Exercise Interventions for the Individual With Osteoporosis

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ABSTRACT
Osteoporosis is a common condition that can affect both men and women, typically after the fourth decade of life. Often, physicians advise patients diagnosed with osteoporosis to exercise, but frequently offer no specifics. By gaining a sound understanding of the mechanism involved with osteoporosis, the exercise professional will be better suited to design exercise and injury prevention programs for this client population. The purpose of this manuscript is to define osteoporosis, review the diagnostic process, and discuss treatment options with an emphasis on exercise interventions.

INTRODUCTION AND EPIDEMIOLOGY
Osteoporosis is a systemic skeletal disorder that results in low bone mass and microarchitectural deterioration of bone tissue (17,31). As a result, individuals with osteoporosis are at higher risk for fracture when compared with the general population (17,31). Most commonly, osteoporosis affects postmenopausal women, primarily older than 70 years, although the possibility of osteoporotic fracture increases after the age of 50 years. Additionally, it is estimated that 1 in 12 men in this age group are also affected with osteoporosis and at risk for fracture (31,38). In the United States, approximately 1.5 million fractures occur annually because of osteoporosis.

A number of risk factors are thought to contribute to the development of osteoporosis (17,31,38). Age, sex, body mass index, low bone mineral density (BMD), low birth weight, genetics, hormonal changes, alcohol use, long-term corticosteroid use, cancer, certain disease states, smoking, and calcium and vitamin D deficiency have all been reported (17). Research suggests a number of treatment options, including pharmaceuticals, diet, vitamin supplementation, and exercises.

Fracture of the hip, vertebrae, and wrist are common in individuals with osteoporosis and are responsible for increased rates of mortality, morbidity, chronic pain, and altered quality of life (15). Costs associated with osteoporotic fracture treatment are high, primarily with fractures of the hip (15,17). The estimated number of hip fractures seen worldwide could rise from 1.7 million in 1990 to 6.3 million by 2050, with a projected cost exceeding 131 billion dollars (16,22). For example, a hormone imbalance, specifically a deficiency in estrogen, leads to an increase in resorption without subsequent bone formation (22).

Bone quality is determined by a number of factors. Bone geometry, cortical thickness, porosity, trabecular bone morphology, and intrinsic properties of the bony tissue play a role in bone strength (22). Prevention of an osteoporotic fracture is dependent on accurate diagnosis leading to fracture probability estimates (15). Loss of bone mass is a significant risk factor for fracture and can be determined by various techniques, such as bone density; exercise; osteoporosis
Osteoporosis Exercise

as dual-energy x-ray absorptiometry (DXA), quantitative ultrasound, magnetic resonance imaging, quantitative computed tomography, and peripheral quantitative computed tomography (25). Currently, the gold standard for determining BMD is DXA (15,22). Initially introduced in 1987, DXA is a well-standardized technique that delivers low doses of radiation to the patient while delivering a high degree of precision (22). The DXA uses 2 x-ray beams to determine bone mineral content. Scan outcomes are then compared with standardized results obtained from a young adult reference population. Results are then expressed in terms of T-scores and Z-scores compared with an age-matched reference population. T-scores are expressed in standard deviations from the mean and compared with young adult white female values. Based on the World Health Organization, T-score results are defined as follows: normal, 0 to −0.99; osteopenia, −1 to −2.49; and osteoporosis, equal to or less than −2.5 (29). Z scores compare the patient’s results to a population of similar sex, age, and height and are useful for determining the likelihood of a secondary cause of osteoporosis, such as malignancy. Z scores are expressed in terms of standard deviations from the population mean with a Z score ranging from 1.5 to 2.0 below the mean indicating possible secondary osteoporosis.

PHYSICAL PRESENTATION

Osteoporosis is a slow process where bone breakdown exceeds bone growth. This process is most commonly asymptomatic but occasionally the earliest signs and symptoms can be an acute bout of back pain (12). The most common sites for osteoporotic fractures and back pain are the thoracic (T7-8) and lumbar (T12-L1) spine segments (20). Patients experiencing vertebral compression fractures demonstrate reduced vertebral height with an associated slouched and kyphotic posture. The kyphotic posture is because of the vertebral bone loss and anterior collapse of the vertebrae (8). The exaggerated curvature of the vertebral column often involves a compensatory cervical and in some cases lumbar hyperlordotic posture (10). These compensatory adaptations of the lumbar and cervical spine are often associated with tight hip flexors and pectoral minor muscles, respectively. Moreover, clients with vertebral compression fractures have the tendency to walk with a stooped posture and often sit for extended periods. These postures lead to further muscular tightness and perpetuate postural dysfunctions that may place greater compressive forces on the anterior aspect of the vertebra.

