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A Literature Review on Efficacy of Strength and Balance Training in Preventing Osteoporosis in Peri-Menopausal Women with Low Bone Mineral Density

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ABSTRACT
Background: Low bone mineral density (BMD) is a significant health concern among older adults, particularly women. Studies indicate that osteoporosis affects approximately one in four women over the age of 50, with bone loss accelerating during and after menopause due to declining estrogen levels. This hormonal change leads to reduced bone formation, increased bone resorption, and higher fracture risk. Peripheral DXA measures bone mineral content and density by analyzing differential attenuation of X-rays. Research suggests that exercise especially weight-bearing and high-impact activities can play a vital role in maintaining BMD, although its benefits are often modest. Perimenopausal women are at a crucial stage where preventive strategies, including targeted exercise and lifestyle interventions, may effectively reduce the future risk of osteoporosis.
Aim: This study aimed to evaluate strategies to prevent osteoporosis in perimenopausal women by exploring the potential of exercise interventions to maintain bone health during this transitional stage.
Search Method: Relevant literature was searched through PubMed, Google Scholar, ScienceDirect, and ResearchGate.
Selection Criteria: Articles were included based on the inclusion criteria focusing on perimenopausal women, assessed BMD changes and examined exercise interventions for preventing osteoporosis.
Objective: This review aimed to evaluate the effectiveness of strength, balance, and other exercise-based interventions in reducing bone mineral density (BMD) loss among perimenopausal women with low BMD. It further examined the impact of various exercise modalities—such as resistance, weight-bearing, high-impact, and balance training—on musculoskeletal health, fall prevention, and functional outcomes. Additionally, the review sought to identify optimal non-pharmacological exercise strategies to lower the future risk of osteoporosis in this population.
Results: The findings indicate that many women choose alternative therapies to manage osteoporosis symptoms due to concerns about the side effects of hormonal and non-hormonal medications. Exercise has emerged as a key non-pharmacological approach to support bone health. The reviewed studies collectively suggest that strength and balance training can have beneficial effects in preventing osteoporosis
Conclusion: Evidence from reviewed studies shows that perimenopausal women experience a marked decline in BMD due to hormonal changes, particularly estrogen deficiency. Weight-bearing and resistance exercises, when performed regularly, can slow bone loss and improve musculoskeletal strength, reducing fracture risk in later life. Therefore, early intervention during perimenopause is essential to preserve bone mass and promote healthier aging among women.

KEYWORDS: Menopause, Perimenopause women, Osteoporosis, Low Bone Mineral density, Strength and Balance training, and Physical activity.

INTRODUCTION

Perimenopause is a loosely defined period that marks the final years of a woman's reproductive life. It begins with the onset of menstrual irregularity and ends after one year of amenorrhea, which defines the final menstrual period (FMP).Perimenopause has two stages: the early transition, where menstrual cycles are mostly regular with few interruptions, and the late transition, where amenorrhea becomes more prolonged, lasting at least 60 days, leading up to the FMP. Studies from several global cohorts have detailed the natural history of the menopausal transition, linking these stages to specific hormonal events and associated symptoms[(5)].

A Literature Review on Efficacy of Strength and Balance Training in Preventing Osteoporosis in Peri-Menopausal Women with Low Bone Mineral Density

Low bone mineral density (BMD) is a major health issue for older adults, especially women [(1)]. Among 524 people with an average age of 50 included 41.2% women and 58.8% men. Osteoporosis was found in 6.9% of the people (11.1% of women and 4.2% of men), and osteopenia was found in 34% (40.3% of women and 29.9% of men). Men had higher BMD than women at all bone sites. The rate of osteoporosis increased with age in women but not in men [(4)]. One in four women over 50 is believed to have osteoporosis. Another study found that in women over 40, BMD dropped by 4 to 5.7 percent from peri- to post-menopause. After adjusting for age, weight, and height, the BMD loss due to menopause was around 2.1% in the lumbar spine, 2.5% in the femoral neck, and 4.5% in the total hip. This accelerated bone loss after menopause is due to lower estrogen levels [(3)].Peripheral DXA is commonly used to measure BMD and diagnose osteoporosis or low bone mass. Changes in BMD can be linked to conditions like osteoarthritis [(1)]. Low bone mineral density is defined as a BMD T-score between -1.0 and -2.5. A BMD that is 2.5 standard deviations or more below the average BMD of a young adult is diagnosed as osteoporosis [(2)]

Osteoporosis (OP) is a major health problem, especially in post-menopausal women.It impacts millions of individuals globally and its prevalence increases with advancing age.. Osteoporosis is characterized by unusually low bone mass and defects in bone structure,leading to increased bone fragility and a higher risk of fractures. At the cellular level,adult bone tissue undergoes continuous remodeling, where bone-resorbing cells (osteoclasts) remove old bone, and bone-forming cells (osteoblasts) replace it with new bone. When resorption exceeds formation, bone density decreases, and the micro-architecture becomes disrupted, leading to osteoporosis, increased fragility, and a higher risk of fractures [(2)].

