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REVIEW ARTICLE

Role of Exercise in Prevention and Treatment of Osteoporosis - A Narrative Review

Merry Mathew[1#], Mimi Zumwalt[2] and Sachi Khemka[1#]*

[1]School of Medicine, Texas Tech University Health Sciences Center, Lubbock, TX 79430, USA

[2]Department of Orthopedic Surgery and Rehabilitation, Texas Tech University Health Sciences Center, Lubbock, TX 79430, USA

[#]Equal Contribution

***Corresponding author:** *Sachi Khemka, School of Medicine, Texas Tech University Health Sciences Center, Lubbock, TX 79430, USA*

Abstract

Background: Osteoporosis is characterized by diminished bone density and structural integrity, which presents a significant health concern, particularly among older adults and postmenopausal women. Exercise has emerged as an important preventive measure and therapeutic intervention for osteoporosis, with positive impacts on bone metabolism and bone mineral density (BMD). This narrative review examines the utility of exercise for the management of osteoporosis in postmenopausal women, with a special focus on different exercise modalities.

Methods: A literature search was conducted on articles focusing on resistance training, aquatic exercises, high impact activities, mind-body exercises, and walking. Articles studying combined (two different exercise types) regimens were also included.

Results: Combined protocols involving two exercise modalities, especially the high-intensity resistance and impact training (HiRIT) regimen, appear to be the most effective in the management of osteoporosis. Unimodal approaches such as resistance training in isolation also show some promise in increasing BMD.

Conclusion: Each exercise modality showed distinct benefits, highlighting the importance of individualizing exercise regimens according to functional status, preferences, and personal health goals. Nonetheless, further research is warranted to delineate optimal exercise prescriptions and refine interventions for osteoporosis prevention and treatment.

Keywords

Bone density, Female, Postmenopause, Resistance training, Osteoporosis

Introduction

Osteoporosis is a prevalent skeletal disease characterized by decreased bone mineral density (BMD) and deterioration of bone structure, resulting in bones becoming weaker and more prone to fractures. Healthy bone resembles a honeycomb structure, but in osteoporosis, the cortical bone becomes more porous, exacerbating skeletal weakness [1]. This condition affects millions of people globally [2]. Osteoporotic fractures can lead to severe complications and increased medical costs [3]. Osteoporosis is often referred to as a "silent" disease, since it typically presents without any symptoms until a fracture occurs. This bone disorder impacts individuals across all ages, genders, and ethnicities, although it is more prevalent among Caucasians, older adults, and women [4]. Osteoporosis predominantly affects postmenopausal women due to the decline in estrogen levels during and after menopause thereby accelerating bone loss [5]. In females, bone mass typically reaches its peak in the early 20s then gradually declines thereafter, leading to increased susceptibility to osteoporosis and fractures [6]. A systematic review emphasizes the crucial role of physical activity, especially high impact weight bearing exercises, during adolescence for maximizing peak bone mass acquisition [7]. Additionally, exercise interventions in young and middle-aged adults have shown improvements in bone geometry, especially with high-intensity military-style training or impact exercises

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[8-10]. Other risk factors include a family history of osteoporosis or osteoporotic fractures, a small body frame, certain medical conditions such as endocrine disorders and rheumatoid arthritis, and the use of medications such as corticosteroids or chemotherapy [11-15]. Lifestyle factors can also contribute to bone loss such as smoking, excessive alcohol consumption, and physical inactivity [12,16,17].

Exercise has been found to play a critical role in preventing and treating osteoporosis. Numerous research studies have corroborated these findings. For instance, Pinheiro and colleagues' systematic review explores the link between physical activity and osteoporosis prevention in individuals aged 65 years and older, indicating that physical activity has a modest yet significant effect on bone health, particularly on lumbar BMD [18]. While evidence for femoral neck BMD is weaker, programs involving higher doses of physical activity or multiple exercise types show greater effectiveness. A more recent systematic review and meta-analysis endorses positive effects of exercise on BMD at the lumbar spine, femoral neck, and total hip in postmenopausal women [19]. Overall, exercise interventions are promising for preventing and improving bone health. The aim of this review is to delve into distinct exercise modalities, primarily focusing on their impact on BMD as a metric of bone health in postmenopausal women.

Methods

A literature review was conducted using several databases to examine the relationship between exercise modalities and osteoporosis in postmenopausal women. Searches were performed on PubMed, Cochrane Library, and Web of Science. Search terms included combinations of 'exercise,' 'osteoporosis,' and 'postmenopausal women,' and searches were restricted to articles in the English language. The search included articles published between 2002 to 2023. A total of 38 articles were selected for review based on relevance to the research topic.

