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Sport as one of the preventive factors of osteoporosis - a literature review

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Abstract:

Introduction: Osteoporosis is a systemic skeletal disorder characterized by reduced bone mass and deterioration of bone microarchitecture, leading to increased fracture risk. Its prevalence continues to rise with population aging, and osteoporotic fractures-particularly of the hip, vertebrae, and distal radius-represent a major cause of disability and mortality in older adults. Lifestyle factors play a crucial role in the development and progression of the disease, with physical inactivity identified as one of the key modifiable risk factors. Evidence indicates that appropriately designed physical activity, especially resistance and weight-bearing training, can effectively improve bone mineral density, reduce fall risk, and contribute to long-term fracture prevention. This review summarizes current knowledge on osteoporosis with particular emphasis on the role of sport and structured physical activity in its prevention.

Purpose of work: The purpose of this article is to review current scientific literature regarding the epidemiology, risk factors, pathophysiology, and clinical consequences of osteoporosis, with a particular emphasis on the role of physical activity and sports as preventive measures. The work aims to summarize evidence on exercise interventions effective in improving bone mineral density and reducing fracture risk in at-risk populations.

Materials and methods: An analysis of scientific articles available on PubMed and Google Scholar was conducted using the following keywords: osteoporosis, weight-bearing exercise, fracture prevention, aging, postmenopausal women, fall risk, musculoskeletal health, vitamin D, calcium, bone metabolism, epidemiology, risk factors, preventive medicine

Results: The reviewed literature confirms that physical activity is a key factor in maintaining bone health and preventing osteoporosis progression. Resistance and weight-bearing exercises consistently improve or preserve bone mineral density, particularly in the femoral neck and lumbar spine. Multimodal programs combining strength, balance, and mobility training show superior effects compared with low-intensity activities such as swimming or recreational walking. Regular exercise also enhances muscle strength, balance, and coordination, leading to a reduced risk of falls-one of the primary causes of osteoporotic fractures. High-impact sports are associated with higher BMD, while supervised resistance training is especially effective for older adults.
Keywords: Osteoporosis; bone mineral density; physical activity; sports; fracture prevention; aging; resistance training; epidemiology.

EPIDEMIOLOGY

Osteoporosis is defined in various consensus statements as a systemic skeletal disease that leads to a decrease in bone mass and microarchitectural deterioration of bone tissue, resulting in increased susceptibility to fractures [1], or it is also defined as a decrease in bone mineral density and increased susceptibility of bone tissue to fractures [2]. In Poland, the proportion of people over 65 years of age increased from 4.8% in 1931 to 13.3% in 2005, and according to forecasts, it will reach as much as 31.3% in 2050. This means an increase in the size of this group by approximately 4.3 million people. The aging of the population is also associated with an increase in the number of patients with senile osteoporosis. Currently, these people account for about 20% of primary osteoporosis cases, and most of them are over 75 years of age. [3] Osteoporosis-related fractures have particularly serious consequences in older people; a hip fracture in this age group is sometimes referred to as the "last fracture" in life. In addition, it is estimated that about 30% of women and 20% of men over the age of 50 experience such injuries. [4] Poland is classified as a country with a moderate risk of osteoporotic fractures. Significantly higher rates are observed in Western European and Scandinavian countries, which is probably due to their longer average life expectancy. [5] It is estimated that the number of hip fractures worldwide, which currently stands at around 1.6 million, will rise to almost 4 million in 2025 and to over 6 million in 2050. [6] It is assumed that globally, one in three women and one in five men over the age of 50 will experience an osteoporosis-related fracture later in life. [7] Although studies show that osteoporosis is less common in men than in women, they also indicate that men are more likely to experience complications and a greater deterioration in quality of life associated with the disease. [8] About one-third of all hip fractures occur in men, and one in eight men over the age of 50 will suffer an osteoporosis-related fracture. [9] It is worth noting that hip fractures are much more common in women – their incidence compared to men is about 5:1. However, this ratio decreases with the age of the population and reaches values close to 2:1 after the age of 75. [10,11] In advanced cases, the disease can lead to fractures, which result in an increased risk of disability, deterioration in mood, a decline in quality of life, and sometimes also increased mortality. [12]. Currently, there is still a significant gap in primary fracture prevention. Studies indicate that an estimated 80-90% of adults do not receive adequate treatment for osteoporosis, even as part of secondary prevention measures.

