Review / *Derleme*

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The Exercise Recommendation for Patients with Osteoporosis: Which Type of Exercise and When?

Osteoporoz Hastaları için Egzersiz Önerileri: Hangi Egzersiz Türü? Ne Zaman?

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Abstract

Exercises are crucial for enhancing and maintaining bone and muscle health. 'Preventative Strategies' including certain exercises are fundamental in osteosarcopenia's management. Determining the Frequency, Intensity, Time, and Type are major elements of prescribing an effective exercise program for osteoporosis. Patients with osteoporosis may need modifications in exercise programs due to pain, kyphosis, poor balance, arthritis, frailty, neuromuscular impairments, and cardiovascular and/or pulmonary diseases. In addition, specific exercises for accompanying disorders should be given priority. Consequently, exercise recommendations for osteoporosis must be target-specific, safe, effective, and tailored to patients' needs.
Keywords: Osteoporosis, exercise, prevention of bone health

Öz

Egzersizler kemik ve kas sağlığını korumak ve geliştirmek için çok önemlidir. Belirli egzersizleri içeren 'Önleyici Stratejiler' osteosarkopeni yönetiminde esastır. Sıklık, yoğunluk, zaman ve egzersiz türünün (*Frequency, Intensity, Time, Type*) belirlenmesi, osteoporoz için etkili bir egzersiz programının reçete edilmesinin ana unsurlarıdır. Osteoporozlu hastalar ağrı, kifoz, denge bozukluğu, artrit, kırılganlık, nöromusküler bozukluklar ve kardiyovasküler ve/veya pulmoner hastalıklar nedeniyle egzersiz programlarında değişikliklere ihtiyaç duyabilir. Ayrıca, eşlik eden bozukluklara yönelik özel egzersizlere öncelik verilmelidir. Sonuç olarak, osteoporoz için egzersiz önerileri hedefe özgü, güvenli, etkili ve hastaların ihtiyaçlarına göre uyarlanmış olmalıdır.
Anahtar kelimeler: Osteoporoz, egzersiz, kemik sağlığının korunması

Introduction

Osteoporosis (OP) and sarcopenia are growing public health problems in parallel with the increase in the elderly population. Certain genetic, mechanical, nutritional and endocrine factors are blamed in the development of these two diseases, which often accompany each other. Dietary supplements and exercises focused on the preservation of bone mineral density (BMD) and muscle health are crucial in healthy aging. This is named as 'Preventative Strategy' (1).

Mechanical, biochemical and endocrine interrelations have been described between muscle activity and bone metabolism. Especially, progressive resistance exercises stimulate osteoblastogenesis and muscle protein synthesis, leading to better bone microarchitecture, improved muscle mass and strength, and higher functional capacity, in older individuals (1). Moreover, exercises benefit by increasing mobility and functional capacity through endothelial, myocardial and cognitive adaptations (1).

Exercises modulate the dynamic balance between bone formation and resorption by creating mechanical stimuli. Mechanical forces such as compression, strain, tension, and fluid shear stress promote osteoblast differentiation and mineralization, reduce bone loss, increase bone strength and prevent OP in older adults (2). The effects of gravity and appropriate mechanical stimuli are crucial in bone metabolism.

Estrogen, parathyroid hormone, and glucocorticoids play a key role in bone metabolism and remodeling (3-6). Estradiol inhibits

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TRPV5 RANKL expression and promotes OPG expression (2). Exercise could increase serum estradiol and serum testosterone levels (7-9). Moderate intensity exercises reduce proinflammatory cytokines such as IL-1, IL-6, and TNF-α, which can increase bone resorption, while promoting anti-inflammatory cytokines that support bone mineralization such as IL-2, IL-19, IL-12, IL-13, IL-18, and IFN-α (10).

