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The Role of Exercise in the Treatment of Osteoporosis

Mehrsheed Sinaki · Michael Pfeifer · Elisabeth Preisinger · Eiji Itoi · René Rizzoli · Steven Boonen · Piet Geusens · Helmut W. Minne

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Abstract The objective of exercise in the treatment of osteoporosis is to improve axial stability through improvement of muscle strength. Therefore, a back extension exercise program specific to one's musculoskeletal competence and pain can be performed in a sitting position and later advanced to the prone position. When fragility is resolved, back extension is performed against resistance applied to the upper back. To decrease pain and immobility in acute vertebral fracture, use of spinal orthoses become inevitable. Therapeutic exercise should address osteoporosis-related deformities of axial posture, which can increase risk of fall and fracture. Strengthening of the major appendicular muscles decreases fragility. The effect of strengthening exercise is augmented by proper intake of cholecalciferol and calcium. Thus, the role of a therapeutic exercise program is to increase muscle strength safely, decrease immobility-related complications, and prevent fall and fracture. As with pharmacotherapy, therapeutic exercises are individualized.

Keywords Back extension exercise · Bone mineral density · Kyphosis · Muscle strengthening · Osteogenic exercise · Osteoporosis · Rehabilitation · Spinal Proprioceptive Extension Exercise Dynamic (SPEED) · Spinal orthotics · Vertebral fracture

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Introduction

Bone, to be maintained, needs to be mechanically strained—within its biomechanical limits [1]. Pharmacotherapy alone is not sufficient for the comprehensive management of osteoporosis. In 1982, investigators took the first critical look at the benefits and shortcomings of back exercise programs affecting the spine with osteoporosis [2]. Since then, through myriad publications, it has been well documented that exercises and their execution techniques have a significant role in the treatment of osteoporosis [3]. In addition, reports have shown that participation in a therapeutic spinal flexion exercise [4] and recreational physical activities that induce strain

during flexion beyond biomechanical competence of the vertebral bodies [5] can result in fracture.

As with pharmacotherapy, osteogenic exercises and rehabilitation measures need to be individualized. In general, for osteogenicity, loading exercises are preferable to endurance exercises. Strengthening of the axial muscle group can improve the mobility of older individuals and decrease both kyphosis and the risk of vertebral fractures. Studies have shown that even when exercise and rehabilitative measures do not increase bone mass, they still can be beneficial for reducing the occurrence of vertebral fracture [6], improving disequilibrium, and decreasing the risk of falls [7] and subsequent appendicular fractures. In addition to helping with musculoskeletal health, exercise has other benefits that affect quality of life. Some of the well-known benefits of exercise are improved cardiovascular health, decreased body weight, and improvement in diabetes mellitus, hyperlipidemia, depression, and stress management. In this review, we discuss mainly the role of exercise in the treatment of osteoporosis.

Factors in Bone Health

In men and women, the combination of age-related sarcopenia, reduction of type II fast-twitch fibers, and decline of physical activity can affect mobility and contribute to the development of bone fragility and falls. With increasing age, axial loss of muscle strength is more significant in women than appendicular muscle loss [8].

In osteoporosis, decline in axial bone mass and muscle strength can result in kyphosis with or without vertebral fracture. The exponential loss of axial bone mass at the postmenopausal stage is not parallel to incremental loss of muscle strength. This latter loss follows a more gradual course and is not significantly affected by sudden hormonal decline, as is the case with bone loss.

Regarding musculoskeletal strength, women are more challenged than men because they start adulthood with less muscle strength [9, 10] and less bone mass than men [11]. Reduction in the biomechanical competence of the axial skeleton can result in difficult complications [12]. Therefore, rehabilitation measures that address musculoskeletal and psychological aspects of fragility are important for improvement of a patient's quality of life. Osteoporosis rehabilitation and nonpharmacologic interventions consist of axial and appendicular exercise, sedative physical therapy for musculoskeletal pain, timely use of orthotics, and prevention of falls and fractures [13]. In addition, recent studies show the augmentative effect of vitamin D on muscle strength and prevention of falls [14••].

Combining pharmacotherapy with nonpharmacologic therapy is fundamental to the successful treatment of osteopenia and osteoporosis. With the knowledge that skeletal structures are physically and kinematically acted on by muscles, we review the positive and negative effects of exercise on the osteoporotic skeleton.