[13,14] Osteoporosis has become a significant global public health challenge. [15] Osteoporosis can be divided into two main types based on its causes: primary and secondary.

Within primary osteoporosis, the following types are distinguished:

- Type I (postmenopausal) osteoporosis - develops as a result of a sharp drop in estrogen levels after menopause, which disrupts bone metabolism, especially trabecular (spongy) tissue.
- Type II (senile) involutional osteoporosis - its development is associated with the natural aging process of the body, affecting both trabecular and cortical bone.

Secondary osteoporosis, on the other hand, results from the presence of other diseases or the use of certain medications that can affect bone tissue metabolism. [5]

SYMPTOMS

The clinical significance of osteoporosis is most evident when fractures occur. They most commonly affect the hip, vertebrae, and distal radius. These types of fractures have serious consequences - they increase the risk of death, lead to numerous health complications, and generate high treatment costs. [16] The most common fractures in osteoporosis include fractures of the femoral neck, vertebral bodies - especially in the thoracic and lumbar spine - and the distal part of the radius, typically referred to as Colles' fractures. [17] In people over 70 years of age, the most common fracture is the proximal end of the femur, which can result in thromboembolic complications, infections, and permanent disability. Multiple fractures can lead to chronic back, head, and neck pain, pain when coughing, abdominal discomfort, constipation, respiratory failure, reduced height, and excessive thoracic kyphosis, known as “widow's hump.” Severe disability often results in depression, social isolation, and a decline in quality of life. [18]

PATHOPHYSIOLOGY

The aging process leads to an imbalance between bone resorption and formation, resulting in resorption predominating. This results in increased porosity of the cortical bone and thinning and/or perforation of the trabeculae in the cancellous bone, which in turn weakens the

mechanical strength of the skeletal system. One of the important factors exacerbating these changes is calcium deficiency, which is common in older people. [7] In the case of insufficient calcium absorption in the intestines, the active form of vitamin D - 1,25-dihydroxyvitamin D (calcitriol) - mobilizes calcium from the skeleton by acting on VDR receptors in osteoblasts and stimulating RANKL expression. [19] RANKL binds to the RANK receptor on preosteoclasts, which stimulates their maturation, increases the number of osteoclasts, and intensifies bone resorption, thereby mobilizing calcium and phosphorus into the blood. Calcium deficiencies may result from limited supply, impaired absorption, or vitamin D3 deficiency, which promotes secondary hyperparathyroidism.

Calcitriol promotes calcium and phosphorus absorption in the intestines and inhibits parathyroid hormone (PTH) secretion. Vitamin D3 deficiency leads to increased PTH levels, which increases bone turnover and exacerbates bone loss. In bones with accelerated turnover, osteoid tissue accounts for the majority of bone tissue due to more intense bone remodeling. In older people, vitamin D deficiency may result from limited exposure to sunlight, reduced ability of the skin to synthesize cholecalciferol, and dietary deficiencies or malabsorption disorders. It is estimated that vitamin D3 deficiency may affect up to 50% of the elderly population. In postmenopausal women, low estrogen levels are a key factor accelerating bone loss. The most intense reduction in bone density occurs within 5-7 years after the cessation of ovarian function, after which the process slows down and continues for the rest of life. [19,20] Estrogens regulate the balance between bone formation and resorption, both quantitatively and qualitatively, affecting the functioning of trabeculae and bone architecture. During the postmenopausal period, estrogen levels decline along with reduced expression of the estrogen receptor α (ERα), which participates in mechanically activated signaling pathways. Estrogen deficiency prolongs the life of osteoclasts, inhibits their apoptosis, and increases the production of cytokines that stimulate osteoclastogenesis and bone resorption. Kidney dysfunction, including chronic kidney disease (CKD), which promotes the development of osteoporosis, osteomalacia, adynamic bone disease, and renal osteodystrophy, is often observed in older people. In CKD, cortical bone thinning and calcium loss through the kidneys are particularly important, as they can lead to secondary hyperparathyroidism. Even in the early stages of CKD, mineral metabolism disorders are observed, including abnormalities in calcium, phosphorus, PTH, and vitamin D concentrations, as well as changes in bone turnover, mineralization, bone volume and strength, and calcification of blood vessels and soft tissues. Deficiencies in micronutrients such as zinc can exacerbate bone resorption through increased production of prostaglandin E2, which stimulates the formation of multinucleated osteoclast-like cells. Low physical activity and immobilization,