Exercise may have cellular effects on bone metabolism. It leads to osteoblast differentiation and osteoclast inhibition via Wnt/β-catenin, BMP and OPG/RANKL/RANK signaling pathways (11,12). Also, it regulates noncoding RNAs (siRNA, microRNAs, lncRNA, and circRNA) activating bone formation (13). Bone remodeling is closely related to vascularity in terms of the microenvironment in which it occurs. Vascular endothelial growth factor, hypoxia-inducible factor 1, epidermal growth factor-like, nephronectin, FGF, matrix metalloproteinase and Notch signaling pathways have been reported to be involved in communication between osteoblasts/osteoclasts and angiogenesis (12,13). Another effect of exercise on bone formation could be regulating angiogenic factors. Mechanical loading has been shown to increase periosteal vascularity (12). The mechanisms of the effects of exercise on bone metabolism are summarized in Figure 1.

Exercise recommendations aiming at the prevention of osteoporotic fracture should address not only bone quality but also fall-related risk factors. This can be achieved by multimodal exercise approaches involving at least two activity modes including weight-bearing impact exercises (WBIEs), progressive resistance or high-velocity power training, interventions enhancing balance, posture and functional task activities (14). Besides, an exercise prescription must describe the appropriate dose, modality and intensity. Frequency, Intensity, Time and Type are major domains of an effective exercise program.

Exercise Modalities

a) Weight-bearing Impact Exercises

The close relationship between the reduced effect of gravity and bone mass loss underpins the importance of impact loading exercises in preventing OP. Bone responds well to intermittent, rapid, high magnitude and multidirectional dynamic forces (the adequate load) (14). On the other hand, bone cells desensitize to continuous forces or uniform repetitive cycles of loading over time (15). This perspective should be considered when prescribing a clinical exercise program for OP (16). The response of bone metabolism to a resistance or loading exercise is based on the principles of specificity, progressive overload, reversibility, initial values and diminishing returns (17).

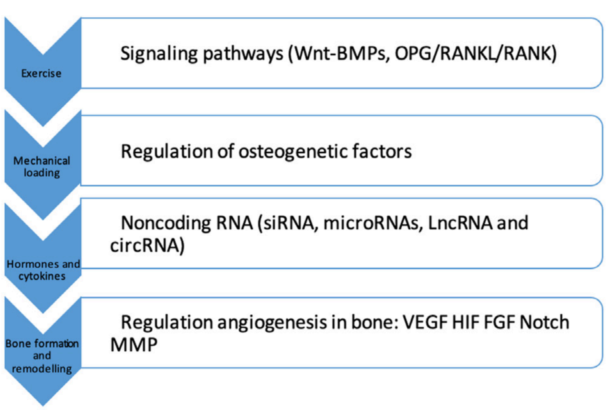

Figure 1. The effects of exercise on bone metabolism

Principle of specificity: Exercise is not systemic in nature and should be planned according to the region. Therefore, the exercise prescription should include activities known to load the relevant skeletal region (14).

Principle of progressive overload: During an exercise, the load exerted on the bone by gravity or muscle forces must be further than the loading encountered during daily activities. The loading stimulus must be increased gradually as the bone adapts (14).

Principle of reversibility: The skeletal benefits of exercise are gradually lost when the exercise program is discontinued but it is not yet clear what minimum exercise dose is required to maintain skeletal gains (14).

Principle of initial values: With loading, the most significant changes in bone occur in those with the lowest initial BMD (18).

Principle of diminished returns: Once skeletal adaptation is gained after the first exercise, subsequent adaptations are likely to be slower with a similar loading mode and intensity. This is an example of the "Principle of Cellular Adaptation", in which bone initially responds strongly to a sufficient load, but this response will gradually decrease as cells adapt to new mechanical forces (19).

When determining the duration of the exercise program, it should be noted that the response of bone is late, as the typical remodeling cycle takes 3-8 months (14). Therefore, interventions should last at least 6-9 months (preferably 12 to 24 months) (14). It has been reported that the greatest changes in BMD occur in the first 5-6 months over 12-18 months with various exercise interventions (20,21). However, there is also research showing a linear increase in BMD with continuous exercise training (22,23). Consequently, an exercise program for OP should be long-term and gradually increase in intensity.

