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The role of resistance training in the prevention of osteoporosis in postmenopausal women – a narrative review

Klaudia Walczak[1], Małgorzata Wińska[2], Zuzanna Bomze[3], Julia Dębkowska[4], Aleksandra Taraś[5], Klaudia Michułka[6]

Abstract

Introduction: Postmenopausal osteoporosis is a common metabolic bone disease characterized by reduced bone mineral density (BMD) and an increased risk of fractures. Estrogen deficiency accelerates bone resorption, leading to progressive bone loss and impaired skeletal strength. Resistance training has gained attention as a non-pharmacological strategy for osteoporosis prevention due to its ability to stimulate bone remodeling through mechanical loading.

Objective: To evaluate the effects of resistance training on bone mineral density, fracture risk, and musculoskeletal function in postmenopausal women based on current scientific evidence.

[1] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland
[2] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland
[3] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland
[4] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland
[5] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland
[6] Medical University of Warsaw, 61 Żwirki i Wigury Street, 02-091 Warsaw, Poland

Materials and methods: A narrative literature review was conducted using studies indexed in the PubMed database. Publications from 2015–2026 concerning resistance training and osteoporosis prevention in postmenopausal women were included. Earlier landmark studies were also considered when relevant.

Results: The reviewed studies indicate that resistance training is an effective intervention for preventing postmenopausal osteoporosis. Most studies reported stabilization or modest increases in BMD, particularly in the lumbar spine and femoral neck. The effectiveness of training was influenced by exercise intensity, duration, and progressive overload. Moderate- to high-intensity, long-term programs produced the most favorable outcomes, whereas low-intensity or short-term interventions showed limited effects. Although evidence regarding fracture reduction remains inconclusive, improvements in muscle strength, balance, and fall prevention may indirectly decrease fracture risk.

Conclusions: Resistance training appears to be a beneficial non-pharmacological approach for maintaining bone health in postmenopausal women. Regular participation may improve BMD and support fracture prevention. Further research is needed to establish standardized training protocols and optimize exercise recommendations.

Keywords: osteoporosis, postmenopausal women, resistance training, bone mineral density, exercise therapy, fracture

Introduction and purpose: Osteoporosis is a chronic skeletal disease characterized by reduced bone mineral density (BMD) and deterioration of bone microarchitecture, leading to increased susceptibility to fractures, particularly in the postmenopausal female population [1,2]. Postmenopausal bone loss is closely associated with a decline in estrogen levels, which results in increased bone resorption and a disruption of the balance between bone formation and resorption [3,4]. Due to the rising prevalence of osteoporosis in aging populations, increasing importance is being attributed to non-pharmacological prevention, including regular physical activity as a key component in preventing bone mass loss [5]. Resistance training plays a particularly important role in maintaining skeletal health, as mechanical loading of the skeleton stimulates osteogenesis and structural adaptation of bone to applied external forces [6,7]. Available meta-analyses and systematic reviews indicate that resistance training may lead to stabilization or a slight increase in bone mineral density, particularly in the lumbar spine and femoral neck in postmenopausal women [8]. At the same time, the effectiveness of training interventions depends on multiple factors such as intensity, volume, frequency, and load selection, which determine the magnitude of the mechanical stimulus acting on bone tissue [6,9]. Recent analyses suggest that higher-intensity training may be associated with a stronger adaptive response of bone tissue compared to lower-intensity training [10]. Despite the growing body of research, discrepancies still exist regarding optimal resistance training protocols for osteoporosis prevention, which justifies the need for further synthesis of available scientific data [6,8].

Materials and methods: This narrative review was conducted to collect and summarize current evidence regarding the role of resistance training in the prevention of osteoporosis in postmenopausal women. A literature search was performed in the PubMed database.

The search covered publications from 2015–2026 in order to capture the most recent findings, supplemented by selected earlier studies of key importance for understanding the mechanisms of bone tissue remodeling and adaptation to mechanical loading.

