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The significance of physical activity in the prevention of osteoporosis in older adults

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Abstract

Introduction and objective

Osteoporosis is a disorder that leads to a decrease in bone mass, accompanied by a disruption in bone structure, resulting in an increased risk of bone fractures. It affects a large number of people worldwide and constitutes a significant social and economic problem. It primarily affects older individuals, especially postmenopausal women. Fractures associated with osteoporosis diminish the quality of life. Osteoporosis often remains asymptomatic and is difficult to diagnose, typically identified incidentally following a low-energy fracture.

Diagnosis of osteoporosis involves measuring bone mineral density using dual-energy X-ray absorptiometry (DEXA). Osteoporosis is diagnosed when bone mineral density is found to be more than 2.5 standard deviations (SD) below the mean bone mineral density of healthy young adults with peak bone mass. Modifiable risk factors for osteoporosis include lack of physical activity, calcium deficiency in the diet, and alcohol consumption.

Review methods

The article was based on scientific papers retrieved from the PubMed website and scientific literature. The focus was on papers from 2016 to 2024. Articles written in English were utilized.

Brief description of the state of knowledge

Physical activity encompasses any muscular movement that increases energy expenditure beyond the resting metabolic rate, including weight-bearing exercises, strength training, high-intensity strength exercises, and balance and mobility training. Weight-bearing exercises yield the best results in osteoporosis prevention, recommended to be performed three times a week.

Summary

Physical activity is a scientifically proven preventive factor against osteoporosis, reducing the frequency of falls and increasing bone mineral density. Initiating physical activity at a young age yields significant benefits for bone strength.

Keywords

Osteoporosis, Exercise, Bone Tissue

Introduction

Osteoporosis is a disorder of bone tissue structure, leading to a decrease in bone mass. This condition predisposes to an increased risk of bone fractures [1]. We distinguish two major aspects of osteoporosis. The first is the weakening of bone quality and consequently their strength and resilience, and the second is an increased tendency for fractures with relatively minor force of injury [2]. Osteoporosis is a frequently underestimated disease. Annually in the United States, as much, and sometimes even significantly more money is spent on caring for

individuals with fractures related to bone changes due to osteoporosis as on caring for individuals with stroke, breast cancer, and/or heart attack. These facts show us that osteoporosis represents a significant economic problem for healthcare, as it generates very high costs. It is worth noting that in individuals over 70 years of age, the main reason for loss of independence is falls from their own height and the fractures resulting from bone fragility [3]. It is estimated that currently about 200 million people worldwide suffer from hip fractures due to osteoporosis [4]. There are approximately 8.9 million bone fractures associated with this condition annually. Another problem of this disease is that it does not have clear clinical symptoms and is only noticed at the time of fracture occurrence. These fractures lead to a deterioration in quality of life, cause pain, and increase mortality in patients. It is estimated that one in three women and one in five men over the age of 50 will experience fractures due to osteoporosis [5]. Older postmenopausal women are particularly susceptible to it. This is because postmenopausal women experience a decrease in estrogen production in the ovaries. The lack of these hormones leads to increased loss of bone mass and structural changes in bones, which consequently leads to their weakening and increased fragility, known as postmenopausal osteoporosis. The cells that make up bone are osteoblasts, osteocytes, and osteoclasts. Estrogens, through their influence on these cells, maintain the proper structure of bone tissue. These hormones maintain a balance between bone formation and resorption. This happens because they inhibit the apoptosis of osteoblasts, which are involved in forming new bone tissue, and promote the apoptosis of osteoclasts, which are responsible for decreasing bone tissue [6]. As mentioned earlier, osteoporosis does not present clinical symptoms and it is difficult to diagnose until a low-energy fracture occurs. Performing a DEXA scan on individuals at risk of this disease can help diagnose osteoporosis before a fracture occurs. DEXA is a measurement of bone mineral density (BMD) using dual-energy X-ray absorptiometry. Osteoporosis can be diagnosed when the bone mineral density value is lower than 2.5 standard deviations (SD) from the bone mineral density of healthy young adults with peak bone mass (T-score < -2.5 SD). According to the World Health Organization, each 1 standard deviation decrease in T-score of hip bone mineral density is associated with a 2.6-fold increase in the risk of hip fracture. However, DEXA scanning is an expensive procedure, so most countries have not implemented it as a screening test for the entire population. Considering this examination is recommended for individuals classified as having a high risk of osteoporosis [7]. Risk factors can be divided into modifiable and non-modifiable. Among modifiable factors, lack of physical activity, calcium deficiency in the diet, alcohol