To ensure the inclusion of high-quality papers, the articles were manually reviewed using the study design, sample size, and target population. Preference was given to randomized controlled trials (RCTs), systematic reviews, and meta-analyses. The selected studies covered a range of exercise modalities, including resistance training, aquatic exercises, high-impact activities, mind-body exercises, walking, and their combinations, with a focus on their impact on BMD.

Results

Unimodal exercise

Resistance training: Resistance training, also known as strength training or weight training, is a form of exercise that uses resistance to build muscle mass, strength, and endurance. Much research has been done to investigate the intricate relationship between resistance training and BMD.

Shojaa and colleagues' systematic review with meta-analysis reveals significant increases in lumbar spine (LS) and total hip BMD in postmenopausal women following dynamic resistance training, particularly with free weight exercises [20]. Furthermore, Massini, et al.'s meta-analysis suggests that the positive effect of resistance training on BMD beyond 12 weeks of intervention in healthy older adults may play a crucial role in attenuating age-related BMD loss [21]. Both the papers by Massini, et al. and Shojaa, et al. primarily included studies of moderate to high quality [20,21]. Moreover, Kelley, et al.'s meta-analysis emphasizes the efficacy of resistance exercises in enhancing LS and femoral neck (FN) BMD among postmenopausal women [22].

Thabet, et al.'s RCT discusses closed and open kinetic chain exercises with their findings on osteoporosis. Open chain exercises are defined as those in which the distal part of the limb i.e. foot or hand is free to move in space, isolating a muscle group. In this study, open chain exercises included the straight leg raise, hip shrugs from a half crook supine lying position, hip extension from a prone lying position, and hip abduction/adduction from a side lying position. On the other hand, closed chain exercises, also a form of resistance training, are those in which the distal part of the limb is in contact with a surface and fixed, involving compound muscles. Closed chain exercises in this study included leg presses in the horizontal position, bicycling, and using the stair climbing machine. These researchers found that closed kinetic chain exercises significantly improve both BMD and fall risk [23].

A few RCTs have shown that high-velocity power training, a type of resistance training with rapid concentric muscle contractions, is more effective than traditional progressive resistance training for maintaining LS BMD, along with improving functional performance [24,25]. More research is needed on high-velocity power training before it can be confidently recommended as a therapeutic option for osteoporosis, but it is promising as a superior alternative to progressive resistance training.

High impact training: High impact exercises, such as jumping and weight bearing sports, have emerged as a promising intervention for improving bone health, particularly in postmenopausal women more at risk of osteoporosis. A RCT conducted by Basat, et al. demonstrated that a high impact exercise regimen led to significant increases in LS and FN BMD compared to strength training and control groups, accompanied by favorable changes in bone turnover markers [26]. Koshy and colleagues' systematic review highlights the benefits of high impact exercises on BMD in

postmenopausal women, attributing positive results to the compressive force, shear stress, and high loads these exercises exert on bones, which promotes bone remodeling [27]. In contrast, a RCT by Montgomery, et al. found no significant impact on BMD among early postmenopausal women following a jumping intervention [28]. Considering these opposing findings and the absence of larger trials examining high impact exercise as a sole exercise intervention, it is difficult to definitively recommend high impact exercise as a solitary intervention for improving BMD in postmenopausal women.

Water-based exercises: Water-based exercises (WBE) have garnered attention for their potential role in preserving bone health, particularly in individuals at risk of osteoporosis. Su, et al.'s systematic review and meta-analysis found conflicting evidence, with some studies suggesting that swimming has no effect on bone mass while others indicated potential benefits, especially with longer durations of swimming in older individuals. Additionally, these researchers posit that swimming may affect bone turnover markers and stimulate osteoblasts through muscle-powered skeletal movement and water pressure, potentially promoting bone formation [29].

Simas, et al. provide further insights into this exercise modality, suggesting that WBE may improve or maintain BMD in postmenopausal women. Their systematic review and meta-analysis revealed significant differences favoring WBE over sedentary control groups in terms of changes in LS and FN BMD. However, when compared to land-based exercise (LBE), WBE showed less benefit, with LBE demonstrating greater improvements in LS BMD. Despite this, WBE was found to positively affect bone metabolism, with increased levels of biomarkers associated with bone formation compared to sedentary controls [30].