common in older people with multiple diseases, lead to a decrease in bone mass and strength – in chronically immobilized patients, bone loss after 6 months can reach 25-45%. Regular physical activity increases the OPG/RANKL ratio, inhibits osteoclast function, and promotes osteoblast differentiation. Aging is also associated with increased inflammation related to diseases such as atherosclerosis, asthma, Alzheimer's disease, and autoimmune disorders. Higher concentrations of inflammatory mediators, including IL-6, IL-1, and TNF-α, activate osteoclasts, introducing an inflammatory component to the mechanisms of osteoporosis. The concept of "cellular aging," introduced by Hayflick in the 1960s, refers to the point at which cells stop dividing under stress leading to DNA damage. These cells secrete cytokines, chemokines, and extracellular matrix proteins, creating a toxic microenvironment that can also damage healthy cells. Telomere shortening, oxidative stress, and genetic and epigenetic changes contribute to the aging of bone marrow stromal cells (BMSCs), which plays a role in the pathomechanism of senile osteoporosis. [21]

Risk factors for osteoporosis are divided into two groups. These include modifiable factors (1) and non-modifiable factors (2).

Modifiable factors include:

- Low intake of calcium and vitamin D in the diet;
- Deficiency of protein and other micronutrients essential for bones;
- Smoking;
- Excessive alcohol consumption;
- Sedentary lifestyle and lack of regular physical activity;
- Certain chronic diseases (e.g., rheumatoid arthritis, thyroid disease) and use of medications (e.g., glucocorticosteroids).

Non-modifiable factors include:

- Age – the risk increases with age, especially after the age of 50;
- Female gender – women are more at risk, especially after menopause;
- Family history – osteoporotic fractures in parents increase the risk;
- Previous fractures – a history of bone injury increases the likelihood of further fractures;
- Low body weight and small skeletal frame;
- Ethnicity – Caucasian and Asian races are associated with a higher risk.

Particular importance is currently attached to proper nutrition, which plays a key role in slowing bone loss and reducing the risk of fractures. Numerous studies emphasize that a diet rich in calcium, protein, and vitamins C and D is an important part of osteoporosis prevention. [22,23,24] Studies to date have shown that micronutrients play an important role in the prevention of osteoporosis, which emphasizes the importance of proper nutrition. [25] On the other hand, poor eating habits are considered a factor contributing to the development of osteoporosis and an increased risk of fractures. [26]

PREVENTION

Prevention of osteoporosis includes measures aimed at maintaining normal bone mass, improving skeletal strength, and reducing the risk of fractures. This strategy should combine lifestyle modifications, proper diet, supplementation, and physical activity programs tailored to the patient's age and health status. We distinguish four key preventive measures:

1. Physical activity – regular exercise is a key element in the prevention of osteoporosis. Training should combine weight-bearing, resistance (PRT), balance, and mobility exercises as part of multimodal programs. High-intensity exercises and rapid muscle contractions (explosive training) have the greatest impact on increasing bone mineral density (BMD) and improving musculoskeletal function. These programs should be tailored to individual abilities, take into account the risk of falls, and apply the principles of training: specificity, progressive overload, reversibility, initial values, and the principle of diminishing returns.

2. Diet and supplementation - adequate intake of calcium and vitamin D3 is essential for normal bone metabolism. A diet rich in dairy products, fish, leafy vegetables, and foods fortified with vitamin D is recommended. Calcium and vitamin D supplementation may be particularly beneficial for older adults or those with limited exposure to sunlight. Maintaining adequate levels of these nutrients minimizes the risk of secondary hyperparathyroidism and reduces bone loss.

3. Lifestyle – prevention should also include modifying risk factors such as smoking, excessive alcohol consumption, and a sedentary lifestyle. Regular physical activity and avoiding prolonged immobility reduce bone loss and improve balance and muscle strength, which reduces the risk of falls.

4. Risk assessment and monitoring - In people at increased risk, such as postmenopausal women or people with chronic kidney disease, regular BMD assessment and monitoring of fracture risk factors is recommended. If osteopenia or osteoporosis is diagnosed, it may be necessary to introduce an individualized physiotherapy program and, possibly, pharmacological treatment.