consumption, and smoking can be distinguished. Non-modifiable factors include age, gender, race, and genetic traits. Osteoporosis can be classified as primary or secondary. Primary osteoporosis affects postmenopausal women and individuals over 70 years of age as a consequence of aging. Secondary osteoporosis can be idiopathic, caused by treatment, or other diseases. These diseases include endocrine disorders, systemic diseases, and malignant tumors. Osteoporosis can also occur with chronic use of glucocorticoids, improper habits, and depression [8]. For some patients, this disease requires treatment. Among these patients are postmenopausal women and men over 50 years of age who have: experienced a hip or spine fracture, as it has been shown that patients with these fractures have a lower risk of subsequent fractures if they undergo pharmacological therapy, a fracture has been diagnosed with a T-score of less than or equal to -2.5 in the femoral neck, lumbar spine, or whole hip, when low bone mass is present, and when the 10-year probability of hip fracture is at least 3% or the 10-year probability of fracture related to osteoporosis is 20% or more. Most therapies used for osteoporosis lead to a decrease in bone resorption [4]. These therapies include oral bisphosphonates (alendronate, risedronate) or intravenous zoledronic acid, which are considered the most cost-effective interventions. Alternative options include denosumab (a human monoclonal antibody against receptor activator of nuclear factor-kappa B ligand (RANKL)), ibandronate, hormone replacement therapy, selective estrogen receptor modulators (SERMs) (raloxifene), and strontium ranelate (strong recommendation). Intravenous zoledronic acid therapy should be used as the first-line option in the treatment after hip fracture. During denosumab therapy, close monitoring by the treating physician is necessary, as unplanned discontinuation of this medication without considering alternative therapy should be avoided, as it may increase the risk of vertebral fractures [9]. Denosumab, by long-term inhibition of bone turnover, leads to a positive balance of trabecular and cortical bone mineral density (BMD) resulting in continuous increase in BMD and reduction of fracture risk. No increase in infection rates or malignancies has been observed, indicating that long-term RANKL inhibition does not impair immune function [10]. In addition to treatment that leads to decreased bone resorption, there is also anabolic treatment leading to increased bone mass. In such treatment, teriparatide or romosozumab should be considered as first-line options in the treatment of postmenopausal women at very high risk of fractures, especially those with vertebral fractures. In men aged 50 and older with very high fracture risk, teriparatide should be considered as a first-line option in this type of treatment. Teriparatide and romosozumab should be considered as second-line options in postmenopausal women and

men aged 50 and older with bisphosphonate intolerance. After treatment with teriparatide or romosozumab (for 24 or 12 months, respectively), treatment with alendronate, zoledronic acid, or denosumab should be initiated without delay. Raloxifene should also be considered as one of the options for subsequent treatment after anabolic drugs in women [9]. Osteoporosis is a preventable disease. It is worth focusing on factors that can reduce the risk of osteoporosis. They are recommended for the general population and aim to maintain bone strength. These include adequate intake of vitamin D, identification and treatment of excessive alcohol consumption, quitting smoking, regular physical activity – weight-bearing and muscle-strengthening exercises (weightlifting), and treatment of conditions associated with falls, such as visual impairments and the use of sleep medications. High calcium intake is essential for maintaining peak bone mass and bone health throughout life. It's important to remember that 99% of the body's calcium reserves are stored in the skeleton. When there is a calcium deficiency due to inadequate exogenous intake, bone tissue resorption occurs to maintain its proper level in the blood [11]. Secondary hyperparathyroidism may also occur, which can also result in increased bone breakdown. Calcium is essential in the bone formation phase during remodeling [12]. It is recommended that men aged 19-70 and women aged 19-50 consume 1000mg of calcium per day. Men over 70 years of age and women over 50 should consume 1200 mg of calcium per day. These recommendations refer to elemental calcium intake from supplements. Dietary sources of calcium include low-fat dairy products, selected dark green vegetables, fish, and various fortified food products [11].