Axial Deformities

Kyphosis commonly occurs with reduced back muscle strength or vertebral bone loss or fracture, or both. Hyperkyphosis results in back pain, decreased physical activity, increased risk of further vertebral fractures, and postural instability [15].

Posture in osteoporotic patients is classified into five types: normal, round back, hollow round back, lower acute kyphosis, and whole kyphosis [16]. Round back is a posture with increased thoracic kyphosis and normal lumbar lordosis; hollow round back has increased thoracic kyphosis and increased lumbar lordosis; lower acute kyphosis has thoracic lordosis and lumbar kyphosis; and whole kyphosis has kyphosis of the entire spine.

Spinal curvature is determined by the shape of the vertebral bodies and the back muscle strength. Because of bone fragility, vertebral fracture occurs commonly in patients with osteoporosis. Initial vertebral fracture usually occurs at the midthoracic or thoracolumbar spine as a wedge fracture [4, 17]. As osteoporosis advances, biconcavity fractures more commonly occur at the lumbar spine. Because of these fractures, the spinal column undergoes deformity not only in the sagittal plane, but also in the coronal plane. However, despite these spinal deformities, most of these patients are able to stand without a support because the pelvic inclination, hip extension, and knee flexion can compensate for the spinal deformity.

Back muscle strength is another important factor that determines the spinal curvature. Back extensor strength decreases with age in men and women (Fig. 1) [10]. There are negative correlations between back extensor strength and both kyphosis and the number of vertebral fractures [18]. Hyperkyphosis is known to be related to postural instability [19].

Lumbar kyphosis and anterior spinal inclination are also known to be factors related to postural instability [20•]. In addition, persons with a history of falls have weaker back extensor strength than those without such history [21•]. All these data suggest that increasing back extensor strength can be an effective therapeutic intervention for the osteoporotic spine [7].

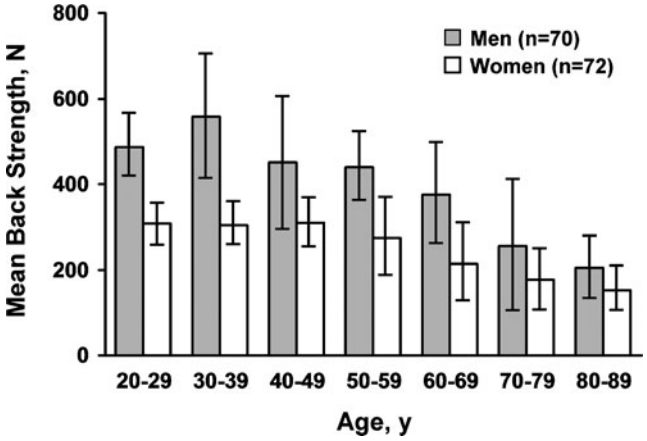

Fig. 1 Back extensor strength in men and women during the third through ninth decades. *Error bars* represent SD. (*From* Sinaki et al. [10]; with permission.)

Recommended Interventions

The effectiveness of conventional back extension exercise and physical therapy in osteoporosis was first reported in 1982 [2]. Later, in 1986, the progressive, resistive back extension exercise study was performed using a backpack containing weight equivalent to 30% of the individual's maximum back extensor strength [6]. The results of this study showed significant improvement in back extensor strength in healthy and osteopenic women without significant increase in bone mass. The exercise regimen in this study also proved to be effective in improving kyphotic posture in healthy postmenopausal women [22]. After 8 years of cessation of the exercise, the back extensor strength was still significantly greater in the previously exercised group than in the control group; this 2-year exercise was shown to decrease the relative risk of vertebral fractures by 63% [23].

However, the muscle resistance due to a heavy backpack could be too strenuous or beyond biomechanical competence for fragile women with osteoporosis. The effectiveness of this exercise seems to be enhanced with oral administration of cholecalciferol [24].

In cases of osteopenia, back extension from a prone position with application of weight as tolerated with a backpack is recommended. Low-intensity back strengthening exercise without a backpack was prescribed to women with osteoporosis and proved to be effective in increasing back extensor strength and improving quality of life [25••].

The quantitative evaluation of the efficacy of conventional back extension exercise in increasing back extensor strength in women with back pain was first reported in 1989 [26]. Rehabilitation of osteoporosis is a comprehensive program that includes strengthening of back extensors and upper and lower extremities without overstraining the ligamentous and capsular structures of the engaging joints [13].