Osteoporosis prevention should be comprehensive, including educational, dietary, exercise, and medical measures, taking into account the patient's age and health condition. Effective implementation of these strategies can slow bone loss, improve musculoskeletal function, and reduce the risk of fractures, which translates into an improved quality of life for older people.

SPORTS AS PREVENTION

All elderly people, especially those with osteoporosis, should receive recommendations on fall prevention. These include regular physical exercise, with particular emphasis on strength and balance training, limiting or discontinuing sedatives and sleeping pills, and adapting the environment to reduce the risk of injury. Most specialists recommend basic laboratory tests, such as a complete blood count, a chemistry panel including calcium, phosphorus, and alkaline phosphatase, and measurement of 25-hydroxyvitamin D levels. Further testing is indicated if disorders such as hyperthyroidism, celiac disease, multiple myeloma, hypogonadism, or hyperparathyroidism are suspected. [27,28,29] The effect of physical activity on individual parts of the skeleton varies. Programs combining weight-bearing exercises with resistance training are effective in reducing bone loss in the femoral neck and lumbar spine in postmenopausal women. [30,31] Resistance exercises involving the upper body also contribute to increased bone density in the forearms. [32] A meta-analysis evaluating the effect of physical activity on bone mineral density (BMD) in men included only three studies. They showed a significant, albeit moderate, improvement in BMD in the femoral neck and a tendency to increase BMD in the lumbar spine. [33] Population-based studies of athletes have shown that high-intensity activities such as running, squash, and weightlifting contribute to increased bone mineral density (BMD), while low-intensity sports such as swimming do not have a significant effect. [34,35,36,37] Although observational studies in men and women aged 45 years and older have shown that aquatic training reduced age-related bone loss in the hip and lumbar spine, land-based exercise has been shown to be more effective in improving bone health. [38] The effectiveness of exercise depends on its intensity and duration. Progressive resistance training

(PRT) is recommended as an effective method for increasing or maintaining bone mineral density (BMD) in postmenopausal women because it generates various loads on bones. These loads are generated both by direct muscle action (joint reaction forces) and by the increased influence of gravitational forces on the skeleton when bones support heavier loads (ground reaction forces). [39] Resistance training may be more effective when performed under the supervision of a trainer. People at risk for falls or with back problems should first receive specific guidance and a health assessment before increasing the intensity of their exercise. [40] In patients with osteoporosis, caution should be exercised when performing repetitive exercises that require forward flexion of the spine, as this movement may increase the risk of subsequent vertebral fractures. In general, people with osteoporosis can safely participate in exercise, as the risk of serious complications is very low. [41] Physical activity can significantly reduce the risk of falls, and potentially subsequent fractures, by strengthening muscles, improving balance and posture, increasing self-confidence, and improving reaction time. Combined exercise programs can include resistance training, balance exercises, aerobic activity, and weight-bearing exercises. Although current clinical guidelines for the prevention and treatment of osteoporosis recommend physical activity as an effective way to maintain or slow bone loss during postmenopause and in old age, not all forms or intensities of exercise provide the same benefits for the skeletal system. [42] Studies have shown that solitary recreational walking and other low- or minimal-intensity aerobic exercise, such as cycling or swimming, have limited or no effect on preventing age-related bone loss in postmenopausal women. [43,44] This is because these activities typically generate low bone loading, which does not exceed the threshold necessary to elicit an adaptive skeletal response. Currently, multimodal programs combining at least two types of activity, such as weight-bearing exercise, postural resistance training (PRT) or strength training, and balance and mobility exercises, are recommended for osteoporosis and fracture prevention. These interventions have been shown to positively impact numerous risk factors related to both skeletal health and falls. [39,42] The best results are achieved with interventions lasting at least 3 hours per week. [25] Any exercise program designed to improve musculoskeletal health and function should be individually tailored to the participant's needs and preferences to ensure maximum effectiveness. Such a program should incorporate five fundamental principles of training: specificity, progressive loading, reversibility, baseline values, and the principle of diminishing returns. For individuals at moderate to high risk of osteoporosis-related fractures and/or functional limitations, it is recommended that a physical therapist or certified exercise specialist perform a complete health assessment and develop a personalized program before beginning exercise. This plan should

include both fall prevention and spine-protective exercises to reduce the risk of vertebral fractures.