People with osteoporosis often demonstrate decreased muscle strength (9). Sinaki et al. (32) found that females with osteoporosis demonstrate weakness of the back extensor musculature compared with females without osteoporosis. Lui-Ambrose et al. (24) found that females with osteoporosis had greater knee extensor muscle weakness compared with age-matched controls. The relationship between osteoporosis and muscle strength can be attributed to many factors including sensory input of osteocytes through muscle strain, the individual’s activity level, and hormonal influences (37). Muscle weakness can also speed up bone demineralization, increasing the risk for osteoporotic fractures (2). Furthermore, trunk and lower extremity weakness can lead to gait and balance impairments, which can increase the risk for falls and fractures.

OSTEOPOROSIS INTERVENTIONS

Osteoporosis is often treated by pharmacologic therapy, complementary and alternative medicines (CAM), and exercise. The overall goal of these interventions is to maintain adequate levels of calcium, promote bone growth, reduce bone breakdown, and mitigate impairments.

PHARMACOLOGIC THERAPIES

The pharmacologic treatment of osteoporosis may include bisphosphonates, calcitonin, estrogen replacement, and/or estrogen receptor modulators (5,25). Bisphosphonates are a group of drugs, including Fosamax (Merck & Co, Whitehouse Station, NJ), Boniva (Roche Laboratories, Nutley, NJ), and Actonel (Warner Chilcott Laboratories, Rockaway, NJ), which inhibit osteoclast activity and bone breakdown (5,27,28). These drugs improve BMD and have been shown to reduce the risk of hip, vertebral, and wrist fracture. Calcitonin is another group of drugs commonly used with patients presenting with osteoporosis. Calcitonin (Cibacalcin [Novartis Pharmaceuticals Corporation, East Hanover, NJ], Micalcin [Novartis], and Calcimar [Aventis Pharmaceuticals, Bridgewater, NJ]) functions by inhibiting osteoclast activity and increasing renal calcium excretion (13).

Osteoporosis is often treated with estrogen replacement therapy (ERT). Medications such as Premarin (Pfizer, New York, NY), Ogden (Pfizer), and Estrace (Warner Chilcott Laboratories, Rockaway, NJ) stabilize bone cell turnover and promote bone formation (5). The evidence clearly demonstrates the benefits of ERT in the prevention of fractures; however, because of elevated risks for breast cancer, venous thrombosis, stroke, and coronary diseases, ERT is no longer the preferred treatment for osteoporosis (6). Recently, selective estrogen receptor modulators, such as Evista (Eli Lilly, Indianapolis, IN), have gained popularity because of fewer side effects. Drugs, such as Evista, preferentially bind to estrogen receptors in bone while bypassing other receptors that are associated with cardiovascular diseases and cancer (7).

COMPLEMENTARY AND ALTERNATIVE MEDICATIONS

Complementary and alternative medications are drugs that are used either in combination with or in place of a conventional treatment (5). Calcium supplements are often used to complement the pharmacological treatment of osteoporosis (18). Short
Clinical trials of calcium supplementation in postmenopausal women provided the necessary amount of calcium in the blood to reduce bone loss and decrease the risk for fracture (35). The recommended dietary intake of calcium for postmenopausal women is approximately 1,200–1,500 mg/d (4). Another CAM is vitamin D, which promotes bone mineralization by increasing the absorption of calcium from the digestive tract (23). Vitamin D promotes bone growth by maintaining adequate amounts of calcium in the blood necessary for bone formation. The recommended dietary intake of vitamin D for postmenopausal women and the elderly is 800 IU (36). However, it is important to note that Levis and Theodore (21) found conflicting evidence about the role of vitamin D in the prevention of fractures. Furthermore, they found moderate evidence suggesting that treating osteoporosis with calcium supplements alone does not reduce vertebral and nonvertebral fractures.