Back Extension Exercise

The spine in osteoporosis requires exercises that can increase axial stability without causing vertebral wedging or fracture. Therefore, exercise programs that can reduce axial deformities without resulting in vertebral fractures are highly desirable. Frost's theory of minimal effective stress stimulus indicates the need for loading the spine to induce bone formation [27]. Therefore, weight lifting that does not result in compression fracture is recommended.

The osteoporotic spine does not tolerate compressive forces beyond its biomechanical competence. To accomplish loading of the spine, the exercise program—as with pharmacotherapy—needs to be prescribed on an individual basis. Past experience proves that trabecular structures do not need to be stimulated vertically when the person already has a predisposition to kyphosis and uneven distribution of forces on vertebral bodies. This objective can be achieved with nonloading back extension exercises [6]. It is hypothesized that these exercises may not initially increase bone mass significantly, but through both strengthening the back extensors strength and loading the horizontal trabeculae of the spine, further vertebral fracture can be prevented (Fig. 2) [6, 28••, 29].

Back exercise programs are prescribed according to the status of the individual's musculoskeletal health [1]. Back extension exercise for the fragile spine can be initiated in the sitting position and later advanced to back extension in the prone position [2, 4]. Specific exercises are recommended for the spine with osteopenia, osteoporosis, and severe osteoporosis. Back extension in a sitting position is safe for new vertebral compression fracture; however, the implementation needs some innovative interventions.

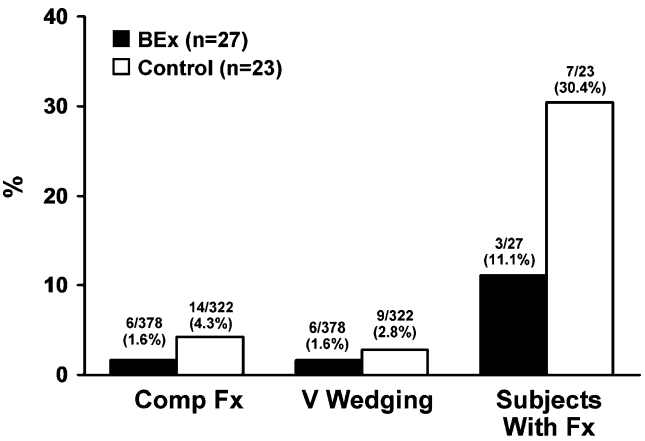

Fig. 2 Effect of back muscle strengthening on the rate of vertebral fractures in postmenopausal women. In the back exercise group (BEx), 378 vertebrae were examined; in the control group, 322 vertebrae were examined (14 vertebrae, T4–L5, were examined for each patient). *Comp Fx* compression fracture; *Fx* fracture; *V* vertebral. (*From* Sinaki [29]; with permission.)

Spinal Orthotics in Osteoporosis: To Brace or Not to Brace

Timely and proper application of spinal orthotics for management of acute compression fracture-related pain decreases immobility-related muscle disuse. This application decreases kyphotic posturing, back pain, and posture-related loss of height [30]. Spinal orthotics are to be used for a limited period unless their application for pain management becomes inevitable. After the acute stage of compression fracture-related pain, spinal orthotics that improve the patient's compliance with exercise are preferred [29–31].

With osteoporosis-related vertebral fracture, spinal flexors go through a cocontraction phase. This cocontraction prevents any further strain on vertebral bodies, which inadvertently could induce further pain. Any physical intervention that can reduce use of the spinal extensors unloads the vertebral bodies and decreases spinal flexor spasm. After vertebral fracture and the acute pain phase, sedative physical therapy measures should be applied to the osteoporotic spine as a prelude to initiation of an exercise program.

Falls

Osteoporosis and reduction of muscle strength cause an imbalance in musculoskeletal stability. Increased bone porosity decreases the biomechanical competence of bone. Trauma to the skeletal structure can vary from gravity alone to the high impact of a moving, energized body part to the floor. The point of no return from fracture is defined by bone mass and resilience [29].