WHO RECOMMENDATIONS

Prevention:

- Maintaining an active lifestyle and regular physical activity – exercise and physical activity contribute to bone health;
- Adequate dietary calcium intake (in accordance with regional/country recommendations).
- Maintaining a healthy body weight and avoiding underweight – being underweight is a risk factor for osteoporosis.
- Sufficient exposure to sunlight - which promotes vitamin D synthesis and supports bone metabolism.
- Reducing risk factors such as smoking and excessive alcohol consumption – these habits negatively impact bone health.

The Role of Physical Activity:

- Physical activity likely plays a significant role in the prevention of osteoporosis, particularly in maintaining bone mineral density (BMD) in the lumbar spine.
- Higher-intensity exercise programs (longer duration, frequency) and those that incorporate multiple types of activity (e.g., resistance exercise + weight-bearing exercise + balance/mobility) appear to be more effective than light, sporadic forms of exercise.

CONCLUSIONS

Osteoporosis represents a major global health issue associated with substantial morbidity, reduced quality of life, and increased mortality. Evidence consistently shows that physical activity particularly resistance and weight-bearing exercisesis one of the most effective non-pharmacological interventions for improving bone mineral density and reducing fracture risk. Multimodal exercise programs combining strength, balance, and mobility components provide the greatest benefits, especially for older adults and postmenopausal women. Preventive strategies should integrate physical activity with appropriate nutrition, vitamin D and calcium

intake, and lifestyle modifications. Broader implementation of exercise-based interventions may significantly reduce the societal and clinical burden of osteoporosis.

Disclosure

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References

1. Digital Science & Research Solutions, Inc. Consensus development conference: diagnosis, prophylaxis, and treat ment of osteoporosis. Am J Med 1993; 94(6): 646–650. Doi: 10.1016/0002-9343(93)90218-e
2. Lane NE. Epidemiology, etiology, and diagnosis of osteoporosis. Am J Obstet Gynecol. 2006;194(2 Suppl):S3–11. Doi: 10.1016/j.ajog.2005.08.047
3. Kuczera W, Pluskiewicz W. Osteoporoza starcza. Ann. Acad. Med. Siles. 2012;6(66):57-65.
4. "NIH consensus development panel on osteoporosis prevention, diagnosis, and therapy, March 7-29, 2000: highlights of the conference," Southern Medical Journal, vol. 94, no. 6, pp. 569–573, 2001.
5. Sakowska J, Okurowska-Zawada B, Krajewska-Kułak E. Zadania fizjoterapii w leczeniu i zapobieganiu osteoporozie. W: Krajewska-Kułak E [i in.]. Holistyczny wymiar współczesnej medycyny (tom 7). Białystok: Uniwersytet Medyczny w Białymstoku; 2020. pp. 199-220.
6. Marcinowska-Suchowierska E, Czerwiński E, Badurski J, i wsp. Osteoporoza: diagnostyka i terapia u osób starszych. Postępy Nauk Medycznych. 2011;24(5):410-32. Gschwind YJ,

Bischoff-Ferrari HA, Bridenbaugh SA, et al. Association between serum vitamin D status and functional mobility in memory clinic patients aged 65 years and older. Gerontology. 2014;60(2):123-9.

7. Kanis JA, Johnell O, Oden A, et al. Risk of hip fracture according to the World Health Organization criteria for osteopenia and osteoporosis. Bone 2000; 27(5): 585–590. Doi: 10.1016/s8756-3282(00)00381-1

8. Sözen T, Özışık L and Başaran NÇ. An overview and man agement of osteoporosis. Eur J Rheumatol 2017; 4(1): 46–56. Doi: 10.5152/eurjrheum.2016.048

9. Janiszewska M, Kulik T, Dziedzic M, i wsp. Osteoporoza jako problem społeczny–patogeneza, objawy i czynniki ryzyka osteoporozy pomenopauzalnej. Probl Hig Epidemiol. 2015;96(1):106-114.

10. Rosen CJ. The Epidemiology and Pathogenesis of Osteoporosis. In: Endotext. MDText.com, Inc., South Dartmouth (MA); 2000.

11. Kwiatkowska I, Lubawy M, Formanowicz D. Postępowanie żywieniowe w prewencji osteoporozy u osób starszych Nutritional procedure in osteoporosis prevention in older people. Geriatria. 2019;13:177-183.

