the danger of falling. A discussion of safety hazards in the home and suggestions to remove these hazards is an integral part of any falls-prevention program. Completing a falls risk assessment form such as the one developed by the World Health Organization (WHO) can help identify hazards in the home. The examiner may then make suggestions on how to remove the hazards or how to modify the home to make it safer. These suggestions may be as simple as moving a telephone and light to within reach of the bed to avoid falls when getting up in the dark, eliminating slippery floors, or installing safety features for the

bathub (114, 115). Educating patients on the side effects of medications, such as those that cause dizziness, is also an important step in fall prevention, as is improving muscle weakness and balance with the use of a properly structured exercise program.

Activity Modification

Although proper body mechanics during lifting should be encouraged in all individuals, it is absolutely critical in patients with osteoporosis. Attempting to lift an object with the back flexed is a common mechanism of vertebral fracture in people with osteoporosis. Instructions on how to bend the knees while keeping the back straight in order to pick up an object from the floor must be provided.

Daily activities such as sweeping, vacuuming, or mopping can also present problems for people with osteoporosis because these activities are typically performed by using a lot of bending and twisting of the spine. These activities, however, can be modified to avoid spinal twisting and bending, and instead can provide beneficial loading to the spine and hips. People with osteoporosis should be encouraged to mop, sweep, or vacuum by placing one foot in front of the other, and shifting weight from one foot to the other in a rocking motion (16). The knees are bent and the back is kept straight during this rocking motion. The rocking motion from one foot to the other takes the place of bending and twisting of the spine in order to reach forward when mopping, sweeping, or vacuuming.

Dietary Modifications and Calcium Supplements

The National Institutes of Health recommends a daily calcium intake of 1500 mg for all women over the age of 64 and for any postmenopausal woman not on ERT. A review of foods that are a good source of calcium should be provided along with instructions stating how to read food labels. Food labels show what percentage of the recommended daily requirement is provided by the food item. Unfortunately, these percentages are based on the inaccurate assumption that the recommended daily requirement is 1000 mg for everybody, regardless of age or gender. Converting from percentages to actual quantity of calcium in milligrams is not difficult. People simply need to be educated on how to do the conversion.

A discussion about the different types of calcium supplements is also valuable because people often take their supplements incorrectly and therefore reduce the effectiveness. Calcium comes in many different forms, but the two most common forms are calcium citrate (Ex. Citracal) and calcium carbonate (Ex. Os-Cal, Caltrate, Viactiv). Studies show that calcium citrate is more readily absorbed (116) but has less calcium per tablet than calcium carbonate. That means that more tablets of calcium citrate must be taken per day in order to attain the recommended requirement of 1200 to 1500 mg/day. In any case, if a person chooses calcium carbonate because they can take fewer tablets per day, they should take part of their requirement

after each meal. Taking calcium carbonate after a meal improves the absorption, but it still will not be absorbed as well as calcium citrate. Vitamin D will help increase calcium absorption, and all osteoporotic patients should be encouraged to take in at least 400 IU/day of vitamin D.

Patients should also be made aware of the fact that caffeine causes more of their calcium to be lost in the urine. That doesn't mean that people with osteoporosis must give up all caffeine, however. A good rule of thumb is to restrict the number of servings that contain caffeine to no more than 2 or 3 per day. This recommendation is based on two studies that showed 400–600 mg of caffeine did not cause significant loss in calcium as long as the individual consumed at least 600 mg of calcium per day (117, 118).

CASE STUDY

Jane is a 53-year-old, postmenopausal, Caucasian woman diagnosed in April 1998 with osteoporosis at the femoral neck ($Z = -2.53$) and osteopenia at the lumbar spine (L2–4) ($Z = -1.48$). Jane has no family history of osteoporosis, or history of amenorrhea, has been physically active throughout childhood and adult life, and never abused alcohol nor consumed excessive caffeine. She is 175 cm (69 inches) tall and weighs 50 kg (110 lb). She has never smoked, but as a flight attendant for 32 years was exposed to second-hand smoke from 1967–1997. She has supplemented her diet with 1000 mg of calcium for 20 years. At age 43, Jane initiated hormone replacement therapy. Immediately following diagnosis, Jane increased her calcium supplementation to 1500 mg daily. She also increased her walking program from 30 min, 3–4 days/week to 50 min, 7 days/week and began performing isometric exercises for the abdominals and upper back twice daily. Jane also began a resistance training program consisting of 10 free-weight and machine exercises performed in 2 sets of 8–15 repetitions, 2–3 days/week. Six months after diagnosis, Jane began treatment with 10 mg of alendronate daily. In 18 months of resistance training, Jane has experienced an average increase in strength of 250%. Follow-up bone density scans in October 1999 revealed an increase in BMD of 9.28% at the femoral neck ($Z = -1.99$) and 10.49% at the lumbar spine ($Z = -0.88$). Based on Jane's outcome, it appears that the combination of an aggressive resistive and weight-bearing exercise regimen in the treatment of osteoporosis may be effective in increasing BMD above that expected from calcium supplementation and antiresorptive therapy alone.

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