The keywords included combinations of: “resistance training”, “strength training”, “osteoporosis”, “postmenopausal women”, “bone mineral density”, “fracture risk”, and “mechanical loading”. Boolean operators AND and OR were used to refine the search results.

The review included randomized controlled trials, meta-analyses, systematic reviews, and key studies addressing the mechanisms of resistance training effects on the skeletal system. Studies were selected based on methodological quality, relevance, and clinical significance. Case reports, non-English publications, non-peer-reviewed sources, and studies not directly related to the topic were excluded. The selection process involved screening titles and abstracts, followed by full-text assessment of eligible articles. Due to the narrative nature of the review, no formal systematic review protocol was applied.

1. Mechanisms of the influence of resistance training on bone tissue

1.1. Mechanotransduction and osteocytes as the primary regulators of bone response

Bone tissue is a dynamic organ whose structure and metabolism are closely dependent on mechanical stimuli, in accordance with the principle of functional adaptation of bone to loading [7,9,11]. The key process responsible for this adaptation is mechanotransduction, i.e., the conversion of mechanical forces into biochemical signals that regulate bone remodeling [9,11,12]. The most important cells in this process are osteocytes, which act as the primary mechanosensors of the skeleton [11,13]. Osteocytes detect changes in mechanical strain through the lacuno-canalicular network and cytoskeletal structures, thereby initiating the adaptive response of bone tissue [9,12]. In response to mechanical loading, osteocytes modulate the expression of numerous mediators, including sclerostin, prostaglandin E2, and nitric oxide, which regulate the activity of osteoblasts and osteoclasts [12,13,14]. One of the key regulatory pathways is the Wnt/β-catenin signaling pathway, whose activation promotes bone formation, whereas its inhibition (e.g., by sclerostin) leads to suppression of bone formation [9,11]. In parallel, an important role is played by the RANK/RANKL/OPG system, which controls osteoclast differentiation and thus the rate of bone resorption [2,4].

Studies indicate that physical activity, including resistance training, may modulate this system by reducing RANKL expression and relatively increasing OPG levels, thereby shifting the balance toward bone-forming processes [9,12,15]. Additionally, mechanical loading influences the expression of anabolic factors such as IGF-1, which supports osteoblast proliferation and bone matrix mineralization [2,13]. Consequently, mechanotransduction represents the fundamental biological mechanism responsible for bone adaptation to resistance training [9,11].

1.2. Pathophysiology of postmenopausal osteoporosis

Postmenopausal osteoporosis is a chronic metabolic bone disease whose primary etiological factor is estrogen deficiency, leading to impaired bone remodeling [1,2,3,4]. During the postmenopausal period, an acceleration of bone resorption is observed due to increased osteoclast activity and a relative decrease in osteoblast activity, resulting in progressive bone loss and deterioration of bone microarchitecture [11,16]. The decline in estrogen levels leads to increased RANKL expression and reduced osteoprotegerin (OPG) levels, which enhances osteoclastogenesis and accelerates bone resorption [3,4,17]. At the same time, osteoblast activity is reduced, limiting the bone's regenerative capacity [11].

Chronic low-grade inflammation also plays an important role in the pathogenesis of osteoporosis, associated with increased levels of pro-inflammatory cytokines such as IL-1, IL-6, and TNF-α, which enhance osteoclast activity and further accelerate bone loss [3,4]. Consequently, deterioration of bone microarchitecture occurs, leading to reduced mechanical strength and an increased risk of low-energy fractures, particularly in the spine and femoral neck [2,18]. This process constitutes the basis of the clinical presentation of postmenopausal osteoporosis [19,20].

1.3. Bone adaptation to resistance training

Bone demonstrates the ability to adapt to mechanical loading according to the mechanostat theory, which postulates the existence of a biological threshold for osteogenic stimulation that determines the anabolic response of bone tissue [9,11,13]. Loads below this threshold lead to bone loss, whereas loads exceeding it induce an anabolic response and stimulate bone formation [21].