12. Asoudeh F, Salari-Moghaddam A, Larijani B, Esmaillzadeh A. A systematic review and meta-analysis of prospective cohort studies on the associa tion between alcohol intake and risk of fracture. Crit Rev Food Sci Nutr. 2022;62:5623–37. Doi: 10.1080/10408398.2021.1888691

13. Bessette L, Ste-Marie LG, Jean S, Davison KS, Beaulieu M, Baranci M, et al. The care gap in diagnosis and treatment of women with a fragility fracture. Osteoporos Int 2008;19:79 86. Doi: 10.1007/s00198-007-0426-9

14. Papaioannou A, Giangregorio L, Kvern B, Boulos P, Ioanni dis G, Adachi JD. The osteoporosis care gap in Canada. BMC Musculoskelet Disord 2004;5:11. Doi: 10.1186/1471-2474-5-11

15. Zeng L, Luo M, Liang G, Yang W, Xiao X, Wei X, et al. Can Dietary Intake of vitamin C-Oriented Foods reduce the risk of osteoporosis, fracture, and BMD loss? Systematic review with Meta-analyses of recent studies. Front Endocri nol. 2019;10:844. Doi: 10.3389/fendo.2019.00844

16. Harvey N, Dennison E and Cooper C. Osteoporosis: impact on health and economics. Nat Rev Rheumatol 2010; 6(2): 99–105. Doi: 10.1038/nrrheum.2009.260

17. Olejniczak T, Opala T, Woźniak J, i wsp. Osteoporoza–epidemiologia, patogeneza, diagnostyka i leczenie. Przewodnik Lekarza/Guide for GPs. 2000;9(3):39-46.

18. Dobosz A, Smektała A. Osteoporoza-patofizjologia, objawy, profilaktyka i leczenie. Farmacja Polska. 2020;76(6):344-52.
19. Raisz LG. Pathogenesis of osteoporosis: concepts, conflicts, and prospects. J Clin Invest. 2005;115(12): 3318-25. Doi: 10.1172/JCI27071
20. Wołczyński S, Kita K, Sierakowski S. Estrogeny i SERMY w profilaktyce i leczeniu osteoporozy postmenopauzalnej. Borgis – Nowa Medycyna, 3/2004.
21. Barszczewski K, Kępczyńska A, Karaś R, Górecki K. Osteoporoza starcza -poważny problem starzejącego się społeczeństwa Senile osteoporosis -a serious problem of an aging socjety, GERONTOLOGIA POLSKA 2024; 32; 105-111. Doi: 10.53139/GP.20243208
22. Shi Y, Zhan Y, Chen Y, Jiang Y. Effects of dairy products on bone mineral density in healthy postmenopausal women: a systematic review and meta analysis of randomized controlled trials. Arch Osteoporos. 2020;15:48. Doi: 10.1007/s11657-020-0694-y
23. Park SJ, Jung JH, Kim MS, Lee HJ. High dairy products intake reduces osteopo rosis risk in Korean postmenopausal women: a 4 year follow-up study. Nutr Res Pract. 2018;12:436–42. Doi: 10.4162/nrp.2018.12.5.436
24. Ilesanmi-Oyelere BL, Kruger MC. Nutrient and dietary patterns in relation to the pathogenesis of postmenopausal Osteoporosis-A literature review. Life. 2020;10:220. Doi: 10.3390/life10100220
25. Malmir H, Saneei P, Larijani B, Esmaillzadeh A. Adherence to Mediter ranean diet in relation to bone mineral density and risk of fracture: a systematic review and meta-analysis of observational studies. Eur J Nutr. 2018;57:2147–60. Doi: 10.1007/s00394-017-1490-3
26. Huang Z, Himes JH, McGovern PG. Nutrition and subsequent hip fracture risk among a national cohort of white women. Am J Epidemiol. 1996;144:124–34. Doi: 10.1093/oxfordjournals.aje.a008899
27. Ensrud KE, Crandall CJ. Osteoporosis. Ann Intern Med 2017;167:ITC17–32 [Erratum appears in Ann Intern Med. 2017;167:528.17. Doi: 10.7326/AITC201708010
28. Cosman F, de Beur SJ, LeBoff MS, et al. Clinician's guide to prevention and treat ment of osteoporosis. Osteoporos Int 2014;25:2359–81. Doi: 10.1007/s00198-014-2794-2
29. Black DM, Rosen CJ. Postmenopausal osteoporosis. N Engl J Med 2016;374: 254–62. Doi: 10.1056/NEJMc1602599
30. Howe TE, Shea B, Dawson LJ, Downie F, Murray A, Ross C, Harbour RT, Caldwell LM, Creed G (2011) Exercise for prevent ing and treating osteoporosis in postmenopausal women. Cochrane Database Syst Rev Cd000333. Doi: 10.1002/14651858.CD000333.pub2