Overall, while Su, et al.'s findings regarding swimming's effects on bone mass remain inconclusive, Simas, et al.'s systematic review and meta-analysis suggests that WBE programs, particularly in the form of intense aquatic exercises, may hold promise for maintaining or improving bone health in postmenopausal women. The potential benefits of WBE include improvements in BMD and bone metabolism, with a low risk of causing injuries. However, further research is needed to fully understand the long-term effects and optimal implementation of WBE in this population [30]. Findings from both studies highlight the importance of considering water-based exercises as a therapeutic approach to osteoporosis, especially in populations where rigorous land-based exercises may not be suitable due to physical limitations or chronic medical conditions.

Mind-body exercises: Mind-body exercises, including Pilates, yoga, Tai Chi, and traditional Chinese fitness exercises, have potential benefits in managing osteoporosis. Kucukcakir and colleagues' RCT showed significantly greater improvements in pain, functional status, and quality of life after Pilates intervention [31]. Similarly, Angin and colleagues' RCT investigated the effects of Clinical Pilates Exercises on postmenopausal osteoporosis, demonstrating significant increases in BMD, physical performance, and quality of life, along with pain relief [32].

Moreover, the effect of Tai Chi was also studied independently as an effective intervention to increase BMD in postmenopausal women. Qin, et al.'s case control study found that 12 months of Tai Chi resulted in a significantly higher BMD at the lumbar spine, proximal femur, and the ultra distal tibia [33]. Qin's findings were corroborated by Wayne, et al.'s RCT which found that Tai-Chi had positive effects on FN BMD [34].

A systematic review and meta-analysis conducted by Fernandez-Rodriguez, et al. found that a Pilates-yoga intervention maintained BMD in postmenopausal women, though this was a nonsignificant finding [35]. On the other hand, Motorwala, et al.'s experimental pre-post study showed that yoga increased LS BMD in postmenopausal women [36].

Overall, systematic reviews or meta-analyses studying mind-body exercises are required before recommending them for increasing BMD in postmenopausal osteoporosis management. However, the existing evidence suggests that these exercises may offer valuable benefits for improving BMD, physical function, pain relief, balance, and quality of life in individuals with osteoporosis. Chinese fitness exercises such as Taijiquan, Wuqinxi, Yijin Jing, and Baduanjin have potential to enhance bone mass, slow down bone loss, improve bone metabolism, body balance, and quality of life [37].

Walking: Walking, a simple yet effective form of exercise, has gained attention for its potential positive impact on bone health. Ma, et al.'s systematic review and meta-analysis indicated that walking interventions lasting more than six months showed positive effects on FN BMD in perimenopausal and postmenopausal women, although no significant effects were observed on BMD at other sites [38]. A systematic review and meta-analysis of the effect of walking on BMD in postmenopausal women showed that regular walking had significant positive effects on FN BMD, however the difference observed is likely too small to be clinically significant [39].

Additionally, the published trials that support this conclusion show notable variations in methodology and reporting standards. Collectively, these studies emphasize that walking remains inconclusive as an effective exercise strategy for enhancing BMD in postmenopausal women.

Multimodal exercise

Per previous discussion in section 3.1, research

studies indicate that there are site-specific skeletal effects with unimodal exercise regimens. Combined exercise interventions, which include at least two different types of exercise, such as combining resistance training with impact exercise, are believed to create diverse mechanical strains and positively affect various skeletal loading sites. Additionally, combined exercise interventions can help in addressing various other factors other than BMD, such as fall-risk, balance, muscle strength, functional performance, and pain reduction.

Combined exercise protocols: Combined exercise programs have been proven to be effective in increasing or preserving BMD. A systematic review and meta-analysis found that combined exercise regimens positively affect LS BMD, FN BMD, total hip BMD, and total body BMD [40]. Interestingly, postmenopausal women under 60 years of age were more sensitive to combined exercise protocols at the femoral neck, while postmenopausal women over 60 years of age gained greater skeletal effects at the lumbar spine [40]. One possible explanation is that estrogen levels could play a significant role in how the skeleton responds to mechanical strain. The femoral neck, which often experiences greater mechanical stimulus during mixed exercise, might be particularly sensitive to changes in estrogen levels. Additionally, postmenopausal women under the age of 60, who generally have higher estrogen levels, may be more responsive to mechanical strain compared to those aged 60 or older [40].

Another meta-analysis found that combined physical training protocols (resistance in combination with high impact or weight bearing exercise) proved to be effective in improving or preserving BMD at the spine and hip, while resistance-alone training programs only had non-significant positive effects [41].

Another systematic review and meta-analysis demonstrates that different combinations of exercises can lead to improvement in BMD across various skeletal sites. For example, resistance training, aerobic exercise, and combined aerobic and resistance training were associated with increases in BMD at different skeletal regions, but not significantly at the total body or total hip sites [42]. This suggests that the effectiveness of exercise interventions in improving BMD may depend on the specific combination of exercises, the skeletal site being targeted, and demographic factors such as age.