At least weekly 4 sessions of WBIEs including versatile movement patterns are recommended to prevent bone loss in older adults (16). Several exercise trials involving 2-3 sessions of progressive stepping and jumping training per week or weighted vest jumping (average of 52 jumps per session) have been reported to improve proximal femoral BMD in postmenopausal women compared to controls (24,25). However, to increase peak bone density, it is recommended to perform weight-bearing and impact loading exercises from childhood and young adulthood (26). Exercises applied in early ages provide lifelong gains, unlike those started at older ages (23). Bassey et al. (27) reported that 50 vertical jumps (aiming to load 4 times the body weight) per day, 6 days a week for 12 months had no significant effect in postmenopausal women, despite its benefits in the premenopausal period.

The loads applied in weight-bearing exercises must exceed the usual forces in daily living activities to create adequate response in the bone structure. In a study of 14 postmenopausal elderly women evaluating the osteogenic effects of different exercises at various intensities on the femoral neck; jumping, running (5-9 km/h) and fast walking (5-6 km/h) exercises were founded to have more compressive and tensile strains than walking at 4 km/h, which was considered the minimal loading level for bone preservation (28).

During WBIEs, strains emerging from accompanying muscular activity contribute to osteogenic effects of ground reaction forces. A study of 20 postmenopausal women used computational modeling to predict specific muscles loaded in the femoral neck during various activities (normal walking, brisk walking, stair climbing and descending, and vertical jumping) using strain-distribution models along the proximal femur; and found a number of key findings that could be used to guide the design of future exercise programs for older adults (29). These findings can be listed as follows: a) trochanteric region subjects to highest strains for all activities, b) stair ambulation and vertical jump causes higher strains on the anterior and upper parts of the femoral neck (key areas prone to weakness and fracture) than walking, c) hip extensors are responsible for inducing strains in the femoral neck during stair ambulation and jumping, as opposed to inducing the iliopsoas muscle with walking, d) the ground reaction forces associated with each exercise are closely related to the stretch level. The peak vertical ground reaction forces of common weight bearing activities are given in Figure 2 (14,30-32).

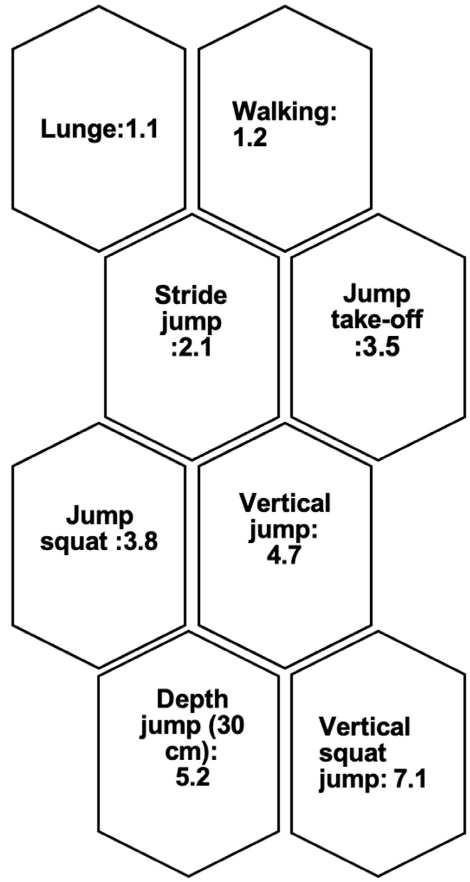

Figure 2. The peak vertical ground reaction forces of common weight bearing activities (normalized to body weight) (14,30-32)

b) Progressive Resistance Training

Resistance exercises have various mechanical effects on bones. Muscle contractions impose compressive, bending, and rotational loads on the skeletal areas they cross over; but distraction on cortical bone in the enthesis areas (33). Bone formatting effects of progressive resistance exercises are limited areas where they create mechanical load rather than the whole skeleton. Therefore, exercise protocols should include muscles related to or crossing over the areas at high risk for fragility fractures, such as the spine and hips (14).