Prevention of falls and a decreased risk of fracture are major components for management of osteoporosis [32]. A significant reduction in back pain, kyphosis, and risk of falls and an improvement in the level of physical activity have been achieved through the SPEED (Spinal Proprioceptive Extension Exercise Dynamic) program ($P<0.05$) [7]. Patients who performed the SPEED program decreased their fear and risk of falls, as evidenced through use of computerized dynamic posturography and gait laboratory (Fig. 3). In yet another study, application of a back support decreased kyphosis and pain related to the compression fracture [30]. It also improved loss of height as related to kyphotic posturing. To maintain the effect of the SPEED program, one needs to continue the program with a lesser intensity [7].

Bone mass is frequently considered the most important determinant of fragility, but it explains only less than half of the observed fracture risk at the level of the spine. Nonpathologic spontaneous vertebral fractures that occur at the level of the spine are purely osteoporosis related.

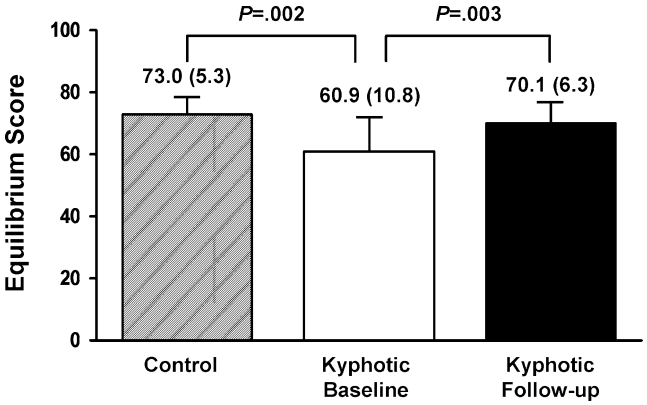

Fig. 3 Composite equilibrium score of computerized dynamic posturography in control subjects and subjects with osteoporosis-kyphosis at baseline and follow-up. Equilibrium of the kyphotic subjects improved significantly after a 4-week trial of the SPEED (Spinal Proprioceptive Extension Exercise Dynamic) program and spinal weighted kypho-orthosis. Data are reported as mean (SD). A score ≥ 68 is normal for a person ≥ 60 years of age. (*From* Sinaki et al. [7]; with permission.)

Conversely, most nonvertebral fractures that are of special clinical significance are fall related. Therefore, reducing the risk of fracture through the prevention of falls is as important as increasing bone mass. However, the prevention of falls is more challenging than improving bone mass. Falls are multifactorial, and prevention or reduction of falls requires a combination of pharmacologic and nonpharmacologic interventions. Risk of falls can be extraskeletal (ie, related to environmental factors) or intrinsic (ie, related to musculoskeletal and neuromuscular health) [32].

Vitamin D can augment the effect of strengthening exercises. Combining exercise for strengthening back extensors and lower-extremity muscles with supplementation of both calcium and vitamin D has proved to be superior to calcium supplementation alone. One study on the effect of long-term use of vitamin D and calcium supplementation on falls showed significant improvement of muscle function in community-dwelling older individuals [14••].

Role of Exercise After Hip Fracture

In osteoporosis, the structural failure and stress fracture that result in severe pain without dislocation of the involved bone structures can be visualized on bone scan [33] or MRI. Inguinal or anterior groin pain is the earliest and most frequent symptom of a stress fracture of the femoral neck. Night pain may develop, especially when the diagnosis is delayed. Discomfort at the extremes of hip rotation and inguinal tenderness are common physical findings.

Treatment of stress fracture initially requires management of pain through the use of ice and NSAIDs and the

reduction of weight bearing on the involved extremity. However, for maintenance of the individual's muscle strength and level of fitness, aquatic exercises such as swimming or walking in water, or both, are recommended. Muscle strengthening of the involved joints needs to continue with the use of antigravity exercises, as before the injury. After 4 weeks of pain-free exercises, the patient is advised to start the advanced stage of treatment. At this stage, a gradual increase in weight-bearing activity with antigravity, out-of-water exercises is recommended, along with pain management measures.

In most cases, hip fractures occur after falls. Therefore, measures that prevent falls, such as strengthening of the core muscles that are the supportive muscles of back and the hip girdle musculature, are beneficial. Measures, whether supportive or proprioceptive, for decreasing disequilibrium also need to be used. After hip fracture and proper orthopedic interventions, mobility with proper gait aids for the initiation of weight bearing, if possible, is recommended. Muscle re-education and isomeric muscle setting and, later, proper strengthening exercises are required. The objective is prevention of immobility and debility due to fear of falls, which results in fragility due to further loss of bone and muscle mass.