Combined high-intensity resistance and impact training: The combination of high impact and resistance training (HiRIT) has emerged as a promising approach for improving BMD and addressing fall-related factors in individuals with osteoporosis. Clinicians often hesitate to recommend HiRIT for osteoporotic patients due to safety concerns. Recent studies, such as the LIFTMOR and MEDEX-OP RCTs, have demonstrated the effectiveness of HiRIT in improving BMD, functional performance, and muscle strength without adverse effects [43].

The LIFTMOR trial showed that HiRIT is superior to the low-intensity home based control program for positive effects on LS BMD, FN BMD and FN cortical thickness, volume, and all functional performance measures [44]. Even though there was only a slight increase in FN BMD after the HiRIT intervention, marked femoral neck cortical bone thickening was observed. This suggests that the femoral neck responds to exercise via structural adaptations that can improve the ability of bone to withstand loading not well measured by BMD. This could also potentially explain Pinheiro, et al.'s findings that combined exercise regimens positively impact LS BMD more so than FN BMD [18].

Exercise in youth, young adults, and middle-aged individuals has been shown to enhance bone geometry, leading to increases in cortical volume and thickness [7-10]. On the other hand, exercise interventions in postmenopausal women have shown promise in improving BMD, but their impact on bone geometry remains less explored. This makes the LIFTMOR trial's finding of cortical bone thickening at the femoral neck a particularly valuable discovery [44].

The MEDEX-OP trial demonstrated that HiRIT was superior to a low-intensity Pilates-based exercise program in improving LS BMD and vertebral height. Additionally, HiRIT had larger functional performance effects for leg and back muscle strength and the sit-to-stand test [43].

The LIFTMOR and MEDEX-OP trials have addressed several common issues in exercise intervention trials for osteoporosis, such as reliance on BMD as the primary measure, exclusion of individuals with osteoporosis, and inadequate exercise intensity [45]. While HiRIT is a promising exercise prescription, further research is necessary before it can be definitively recommended as a therapeutic intervention.

Safety concerns about high intensity loading discourage clinicians from recommending HiRIT as a therapy for osteoporosis, but no adverse effects were induced by the LIFTMOR HiRIT regimen [44]. The MEDEX-OP trial reported only a few adverse events, only one of which was fracture-related [43]. A systematic review of adverse events associated with exercise in adults with osteopenia and osteoporosis corroborates that impact exercises and moderate to high-intensity muscle-strengthening exercises were not associated with symptomatic vertebral fractures [46]. However, most of the studies in the review did not include older women. Although fracture data from studies is limited, the available evidence indicates that high-impact and resistance exercises are unlikely to cause fractures in individuals with osteoporosis.

Exercise intensity

When determining the best type of exercises for managing osteoporosis, the intensity of the specific

exercise is another factor to consider in maximizing BMD.

In a meta-analysis, high-intensity exercise was more effective for increasing LS BMD compared to low or moderate intensity exercises. However, the findings regarding FN BMD were inconclusive, possibly due to limited statistical power [47]. Likewise, a systematic review and meta-analysis showed that HiRIT was advantageous over moderate intensity resistance and impact training (MiRIT) in improving LS BMD, but there was no significant difference noted in FN BMD between the two interventions. However, the included studies showed high heterogeneity and the certainty of evidence was very low [48].

Eslamipour, et al.'s RCT showed that high intensity resistance training (HIRT) was the most effective intervention in increasing BMD when compared to low-intensity resistance training (LIRT) and controls. In those individuals unable to perform HIRT, LIRT is superior to the control group in counteracting age-related losses in bony indices [49].

Borer, et al.'s RCT showed that exercise intensity plays a crucial role in BMD changes with their trial on walking intensity in postmenopausal women [50]. Higher intensity walking led to spinal BMD gains, while lower intensity walking resulted in BMD loss or no significant improvement. The importance of intensity is further emphasized by the correlation between muscle mass, strength, and BMD, suggesting that gains in muscle mass and increased ground reaction forces from faster walking contribute to BMD accrual [50].

In summary, exercise intensity is another key factor in managing osteoporosis and improving BMD, particularly at the lumbar spine in postmenopausal women. High-intensity exercise interventions have been shown to be more effective in increasing LS BMD compared to low or moderate intensity exercises.

Discussion

Exercise has been widely acknowledged as a crucial component in the management and prevention of osteoporosis, with various types of regimens demonstrating benefits. Resistance training has the strongest evidence among the unimodal exercises studied in this paper for improving BMD, as it has been the most extensively studied [20-22]. Other exercise types lack the same level of systematic review. Several systematic reviews with meta-analyses have proved the efficacy of combined regimens in improving BMD in postmenopausal women [40,42].