Vitamin D plays an important role in maintaining bone strength and muscle function. It is a nutrient/cofactor involved in the absorption of calcium and phosphorus from the intestine, bone mineralization, and maintenance of muscle quality. It also exerts various beneficial effects on other organ systems. Vitamin D is synthesized in the skin during sun exposure. It can also be consumed as part of a balanced diet. Older individuals produce less vitamin D in the skin [13]. The recommended daily intake of vitamin D for adults over 50 years of age according to BHOF (Bone Health & Osteoporosis Foundation) ranges from 800 to 1000 units. The BHOF-preferred level of vitamin D in serum is about 30 ng/mL, as it is associated with optimal calcium absorption. Currently, the normal range for the 25(OH)D level is 20-50 ng/mL. The main dietary sources of vitamin D are milk, fatty fish (such as mackerel, salmon, tuna), and cod liver oil [11].

Another very important element in osteoporosis prevention, besides providing adequate substances necessary for bone building, is the aforementioned physical activity, especially resistance training. It not only improves well-being and strengthens bones but also, by increasing overall fitness, helps reduce the risk of falls, which are particularly dangerous in osteoporosis.

Estimated data on osteoporosis from the European Union, Switzerland, and the United Kingdom in 2019 (27)

Measured parameter	**Value**
Number of women suffering from osteoporosis	25 500 000
Number of men suffering from osteoporosis	6 500 000
Number of new fragility fractures	4 300 000
The economic cost of new and prior fragility fractures in 2019	57 000 000 000 Euro
The number of deaths directly related to osteoporosis in 2019	248 487

Materials and methods

The article was based on scientific papers retrieved from the PubMed website and scientific literature. The papers were searched for in February and March 2024. The focus was on

papers from 2016 to 2024. Keywords such as "osteoporosis," "osteoporosis and prevention," "osteoporosis and exercise," and "osteoporosis and strength training" were entered. Some papers were excluded due to paid access. Additionally, some papers were rejected due to a lack of relevance to the topic of the work. Articles written in English were utilized. In total, 26 articles were relied upon.

Discussion

Physical activity is any muscle movement that increases energy expenditure above resting metabolic levels. Physical activity is recommended for many reasons. It has a positive impact on cognitive functions [14]. Evidence suggests that moderate physical activity leads to mood improvement [15]. It may also result in improved working memory in adults with mild depression [16]. In this section, we would like to present its positive impact on osteoporosis prevention in older adults. We can distinguish two main aspects of the impact of physical activity on osteoporosis. Firstly, it may reduce the number of falls, i.e., potential fractures in the case of osteoporosis, and secondly, training may increase bone mineral density. It has been proven that functional and balance training in adults over 50 years of age can reduce the number of falls and the number of people who fall. There is also evidence that functional and balance training can reduce the number of people who have fall-related fractures and may improve quality of life and physical functioning. Controlled randomized trials (RCT) analysis suggests that regular resistance exercises can contribute to improving quality of life, physical abilities, bone mineral density, and reducing the risk of death. When resistance training is combined with functional and balance training for older adults, it can reduce the frequency of falls and the number of people experiencing falls. Observational studies indicate that walking may contribute to reducing mortality rates among older adults. However, the impact of walking on the risk of fractures, frequency of falls, quality of life, physical abilities, or potential injuries in individuals at risk of fractures is unclear or has not been fully investigated yet. Clinical guidelines for osteoporosis treatment and fracture prevention in Canada strongly