Resistance training exercises (hip extension and flexion, hip abduction and adduction) performed at 40-60% of maximum muscle strength induce bone stresses equivalent to less than that reported during walking at normal speed (28). Therefore, it is recommended that resistance exercises that address osteoporosis should be applied at a high intensity (80-85% of 1 repetetif maximum) and speed (high-velocity power exercises). High-velocity and vigorous muscle activities may reduce exercise compliance in elderly patients due to pain, degenerative joint diseases, and sarcopenia. This may also explain the mixed findings regarding the effects of resistance training on hip BMD in older women (14). For safe and effective exercise protocol for elderly and frail patients, moderate-intensity and smooth strengthening exercises are recommended to control pain and increase muscle strength at the beginning, followed by a gradual increase in resistance and velocity (16).

c) Posture, Balance, and Mobility Exercises

The clinical significance of OP is associated with an increased risk of fracture. In this context, strategies to prevent trauma such as falling should not be ignored in the management of OP. Fall prevention requires proper postural control, sufficient dynamic and static balance abilities, and safe mobility (34).

OP may cause kyphotic posture disorder as a result of asymmetric deformities on the thoracolumbar vertebrae. Increased thoracic kyphosis and forward head posture may adversely affect postural control and mobility in elderly patients (35,36). Back muscle strengthening exercises can prevent vertebral anterior compression fracture and reduce the progressive kyphotic deformity (14).

Tai-Chi may be a good choice for balance training in elderly patients with OP (37). The difficulty levels of balance exercises should be modified considering the accompanying muscle weakness, pain and degenerative joint problems. Balance exercises should be started after the sufficient muscle activity level is achieved with progressive strengthening exercises in fragile patients. On the other hand, weight-bearing activities are unsafe unless the patient has adequate balance and postural control (14).

Graded mobility exercises implemented in the balance training may be beneficial for the functionality of the patient. Lower extremity muscle strength is crucial for effective mobility whereas upper extremity extensor muscles gain importance in transfer activities (38,39). Progressive strengthening and neuromuscular control exercises targeting selected muscle groups contribute to mobility (40).

Conclusion

Exercise recommendations for OP are summarized in Table 1. WBIEs could be performed as 10-20 repetitions of vertical, multidirectional jumps, hopping, bounding or drop jumps in 3 to 5 sets with 1 to 2 minutes of rest periods in 4 to 7 sessions per week. Weight-bearing activities such as tennis, dancing, and football could be incorporated into impact exercises for appropriate individuals (14,16,40). Progressive resistance exercises should include major muscle groups such as iliopsoas, quadriceps femoris, erector spinae, gluteus maximus and hip abductors. Intensity and frequency could be determined as a load of 80-85% of a maximum repetition or ≥16 points of perceived exertion on the Borg scale in 2 to 3 sets with 1 to 3 minutes of rest periods in 2 sessions per week. High velocity resistance exercises and functional training for lower extremities could be added (24,16,40). Another crucial component, balance training, should be implemented in the exercise program. Static and dynamic balance exercises such as single leg stance, tandem stance, and toe and heel walking could be applied while eyes open and closed. Posture exercises should be also included. Patients sholud avoid deep forward spine flexion (14). Mind-body exercises such as Tai-Chi may be a good option for balance and posture training. Modification is necessary for patients with pain, kyphosis, poor balance, arthritis, frailty or neuromuscular impairment, cardiovascular and/or pulmonary disease.

Consequently, it is crucial to develop comprehensive exercise programs in terms of preventing/delaying OP and preventing mortality and morbidity related to fragility fractures. Safe, effective, and patient-tailored exercises must be considered an essential part of OP treatment.

Table 1. Exercise recommendations for osteoporosis

Low risk indication • Asymptomatic osteoporosis • Normal bone mineral densitometry • T-score >-1 standard deviation (SD)	**Goal:** To maximize bone mass strength and to improve muscle strength • Weight-bearing impact exercise (WBIE) • Progressive resistance exercise • Power training • Balance training
Moderate risk indication • T-score: -1 to -2.5 SD • Clinical or functional risk factors	**Goal:** To enhance muscle power and function training in technique and supervision is essential. • WBIE • Progressive resistance exercise • Power training • Balance training *Similar to low risk indication
High risk indication • T-score <2.5 SD • Previous fracture or multiple risk factors for fracture	**Goal:** Moderate/low impact activities (2-3 body weight) within the limits of pain under supervision railing, secure support is necessary

Ethics

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: J.M., Concept: J.M., Design: D.E.B., Data Collection or Processing: L.K., Analysis or Interpretation: L.K., Literature Search: D.E.B., J.M., Writing: D.E.B., J.M.

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