31. Kemmler W, Shojaa M, Kohl M, von Stengel S (2020) Effects of different types of exercise on bone mineral density in postmeno pausal women: a systematic review and meta-analysis. Calcif Tis sue Int 107:409–439. Doi: 10.1007/s00223-020-00744-w

32. Babatunde OO, Bourton AL, Hind K, Paskins Z, Forsyth JJ (2020) Exercise interventions for preventing and treating low bone mass in the forearm: a systematic review and meta-analysis. Arch Phys Med Rehabil 101:487–511. Doi: 10.1016/j.apmr.2019.07.007

33. Kelley GA, Kelley KS, Kohrt WM (2013) Exercise and bone mineral density in men: a meta-analysis of randomized controlled trials. Bone 53:103–111. Doi: 10.1016/j.bone.2012.11.031

34. Colletti LA, Edwards J, Gordon L, et al. The effects of muscle-building exercise on bone mineral density of the radius, spine, and hip in young men. Calcif Tissue Int 1989;45:12–14. Doi: 10.1007/BF02556654

35. Davee AM, Rosen CJ, Adler RA. Exercise patterns and trabecular bone density in college women. J Bone Miner Res 1990;5:245–50. Doi: 10.1002/jbmr.5650050307

36. Risser WL, Lee EJ, LeBlanc A, et al. Bone density in eumenorrheic female college athletes. Med Sci Sports Exerc 1990;22:570–4. Doi: 10.1249/00005768-199010000-00005

37. Heinonen A, Oja P, Kannus P, et al. Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone 1995;17:197–203. Doi: 10.1016/8756-3282(95)00151-3

38. Simas V, Hing W, Pope R, Climstein M. Effects of water-based exercise on bone health of middle-aged and older adults: a systematic review and meta-analysis. Open Access J Sports Med. 2017;8:39---60. Doi: 10.2147/OAJSM.S129182

39. Taaffe DR, Daly RM, Suominen H, Galvao DA, Bolam KA. Physical activity and exercise in the maintenance of the adult skeleton and the prevention of osteoporotic fractures. In: Marcus D, Feldman D, Dempster D, Luckey M, Cauley JA, eds. Osteoporosis. Vol. 1, 4th ed. Amsterdam, The Netherlands: Elsevier; 2013:683---719. Doi: 10.1016/B978-0-12-415853-5.00029-7

40. Royal Osteoporosis Society (2018) Strong, Steady and Straight; An Expert Consensus Statement on physical activity and exercise for osteoporosis. https:// theros.org.uk/media/0o5h1l53/ros-strong-steady-straight-quick-guide-february- 2019.pdf. Access 15 September 2025.

41. Kunutsor SK, Leyland S, Skelton DA, James L, Cox M, Gib bons N, Whitney J, Clark EM (2018) Adverse events and safety issues associated with physical activity and exercise for adults with osteoporosis and osteopenia: a systematic review of obser vational studies and an updated

review of interventional studies. Journal of frailty, sarcopenia and falls 3:155–178. Doi: 10.22540/JFSF-03-155

42. Beck BR, Daly RM, Singh MA, Taaffe DR. Exercise and Sports Science Australia (ESSA) position statement on exercise prescription for the prevention and management of osteoporosis. J Sci Med Sport. 2017;20(5):438---445. Doi: 10.1016/j.jsams.2016.10.001

43. Greenway KG, Walkley JW, Rich PA. Does long-term swimming participation have a deleterious effect on the adult female skeleton? Eur J Appl Physiol. 2012;112(9):3217---3225. Doi: 10.1007/s00421-011-2305-5

44. Ma D, Wu L, He Z. Effects of walking on the preservation of bone mineral density in perimenopausal and postmenopausal women: a systematic review and meta-analysis. Menopause. 2013;20(11):1216---1226. Doi: 10.1097/GME.0000000000000100

45. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, Cumming RG, Herbert RD, Close JCT, Lord SR (2017) Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. Br J Sports Med 51:1750–1758. Doi: 10.1136/bjsports-2016-096547