**EXERCISE INTERVENTIONS FOR OSTEOPOROSIS**

Exercise plays an essential role in the treatment of osteoporosis. Anaerobic and aerobic training have been shown to be effective methods of exercise for improving BMD and reducing bone loss (14,30,33). Wolff’s law states that human and animal bone adapts to new or unusual mechanical stress by altering the bone architecture (11). Bone tissue will adjust by increasing osteoblast formation in the areas affected by mechanical stress. Conversely, with a lack of mechanical stress, the bone will progressively weaken because of resorption exceeding bone growth. For bone formation to occur, a minimal essential strain (MES) is required. MES is the minimal threshold required for human bone formation (1,11). It is estimated that the MES for the human bone is approximately 1/10 of what is required for a fracture (11). Exercise can provide the necessary essential strain to maintain and promote bone growth. Exercise has been found to be an effective treatment for osteoporosis in postmenopausal women. Wolff et al. (39) conducted a systematic review of published articles that examined the effect of exercise on BMD. The study concluded that exercise training prevented or reversed bone loss by close to 1% per year in both premenopausal and postmenopausal women. In 2002 Bonaiti et al. (3) conducted a systematic review of 18 randomized controlled trials that examined the effects of exercise on BMD. This study found that aerobic, weight-bearing, and resistance training exercises effectively improve BMD at the spine and wrist. Howe et al. (15) conducted an update to this review in 2011 that found postmenopausal women who participated in different modes of exercises had statistically significant increases in BMD compared with control groups who did not exercise. This review found that dynamic weight-bearing exercises such as jogging, jumping, and vibration exercises improved BMD at the hip. This review also found non-weight-bearing exercises, such as knee extension and flexion, shoulder press, bicep curls, seated row, and lat pull downs with high loads improved BMD at specific sites, such as the lumbar spine and hip regions. Furthermore, Howe et al. (15) concluded that the most effective program for improving BMD at the spine was the combination of dynamic weight bearing and non-weight bearing high-load exercises. Howe et al. (15) defined “high-load” exercises as 80% of 1 repetition maximum (1RM). Moreover, strength training with low load and high repetition (e.g., 16 repetitions with 40% 1RM) demonstrated no additional benefits on BMD. It should be noted that to avoid risk of injury, high-load exercises should be added to a program gradually.

Metcalfe et al. (26) conducted a randomized controlled trial investigating the effects of exercise on BMD in postmenopausal women. This study consisted of a hormone replacement therapy (HRT) group, HRT and exercise, exercise without HRT, and a control group without exercise or HRT (all groups were provided with calcium supplements). The exercise group participated in a program, which consisted of weight-bearing exercises (stepping/stair climbing with weighted vest), stretching (pectoral stretch and back bends), abdominal strengthening, balance (single leg), and strength training with large muscle groups (lat pull downs, military press, back extensions, leg press, and squats). The subjects trained 3 times per week for 1 year. The results of this study demonstrated an increase in BMD ranging from 0.6 to 2.1% for the intervention groups and a loss of 1% for the control group. The exercise group with HRT demonstrated the largest gain in BMD in the hip compared with any other group. This study demonstrated that a combination of weight-bearing exercises, strength training (high loads), balance exercises, HRT, and calcium supplements produces the greatest gains in BMD.

Stengels et al. (34) investigated the impact of power versus strength resistance training on BMD in 53 postmenopausal women. The study consisted of a slow resistance training (4-second concentric and 4-second eccentric contraction) group and fast resistance training (fast concentric and 4-second eccentric contraction) group. For more than 1 year, the groups exercised 4 days a week. Their routine consisted of 2 days of resistance training, 1 day of gymnastic exercises, and 1 day of home exercise training. All participants were provided vitamin D and calcium supplements. The results of this study demonstrated that the fast resistance training group was more effective than the slow resistance training group at preventing bone loss at the hip and at the spine. This study demonstrated the benefits of power training and fast concentric contractions on BMD and the prevention of bone loss for postmenopausal women.
SUMMARY OF EXERCISE EVIDENCE

There is ample evidence that exercise improves BMD in patients with osteoporosis (15,39). The evidence demonstrates that exercises with axial loading, such as jogging, jumping, and vibration exercises, promote the best gains in BMD at the hip (26). However, combining dynamic exercises with a resistance program that involves multiple joints, large muscles, and spinal loading have demonstrated effectiveness for maintaining and promoting bone formation at the hip and at the spine (34). However, to best maintain and stimulate BMD, an exercise program needs to incorporate the principles of specificity, overload, and progression. That is, the exercise program should demand an adaptation to a specific region, should present a load large enough to exceed what is accustomed, and the exercise routine should be progressed and varied (1). The exercise program should also directly load the musculoskeletal system in areas prone to fractures, such as the hip, spine, and wrist. Progression should be slow and gradual to avoid injury, and all clients with osteoporosis should receive medical clearance before initiating an exercise program.

EXERCISE PRECAUTIONS

Special care needs to be taken when designing an exercise program for an individual with osteoporosis. For instance, a resistance training program that exceeds the ability of bone to adapt to new stress may lead to undesired results, such as stress fractures, bone inflammation, spurs, or even complete fractures. The exercise program should be designed to load the musculoskeletal system slowly and provide sufficient time for bone growth and adaptation to occur. This can best be achieved by small increases in resistance over extended periods (less than 5% per week). Symptoms of delayed-onset muscle soreness should be expected. However, undesirable symptoms, such as dull, deep continuous pain and/or antalgic gait or posture should not be expected. These symptoms could be