recommend physical activity - balance and functional training at least twice a week to reduce the risk of falls. They recommend gradually increasing the difficulty, pace, frequency, volume, and resistance over time. Functional exercises provide improvement in performing daily activities (e.g., rising from a chair), recreational or fitness activities (e.g., stair climbing as training before hiking) [17]. Physical activity is safe for both healthy and frail older individuals, and the risk of major cardiovascular and metabolic diseases, obesity, falls, cognitive disorders, osteoporosis, and muscle weakness is reduced by regularly performing exercises of varying intensity, ranging from low-intensity walking to more intense sports and resistance exercises [18]. From one of the studies on European guidelines for the diagnosis and treatment of osteoporosis in postmenopausal women, we can learn that immobilization is a factor causing bone loss. It also states that people bedridden for a week lose as much bone mass as they would normally lose in a year. Weight-bearing exercises are an integral part of osteoporosis treatment. A very important piece of information in this study is that exercises aimed at strengthening muscles and improving balance can prevent falls by restoring confidence and achieving better motor coordination. Additionally, they can also help maintain bone density by stimulating bone formation and reducing the resorption process [19]. Currently, it is recommended to use various training programs, i.e., so-called training interventions encompassing multimodal programs that combine different types of physical activity, such as resistance exercises, strength training, high-intensity strength exercises, and balance and flexibility training. This aims to prevent osteoporosis and fractures by positively influencing many bone-related risk factors and falls. For example, a 12-month community study involving 162 older individuals demonstrated that a multimodal training program incorporating multidirectional resistance exercises, balance training, and flexibility performed three times a week effectively improved the bone mineral density of the hip neck and lumbar spine. It also improved muscle strength and endurance (measured by stair-climbing time) and dynamic balance compared to standard care without activity. Similarly, an 8-month study involving 101 postmenopausal women with osteopenia or osteoporosis showed that regular high-intensity strength training, consisting of four exercises (5 sets of 5 repetitions at intensities above 80-85% of maximal muscle strength), performed twice a week for 30 minutes, led to the maintenance or increase of bone mineral density in the hip and spine regions as well as various functional indicators compared to the control group. Progressive resistance training is recommended as an effective method for increasing or maintaining bone mineral density (BMD) in postmenopausal women. This is because during such training, the

bone is loaded in various ways through direct muscle action and/or increased gravitational force on the bone when supporting heavier loads. Resistance training programs that have been effective in maintaining or improving bone mineral density in older women typically involved moderate to high loads (i.e., performing 2-3 sets of 8-12 repetitions at 70-85% of maximal muscle strength), which gradually increased over time. These exercises focused on large muscles crossing the hip or spine and were performed at least 2-3 times a week. Greater benefits for the lumbar spine are observed in response to this type of training compared to the hip joint, which may be due to insufficient loading of the femur during these exercises to elicit a positive bone response. Despite these mixed results, progressive resistance training is recognized as the most effective strategy for improving various fracture risk factors, especially muscle mass, size, and strength of skeletal muscles, and should therefore form the basis of exercise programs aimed at reducing fracture risk. Resistance exercises are a form of physical activity aimed at improving muscle fitness by working against external resistance. Resistance exercises can be performed using various items such as traditional weights, dumbbells, exercise machines, one's own body, resistance bands, medicine balls, but also bottles filled with sand or food cans. These exercises help maintain functional fitness, prevent injuries, support recovery, and improve athletic performance. Cited in one of the analyzed studies, research indicates that performing resistance training three to four times a week effectively prevents osteoporosis. In menopausal women, intensive resistance-aerobic training or progressive resistance training may increase bone mineral density (BMD) by 1–4% annually. Better results may be achieved through rapid weight lifting than slow, prolonged effort than short, intense training, and using heavier loads. Shigeta and Goto stated in their work that premenopausal women experience a constant increase in bone mineral density due to increased metabolism. In postmenopausal women, increasing metabolism prevents the development of osteoporotic bone changes, although there is no significant increase in bone mineral density. The reason why regular exercise can prevent or delay the development of osteoporosis is that the mechanical stress during physical activity can induce certain changes in the structure of bone tissue. These changes, in turn, stimulate the action of bone resorption (osteoclasts) and bone-building (osteoblasts) cells [21]. Studies show that this mechanical stress is converted into a signal that induces DNA synthesis, resulting in increased bone mineral density. In other words, bone tissue undergoes certain deformations during exercise, causing mechanoreceptors within cells, such as stretch-activated ion channels and integrins, to change their primary conformation to initiate a cascade of signals to ensure a biochemical