For treatment of osteoporosis, whole-body vibration is not recommended, given the extent of fragility in some osteoporosis cases. To our knowledge, the only data available on older persons are of short duration (6 months) (Steven Boonen, Personal communication). In addition, almost no data exist on safety and acceptance of the whole-body vibration technique for older, osteoporotic patients. We believe it is premature to recommend whole-body vibration without knowledge of the long-term effect of such interventions.

A Critical Look at Exercises to Prevent Further Bone Loss in Osteopenia or Osteoporosis

That exercise plays a considerable role in the prevention of osteoporosis is a well-recognized fact. In this section, we address the important role of exercise in the treatment of osteoporosis. Choosing the correct exercise requires knowledge of the individual's musculoskeletal competence to avoid further injuries. For improved compliance, several issues need to be addressed before prescribing an exercise program for management of osteoporosis: 1) spine and hip bone mass, as determined with bone mineral density (BMD) evaluation; 2) past history of physical activity interests; 3) cardiovascular health status; 4) age; 5) extraskeletal factors; 6) clinical evaluation of back extensors and major muscle groups of upper and lower extremities; 7) postural alignment of the spine to determine whether bracing is needed; and 8) gross neuromuscular evaluation of factors (eg, gait stability, equilibrium, coordination). Consideration of all of these factors improves patient compliance with the recommended therapeutic exercises.

In general, an exercise program—therapeutic or otherwise—needs to address flexibility, strength, core stability, cardiovascular fitness, and equilibrium. The program should start with range-of-motion exercises as a warm-up period, followed by stretching and then strengthening, followed by cardiovascular fitness exercises. A cool-down period and stretching can follow this sequence.

Back extensor strength is correlated with BMD of the spine [34]. It has been shown that progressive, resistive back extension exercises can decrease risk of vertebral fractures, even in the absence of other pharmacotherapeutic measures. Therefore, initiation of back extension exercises is recommended, whether or not the patient has vertebral fractures. Back extension exercises can be performed in sitting or prone positions and with or without weight on the back. Performing weight-lifting exercises three or four times per week is adequate.

Lower-Extremity Exercises

Weight-bearing exercises, such as walking, are important for maintenance of BMD of the hips and lower extremities. A study of a population-based survey of the ambulatory US population 60 years of age and older (N=4100) showed that increased 25-hydroxyvitamin D concentrations were associated with improved lower-extremity function, as assessed with an 8-ft walk test [35].

The risk of hip fracture approximately doubles with a decrease in BMD of 1 SD below the age-adjusted mean [36]. Developing muscle mass at the hip area through strengthening exercises can decrease risk of fracture. A low body mass index increases the risk of hip fracture [37]. Therefore, strengthening exercises for hip girdle muscles are recommended. In addition, coordination exercises for the lower extremities could decrease age-related gait disorders [1].

Tai chi may have beneficial effects with respect to coordination, equilibrium, fall reduction, and flexibility. The effect of tai chi on bone mass appears to be equivalent to moderate-speed to slow walking exercises. However, future studies are needed to substantiate osteogenicity [38]. There is no convincing evidence that tai chi has a role in the prevention or treatment of osteoporosis. Strengthening exercise for the main muscle groups, together with aerobic exercise, has a small but positive effect on the BMD of the hip in postmenopausal women with low BMD [39].

Conclusions

In the selection of the most effective exercise program, BMD of the spine and hips needs to be considered. In general, osteopenia indicates that an exercise program can be more strenuous than with osteoporosis, given the musculoskeletal issues. Osteoporosis with vertebral fracture indicates severe osteoporosis that requires a more selective choice of exercise (ie, for the spine, start with extension exercises in a sitting position and progress gradually). Mechanical loading and muscle contraction promote bone formation. Non-weight-bearing exercises, such as swimming, can improve muscle strength, cardiovascular fitness, and coordination, but they are not bone-loading exercises. Vitamin D augments the effect of strengthening exercises. Spinal orthoses, when prescribed properly, can improve kyphosis, back strength, and, subsequently, quality of life. Implementation of the SPEED program can improve disequilibrium, kyphosis, back strength, and level of physical activity and decrease risk of falls, but it needs to be continued on an as-needed basis.

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