<table>
<thead>
<tr>
<th>Exercise type</th>
<th>Exercise movement</th>
<th>Exercise dose</th>
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<tbody>
<tr>
<td>Warm-up</td>
<td>Choice of treadmill, stationary bike, elliptical machine, stair stepping</td>
<td>50% maximum heart rate, 5–10 min</td>
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<tr>
<td>Resistance training alternating upper/ lower-body exercise each session</td>
<td>Lower body: horizontal leg press, hamstring curls, hip abduction, hip adduction</td>
<td>50% of 1RM, 10–15 reps, 2–3 sets</td>
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<td></td>
<td>Upper body: bench press, upright row, latissimus pull down, overhead press</td>
<td>50% of 1RM, 10–15 reps, 2–3 sets</td>
</tr>
<tr>
<td>Spine-specific exercises</td>
<td>Prone press-up (Figure 1) and quadruped stabilization (Figure 2)</td>
<td>20 reps, 2 sets</td>
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<td></td>
<td>Thoracic extension on foam roll (Figure 3)</td>
<td>10 reps</td>
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<td></td>
<td>Thoracic extension with pectoral stretch (Figure 4)</td>
<td>20-s holds, 5 reps</td>
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<td></td>
<td>Thoracic extension in prone position (Figure 5)</td>
<td>10-s holds, 5 reps</td>
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reps = repetitions; 1RM = 1 repetition maximum.

Figure 1. Prone press-up: start with the client lying flat on a table and begin to straighten elbows with palms in front of shoulders while keeping the pelvis on the table.

Figure 2. (A) Quadruped spinal stabilization exercise starting position: client maintains position on hands and knees with a neutral spine and contracted transversus abdominis. (B) Quadruped spinal stabilization exercise end position: while maintaining abdominal contraction and neutral spine position, lift the arm to shoulder height while lifting the opposite side leg to the same level.
signs of serious bone or tendon injury. It is imperative to discontinue the program if symptoms persist and seek immediate medical attention from a qualified healthcare practitioner. Clients diagnosed with osteoporosis should also be encouraged to avoid slouched postures that typically consist of rounded shoulders and a forward head because this position encourages flexion of the spine and stress on anterior vertebral body. If receiving pharmacologic treatment for osteoporosis, special precautions should be taken when participating in an exercise program. For instance, bisphosphonates (Acotonel) may cause acid reflux if the client lies down soon after the administration. Individuals taking bisphosphonates should remain upright for at least 30 minutes before participating in any exercise that requires lying down (19). Finally, postmenopausal women who take large doses of calcium and vitamin D supplements should be aware of potential adverse effects of these supplements, such as low blood pressure, constipation, headaches, dizziness, weakness, fatigue, and gastrointestinal disturbance (5). As previously stated, it is recommended that all individuals with osteoporosis receive clearance from a medical doctor before initiating an exercise program.

SAMPLE EXERCISE PROGRAM

The following is an example of a sample exercise program (Table) that would benefit a patient with osteoporosis, assuming the individual is not experiencing additional injury or dysfunction to the musculoskeletal system. The described program is not all-inclusive and should always be performed with respect to pain. If adverse musculoskeletal symptoms are reported during the program, the client should be referred to the appropriate healthcare provider. The example provided is designed for a beginner with respect to exercise dosage and movements performed. All resistance exercises would be initially performed with pulley-based resistance equipment at moderate intensity. The program would be performed with the frequency of 4 sessions per week and progress as indicated after a period of 4–6 weeks.

The extremity exercises chosen integrate both compound movements in which loading occurs through multiple joints as well as foundational isolated joint movements. It should be noted that during all exercises, spinal flexion is avoided because of the inherent risk of vertebral compression fracture. A neutral or slightly extended spine is maintained throughout the routine.

The specific focus on the hip musculature provides a strength foundation for proximal stability with the understanding that functional movements will be integrated once a strength base is established. The resistance level should be progressed gradually up to 85% of 1RM. Intensity of the exercise program can also be progressed by decreasing rest time between sets from 2 minutes to less than 30 seconds. Specific spine exercises are included in the program to improve spinal dynamic stabilization and spinal extension strength as well as to help the patient avoid a flexed spine posture.

CONCLUSION

Strong evidence exists that exercise should be considered an essential portion of the treatment plan for any individual diagnosed with osteoporosis. As part of the rehabilitation team, the exercise professional should have a client obtain medical clearance before initiating an exercise program. Although the research supports exercise as an intervention for osteoporosis, there is no definitive conclusion on how to progress the osteoporotic client. Based on the available information, the authors recommend a combination of weight bearing and non–weight-bearing exercise starting with lower loads (40–67% 1RM) and higher repetitions with a gradual progression toward higher loads (80–85% 1RM) and lower repetitions. By using the information presented in this article, the exercise professional should be able to design and implement an exercise program.
that will protect an individual from injury and inhibit or potentially reverse the negative effects of osteoporosis.

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