response (such as osteogenesis and bone deposition at the site of deformation). Exercise can activate the Wnt/β-catenin signaling pathway to initiate osteogenesis and bone formation, both through direct stimulation of the bone transcription factor RUNX2 and through communication with the PTH or BMP signaling pathways. Circulating PTH, produced as a result of physical activity, inhibits the secretion of sclerostin (an anti-anabolic protein) in osteocytes, resulting in a significant increase in fibroblast growth factor-23 (FGF-23) expression, a factor regulating phosphate homeostasis and vitamin D metabolism [22]. Additionally, exercise increases the OPG/RANKL ratio and subsequent inhibition of osteoclast differentiation, promotion of osteoblast differentiation, and bone formation [23]. However, caution should be exercised because, as already mentioned, excessive physical activity can negatively affect bone growth and disrupt the hormonal system, mitochondria, pituitary gland, and ovaries. This, in turn, can lead to hormonal and menstrual disturbances, ultimately leading to osteoporosis. Research shows that athletes who engage in excessive physical activity consistently have lower bone mineral density than non-athletes. To reduce the risk of overtraining in athletes, it is recommended to avoid sudden increases in training volume. It is recommended to gradually increase the load by 2–10% when the individual can comfortably perform the current exercises with one or two repetitions above the desired number during two consecutive training sessions [21]. It is worth noting that physical activity should not only be focused on older individuals. Regular physical activity throughout life from a young age is beneficial for health and osteoporosis prevention. It is important to achieve the highest peak bone mass during adolescence to counteract the subsequent gradual physiological decline in bone mass. Additionally, the more bone mass we achieve during growth, the lower the risk of osteoporosis in later life. It is estimated that increasing peak bone mass by 10% may contribute to an additional 13 years of life without osteoporosis for the average older woman [24]. In a 2018 review titled "Exercise Early and Often: Effects of Physical Activity and Exercise on Women's Bone Health," the authors included that physical activity is an essential component of a healthy lifestyle and emphasized its particular benefits for healthy and strong bones in children and adolescents. In women, 80-90% of peak bone mass is achieved by age 16. Bone mass peaks in the third decade of life. Youth should be encouraged to engage in physical activity because bones in young individuals are particularly sensitive to external factors, such as physical exercise. They allow for increased peak bone mass and bone strength, leading to better bone health with age. The most beneficial exercises for children appear to be high-intensity exercises that generate large and rapid loads on the

skeleton. These include exercises based on jumping, for example. Research indicates that six months of such exercises in adolescent girls and boys resulted in an increase in bone mass in the hip and lumbar spine of 1–6% and 0.3% to 2%, respectively. It was also observed that in children and adolescents aged 8-17 years who performed resistance exercises, there was an improvement in bone strength in loaded skeletal areas by 1–8% [25]. Regular exercises can increase bone strength regardless of current bone mineral density changes. They cause changes in bone structure and adaptation of bones to load-bearing areas. Physical exercises increase the thickness of the cortical bone, which translates into greater resistance of bones to bending. This reduces the risk of bone fractures [26].

Conclusions

Physical activity plays a significant role in the prevention of osteoporosis in older individuals. It is one of the essential elements in preventing the development of this condition. Physical activity influences reducing the risk and number of bone fractures, decreases bone fragility by increasing bone mineral density, stimulates bone formation, and reduces bone resorption. Physical activity can be practiced in various ways, including balance training, functional training, resistance exercises, walking, and aerobic exercises. Resistance training is the most effective in preventing osteoporosis. It is the most recommended and effective way to maintain or increase bone mineral density. It should be performed regularly, at least 2-3 times a week. However, it is beneficial to engage in any type of physical activity as it improves coordination and increases self-confidence, thereby reducing the risk and frequency of falls. It is recommended to engage in physical activity both by young and older individuals as it brings benefits at any age, such as strengthening bone endurance. In conclusion, physical activity has a proven positive impact on the prevention of osteoporosis in older individuals, and regular engagement in it brings many health benefits.

Author's contribution

Conceptualization Hubert Stachowicz and Joanna Mazurek; methodology Norbert Stachowicz; software Ewelina Flegiel; check Miłosz Podrażka and Justyna Lenart; formal analysis Monika Adamczyk; investigation Magdalena Ptasznik; resources Magdalena Piotrowska-Żołnierczuk; data curation Aleksandra Baran; writing - rough preparation Joanna Mazurek and Magdalena Ptasznik; writing - review and editing Miłosz Podrażka and Aleksandra Baran; visualization Monika Adamczyk and Justyna Lenart; supervision Norbert Stachowicz; project administration Hubert Stachowicz; receiving funding Magdalena Piotrowska-Żołnierczuk and Ewelina Flegiel

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