Out of these, Zhao's systematic review with meta-analysis indicates that combined exercise protocols are more effective than resistance training alone in enhancing BMD [41]. Based on this, we can infer that combining different exercise modalities are superior to unimodal exercise programs.

Out of the combined regimens, the HiRIT program stands out as particularly effective [43,44].

The LIFTMOR and MEDEX-OP trials found that HiRIT was effective in increasing LS BMD, femoral neck cortical thickness, and muscle strength without adverse effects. Despite safety concerns, the trials reported minimal adverse events, suggesting that HiRIT is a safe and effective intervention for osteoporosis.

For future directions, strict compliance with exercise regimens is an important factor that must be considered when prescribing exercise as a treatment for osteoporosis. In a systematic review and meta-analysis, Cui, et al. found that high adherence to the American College of Sports Medicine (ACSM)'s exercise recommendations (a multimodal regimen) had a positive effect on LS and FN BMD compared to low or uncertain compliance in individuals with osteoporosis [51].

Similarly, Kelley, et al. highlighted in their meta-analysis that higher intensity and better adherence to their strength training program were associated with greater increases in both LS and FN BMD [22]. Future research in this area could explore innovative strategies to improve adherence to exercise regimens. The role of technology, such as mobile apps or wearable devices in monitoring and encouraging compliance is promising for better results [52,53].

Furthermore, understanding the effect of exercise coaching and supervision is essential in optimizing osteoporosis management. Some studies shed light on the differences between supervised versus unsupervised exercise programs in the context of osteoporosis management [54,55]. Bragonzoni, et al.'s randomized controlled trial compared individual training at home with remote periodic trainer supervision against group training with live continuous supervision. Despite the differing levels of supervision, this study found no significant differences between the groups concerning health-related quality of life, physical function, participation, or safety. Both groups experienced improvements in physical function and functional capacity, suggesting similar effectiveness of supervised and unsupervised exercise modalities in enhancing these outcomes [54].

Moreover, Sanchez-Trigo, et al.'s systematic review and meta-analysis revealed that non-supervised exercise regimens led to increases in both LS and FN BMD. Notably, this effect was more pronounced in women with osteopenia or osteoporosis compared to their healthy counterparts. This suggests that even without direct supervision, exercise interventions can significantly improve bone health outcomes, particularly in populations with existing bone density concerns [55].

This study aims to provide a summary of existing literature on the effect of different exercise modalities, both combined and unimodal, on BMD

in postmenopausal women with osteoporosis. By summarizing and noting remarkable findings of existing research, we hope to make an informed recommendation on the most effective exercise type for improving BMD in our target population. Since this is a narrative review, our recommendation is limited by the lack of methodological and systematic review when presenting results. The quality of studies included in this review varies, and a systematic approach was not used to assess quality.

Furthermore, this review does not aim to provide an exhaustive search of all available evidence on this topic. Higher-quality studies were prioritized, such as RCTs and systematic reviews with meta-analyses. Additionally, our focus on BMD as the sole indicator of bone health overlooks other critical outcomes of osteoporosis management, including functional improvement, balance, pain relief, and quality of life. There is a need for more research focused on identifying markers of bone health beyond BMD. BMD might not always be the most precise marker at the femoral neck, highlighting the utility of other bone health indicators. Nonetheless, our paper studies the effects of different exercise modalities on BMD as it is a commonly studied and widely used metric of bone health.

Summary

In conclusion, exercise is a cornerstone in the treatment of osteoporosis, particularly in postmenopausal women. Combined exercise protocols, such as the HiRIT regimen, have shown significant benefits in managing this condition. This exercise program can increase BMD and reduce the risk of osteoporotic fractures. For those individuals in which instituting combined protocols is not feasible, unimodal regimens focusing on resistance training have also demonstrated effectiveness in maintaining or increasing BMD. For the practicing clinician, it is important to consider the specific benefits of each type of exercise when tailoring treatment plans for postmenopausal women with osteoporosis. Regular exercise not only improves bone health but also enhances overall physical fitness, balance, and quality of life, making it a critical component of osteoporosis management.

Authors' Contributions

MM & SK contributed equally to this work and should be considered co-first authors.

MM contributed to conceptualization, data collection, and manuscript writing and editing. SK contributed to conceptualization, data collection, and manuscript writing and editing. MZ contributed to conceptualization, data collection, and manuscript editing.

Competing Interests

The authors declare that they have no competing interests. The authors have no funding sources to disclose.

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