Resistance training generates high mechanical forces that may cause microdamage to the bone matrix, serving as an important stimulus for initiating bone remodeling [9,11,13]. In response, osteoblasts are activated to synthesize new bone tissue and mineralize the matrix [22,23]. Pro-inflammatory cytokines enhance osteoclast activity and accelerate bone loss by disrupting bone tissue homeostasis and shifting the remodeling balance toward resorption [24,25].

The most pronounced adaptive changes, as well as clinically relevant effects in osteoporosis, are observed in the lumbar spine and femoral neck—regions most exposed to axial loading and the most common sites of osteoporotic fractures [1,19]. Meta-analyses indicate that regular resistance training may lead to stabilization or a slight increase in bone mineral density (BMD) in postmenopausal women, particularly in higher-intensity and longer-duration interventions [6,7]. However, this effect is dependent on training parameters such as intensity, volume, and load progression, which significantly modulate the bone tissue response to mechanical stimuli [8,10].

Table 1. Key mechanisms of resistance training effects on bone tissue in postmenopausal women

Mechanism	Main biological pathway	Key mediators/cells involved	Resulting effect on bone
Mechanotransduction	Conversion of mechanical loading into biochemical signals	Osteocytes, lacuno-canalicular network	Initiation of bone remodeling response
Wnt/β-catenin signaling	Regulation of osteoblast activity	Sclerostin, β-catenin	Increased bone formation
RANK/RANKL/OPG system	Regulation of osteoclast differentiation	RANKL, OPG	Reduced bone resorption
Anabolic growth signaling	Stimulation of bone formation pathways	IGF-1, osteoblasts	Enhanced osteoblast proliferation and mineralization
Inflammatory modulation	Regulation of cytokine activity	IL-1, IL-6, TNF-α	Reduced bone loss

2. The effect of resistance training on bone mineral density (BMD)

2.1. The significance of BMD and changes in postmenopausal osteoporosis

Bone mineral density (BMD) is a fundamental quantitative indicator of bone mechanical strength and is one of the key parameters used in the diagnosis of osteoporosis and the assessment of fracture risk in postmenopausal women [1,2,19]. In clinical practice, BMD remains the gold standard for evaluating the risk of osteoporotic fractures, particularly in relation to the lumbar spine and the proximal femur [1,16]. A decline in BMD leads to a progressive weakening of bone microarchitecture, affecting both trabecular and cortical compartments, which results in reduced resistance of bone to mechanical loading [2,18,19].

Consequently, the risk of low-energy fractures increases, representing one of the major complications of postmenopausal osteoporosis and a significant public health concern [5,25].

The pathogenesis of reduced BMD is associated with an imbalance between bone formation and resorption processes, where the dominance of osteoclastic activity leads to a net loss of bone tissue over its formation [2,3,4].

2.2. The effect of resistance training on BMD – clinical evidence and meta-analyses

Resistance training is one of the most important non-pharmacological interventions used in the prevention of postmenopausal osteoporosis due to its ability to generate mechanical stimuli that promote bone remodeling [5,9,26].

These stimuli activate mechanotransduction processes that initiate adaptive structural changes in bone in response to loading [11,13,22].

Meta-analyses of randomized controlled trials indicate that regular resistance training may lead to stabilization of BMD or a small but statistically significant increase in postmenopausal women [6,7,15]. This effect is observed primarily in the lumbar spine and femoral neck, which are most sensitive to changes in mechanical loading [2,6].

Long-term training interventions demonstrate greater efficacy in improving BMD than short-term programs, suggesting that bone adaptation requires time and sustained exposure to mechanical stimuli [6,10,15].

Additionally, network meta-analyses indicate that the effectiveness of resistance training varies depending on the applied protocol; however, most interventions demonstrate a beneficial effect on BMD compared with physical inactivity [8,10,26].

2.3. Factors determining bone adaptation to resistance training

The effect of resistance training on BMD is strongly dependent on training variables such as intensity, volume, frequency, and load progression, which determine the magnitude of the mechanical stimulus acting on bone tissue [8,10,15].

The greatest improvements in BMD are observed in programs of moderate to high intensity (≥70% 1RM), which generate sufficiently strong osteogenic stimuli [6,8,10]. In contrast, low-intensity training often results only in the maintenance of BMD without significant improvement, limiting its effectiveness in osteoporosis prevention [2,6,15]. Duration of the intervention is also an important factor—programs lasting at least 6–12 months show a markedly greater adaptive effect than short-term interventions [27].

The most pronounced adaptive changes are observed in the lumbar spine and femoral neck, which is attributed to their high responsiveness to axial loading and their key biomechanical role in force transmission within the skeletal system [2,7,16].

At the same time, it should be emphasized that the bone tissue response to resistance training is highly heterogeneous and depends both on training-related factors and individual characteristics of patients, such as age, hormonal status, and baseline BMD level [3,15].

Table 2. Effect of resistance training parameters on bone mineral density (BMD)

Training parameter	Range	Effect on BMD	Evidence summary
Intensity	≥70% 1RM	Improvement/stabilization	Strong osteogenic stimulus
Low intensity	<50–60% 1RM	Minimal effect	Often maintenance only
Volume	Moderate–high	Positive effect	Supports loading
Frequency	2–3 sessions/week	Supports adaptation	Requires recovery
Duration	≥6–12 months	Greater improvements	Long-term needed
Progression	Progressive overload	Essential	Prevents plateau

3. The effect of resistance training on fracture risk and functional performance

3.1. The effect of resistance training on fall risk and osteoporotic fractures

Osteoporotic fractures represent one of the most serious complications of postmenopausal osteoporosis and are strongly associated with increased disability, mortality, and reduced quality of life in older women [1,19]. Falls play a key role in the pathogenesis of low-energy fractures, particularly in the femoral neck and vertebrae [2,25]. Therefore, increasing emphasis is placed on interventions aimed not only at improving BMD but also at reducing factors that increase fall risk [5,15].

Evidence suggests that resistance training may indirectly reduce fracture risk by improving muscle strength, postural stability, and neuromuscular control [7,15]. Regular physical activity leads to improved function of the lower limb muscles, which play a crucial role in maintaining balance and preventing falls [10].

Meta-analyses suggest that training programs combining resistance exercises with balance and functional training components are the most effective in reducing fall risk in postmenopausal women [28,29].

Despite these beneficial functional effects, the impact of resistance training on the direct reduction of fracture incidence remains less conclusive [5,7]. This is primarily due to the limited number of long-term studies and methodological difficulties associated with assessing fractures as an endpoint in exercise interventions [10,15].

However, available data suggest that improvements in functional performance and a reduction in falls may indirectly contribute to lowering the risk of osteoporotic fractures [30].

3.2. The effect of resistance training on muscle strength and functional performance

The aging process and hormonal changes during the postmenopausal period lead to a progressive decline in musculoskeletal function, including reductions in muscle strength, muscle mass, and functional capacity [3]. These changes are closely associated with osteoporosis and an increased risk of reduced mobility and loss of independence [18,19].

Estrogen deficiency affects not only bone metabolism but also muscle function and neuromuscular regulation [20]. Resistance training is one of the most effective interventions for improving muscle strength, particularly in the lower limbs, which are responsible for postural stability and locomotion [7,15].

Meta-analyses indicate that regular resistance training leads to improvements in muscle strength and physical function, including walking speed and the ability to perform activities of daily living [15]. These improvements result from both muscular and neural adaptations, including more efficient motor unit recruitment and enhanced movement control [9,15].

3.3. The importance of multicomponent training and study limitations

The greatest effectiveness in reducing fall risk is observed in multicomponent programs combining resistance training, balance exercises, and functional training elements [28,30]. Such interventions simultaneously improve muscle strength, postural control, and motor abilities, which is crucial for fall prevention [30].

Meta-analyses indicate that physical exercise significantly improves balance and reduces fall risk in postmenopausal women [28]. At the same time, studies show considerable heterogeneity due to differences in training intensity, duration, and protocol design [10,26].

A limitation of many analyses is the lack of standardized methods for assessing fall and fracture risk, which makes it difficult to compare study results [26]. Despite these limitations, the available evidence consistently indicates that resistance training is an important component of functional prevention strategies in postmenopausal women [15].

Table 3. Functional and clinical outcomes of resistance training in postmenopausal women

Domain	Observed effect	Clinical relevance	Outcome
Muscle strength	Increase	Improved mobility	Better lower limb strength
Postural stability	Improved balance	Reduced fall risk	Better neuromuscular control
Functional performance	Improved gait/ADL	Higher independence	Improved daily function
Fall risk	Reduced incidence	Lower fracture risk	Indirect effect
Fracture risk	Indirect reduction	Preventive benefit	Via fall reduction

4. Optimal parameters of resistance training in postmenopausal osteoporosis

4.1. Intensity, volume, and load progression

The effectiveness of resistance training in improving bone mineral density (BMD) in postmenopausal women is strongly dependent on loading parameters, including intensity, volume, and the manner of progression of exercise stimulus [8,10].

The greatest osteogenic effects are observed in programs of moderate to high intensity, in which the mechanical stimulus is sufficiently strong to activate bone remodeling processes [6]. In contrast, low-intensity training shows a limited effect on BMD, often resulting only in its maintenance without significant improvement [7].

Progressive overload is a crucial component of bone adaptation, as bone tissue requires an increasing mechanical stimulus to maintain an anabolic response [9,22]. Meta-analyses also indicate that protocols based on resistance training with external loading are more effective than general physical activity interventions in terms of BMD changes [26].

4.2. Duration and frequency of training

The duration of the intervention is one of the key determinants of resistance training effectiveness, with more pronounced changes in BMD observed in long-term programs (≥6–12 months) [6,10].

Short-term interventions are often insufficient to induce full structural adaptation of bone tissue, which is due to the slow rate of bone remodeling [19].

Training frequency should ensure regular mechanical-biological stimulation while also allowing sufficient time for bone and muscle tissue recovery [9].

Evidence suggests that sustained exposure to mechanical stimuli over time is essential for maintaining adaptive effects [8].

Meta-analyses confirm that the greatest benefits in terms of BMD and physical function are observed in regular, long-term programs rather than short experimental interventions [7].

4.3. Training safety and clinical limitations

Resistance training in postmenopausal women is considered a safe form of physical activity; however, its implementation requires consideration of the severity of osteoporosis and individual fracture risk [5].

Appropriate exercise selection is crucial, as improperly programmed high axial-load exercise may increase the risk of injury in patients with advanced osteoporosis [30].

Therefore, individualized training programs and gradual load progression are recommended, particularly in individuals with low baseline bone mass [8].

An additional limitation is the high heterogeneity of training protocols used in studies, which makes it difficult to develop a single universal intervention model [10].

Despite these limitations, available evidence indicates that resistance training is an effective and safe method supporting the prevention of postmenopausal osteoporosis and improving patients' quality of life [15].

Table 4. Optimal Parameters of Resistance Training in Postmenopausal Osteoporosis

Area	Key Findings	Clinical Significance
Training Intensity	The greatest osteogenic effects are achieved with moderate- to high-intensity training.	Improves or maintains BMD, especially in the lumbar spine and femoral neck.
Volume and Load Progression	Progressive overload is essential for continued bone adaptation.	Prevents stagnation of training effects and supports bone remodeling.
Program Duration	The best outcomes are observed after ≥6–12 months of regular exercise.	Long-term programs are more effective in increasing BMD.
Training Frequency	Regular mechanical stimulation combined with adequate recovery is required.	Supports sustained musculoskeletal adaptation.
Safety	Programs should be individualized, particularly in women with severe osteoporosis.	Reduces the risk of injury and fracture.
Study Limitations	Considerable heterogeneity exists among training protocols.	Limits the development of universal recommendations.

5. The importance of physical activity in the prevention of postmenopausal osteoporosis

5.1. The role of physical activity in maintaining bone health

Regular physical activity is one of the key components of non-pharmacological prevention of postmenopausal osteoporosis, affecting both bone mineral density and musculoskeletal function [26]. Systematically performed physical exercise plays a significant role in maintaining proper bone tissue structure and supporting functional capacity in postmenopausal women [15].

Mechanical loading of bone during physical activity constitutes an important stimulus for bone remodeling processes, activating osteocyte-dependent adaptive mechanisms. The adaptive response of bone tissue is associated with the conversion of mechanical stimuli into biological signals regulating bone remodeling processes [13].

Additionally, physical activity has a beneficial effect on the muscular system by improving strength, coordination, and balance, which is crucial in fall prevention. Improved musculoskeletal function supports postural stability and reduces the risk of balance disorders in postmenopausal women [28].

5.2. The effect of different forms of exercise on fracture and fall risk

Multicomponent interventions, including resistance training, balance exercises, and functional training, demonstrate the highest effectiveness in reducing the risk of falls and fractures in postmenopausal women [30]. Such programs have a comprehensive effect on the musculoskeletal system, contributing not only to improved muscle strength but also to postural control and dynamic stability, which directly reduces the risk of injuries and balance disturbances [28].

Available meta-analyses further indicate that regularly performed exercise programs can significantly reduce fall incidence in postmenopausal women, particularly when interventions are of adequate intensity and long duration [30].

5.3. The importance of prevention and study limitations

Prevention of postmenopausal osteoporosis based on regular physical activity is currently considered an important element of public health strategies, particularly in the context of an aging female population and the increasing incidence of osteoporotic fractures [2]. At the same time, it should be emphasized that the effectiveness of exercise interventions depends on multiple factors, including training parameters such as intensity and type of activity, as well as individual patient characteristics, including baseline bone mineral density and hormonal status [10].

A significant limitation of the available research remains its considerable methodological heterogeneity, including differences in intervention duration, characteristics of study populations, and training protocols, which makes it difficult to develop clear and universal clinical recommendations [15]. Despite these limitations, the results of most studies are consistent and indicate that regular physical activity is an effective tool supporting osteoporosis prevention and improving the quality of life of postmenopausal women [26].

Table 5. Importance of Physical Activity in the Prevention of Postmenopausal Osteoporosis

Topic	Main Observations	Practical Benefits
Bone Health Maintenance	Physical activity stimulates bone remodeling through mechanical loading.	Supports BMD maintenance and skeletal integrity.
Effects on the Muscular System	Improves muscle strength, coordination, and balance.	Reduces the risk of falls.
Multicomponent Training	Programs combining resistance, balance, and functional exercises show the greatest effectiveness.	Decreases fall and fracture risk.
Fracture Prevention	Exercise may indirectly reduce fracture risk by improving physical function.	Enhances postural stability and movement safety.

Public Health Importance	Physical activity is a key component of osteoporosis prevention strategies.	Improves quality of life and reduces disease burden.
Study Limitations	Differences in study populations, duration, and exercise protocols remain significant.	Further research and standardization are needed.

Discussion

The conducted literature analysis indicates that resistance training is one of the most important non-pharmacological interventions in the prevention of postmenopausal osteoporosis, affecting both bone tissue structure and musculoskeletal function [15]. Its effect is based on the mechanism of mechanotransduction, in which mechanical stimuli are converted into biological signals regulating bone remodeling processes [13]. Available meta-analyses indicate that regular resistance training may lead to stabilization or a slight increase in bone mineral density, particularly in the lumbar spine and femoral neck regions [6]. At the same time, the effectiveness of this intervention is strongly dependent on training parameters such as intensity, volume, and load progression, which determine the magnitude of the osteogenic stimulus [10]. Higher training intensity and its progressive nature are associated with greater activation of bone formation processes compared with low loads, which are often insufficient to induce significant structural changes in bone tissue [8]. The duration of the intervention is also an important factor, as bone remodeling is a slow process requiring long-term exposure to mechanical stimuli [19].

Resistance training affects not only the skeletal system but also the muscular system, leading to improvements in strength, postural stability, and neuromuscular control [9]. These changes are of clinical importance, as improved muscle function translates into a reduced risk of falls, which are the main cause of osteoporotic fractures in postmenopausal women [28]. Consequently, resistance training acts on multiple levels, combining skeletal and muscular effects within a single adaptive mechanism, which makes it a particularly important component of fracture prevention strategies [30].

Despite substantial evidence supporting the effectiveness of resistance training, there are important limitations in the literature, such as high heterogeneity of training protocols, differences in intervention duration, and a lack of full standardization in outcome assessment methods [10]. Additionally, significant variability in individual responses to training is observed, resulting from factors such as age, hormonal status, and baseline bone mineral density [8,10,13,26]. Therefore, the need for individualized training programs and further development of standardized intervention protocols is emphasized, enabling comparison of results across different populations [15].

In summary, resistance training is an effective strategy supporting skeletal health in postmenopausal women; however, its effectiveness depends on appropriate selection of training parameters and consistency of implementation [6]. The greatest benefits are observed in long-term programs of sufficiently high intensity, highlighting the importance of individualized therapeutic approaches in osteoporosis prevention [10].

Conclusions

Resistance training constitutes an important and well-documented non-pharmacological method supporting the prevention and treatment of postmenopausal osteoporosis. Its effectiveness results primarily from the generation of mechanical stimuli that initiate mechanotransduction processes and activate bone cells responsible for bone tissue remodeling. As a result, a shift in bone remodeling balance toward bone formation processes occurs, which may lead to stabilization or a moderate increase in bone mineral density.

The most beneficial effects of resistance training are observed in the lumbar spine and femoral neck, i.e., sites particularly susceptible to osteoporotic fractures. However, these changes are usually modest and require long-term, systematic intervention, which highlights the slow nature of bone tissue adaptation to mechanical loading. Properly selected exercise intensity, its progression, and regularity are crucial for achieving an osteogenic effect, with the greatest efficacy observed in moderate- to high-intensity programs conducted over a longer time horizon.

In addition to its effects on the skeletal system, resistance training plays an important role in improving muscular and neuromuscular function. Increases in muscle strength, improved postural control, and enhanced balance stability translate into a reduced risk of falls, which represent the main mechanism leading to osteoporotic fractures in the postmenopausal female population. Therefore, the clinical effect of resistance training should be viewed not only through changes in bone mineral density, but also through its impact on functional capacity and safe mobility.

Despite substantial evidence confirming the beneficial effects of resistance training, study findings demonstrate considerable heterogeneity, both in terms of applied training protocols and observed outcomes. A further limitation is the variability in individual responses to training, depending on age, hormonal status, and baseline bone mass. These factors hinder the development of uniform, universal clinical guidelines and highlight the need for further standardization of research methods and intervention protocols.

In summary, resistance training should be regarded as a key component of a comprehensive strategy for the prevention of postmenopausal osteoporosis. Its greatest clinical value lies in the combination of skeletal and functional effects, which together contribute to reducing fracture risk and improving patients' quality of life. At the same time, optimization of training parameters and a better understanding of factors determining biological response remain important directions for future research.

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