METHODOLOGY

Search method and eligibility criteria

PubMed, Google Scholar, and ScienceDirect were utilized to conduct a comprehensive literature search from the year 2015. Articles that were not published in English were removed. Here, the articles were searched with the keyword's menopause, perimenopausal women, Osteoporosis, Low Bone mineral density, strength and balance training, and physical activity. Twenty articles were selected and reviewed based on the keywords, inclusion, and exclusion criteria.

Inclusion criteria

- Articles explaining the effects of exercises on perimenopausal women with low bone mineral density.
- Articles published in the last Ten years.
- Articles available in full text.
- Articles published only in English language.

Exclusion criteria

- Articles explaining surgical interventions.

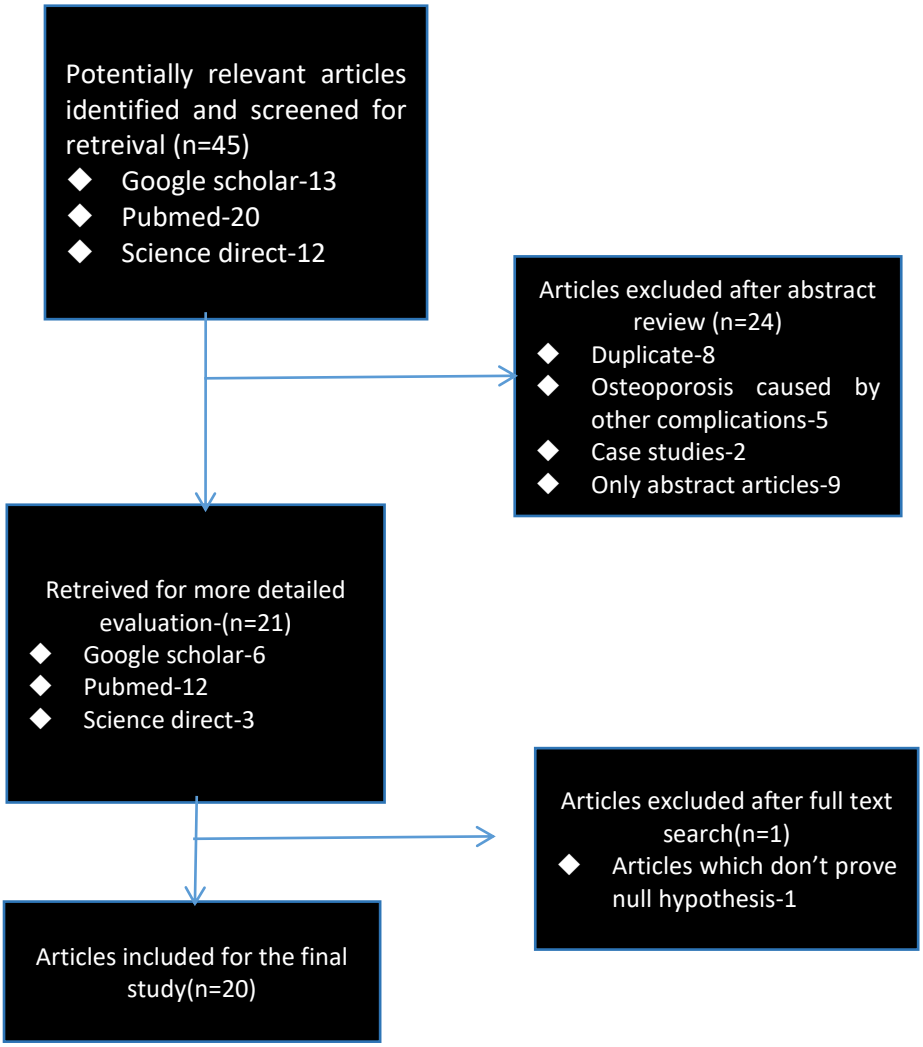
Articles explaining Hormonal replacement therapies.

- Articles discussing other than the effects of exercises on Perimenopausal women with low bone mineral diseases were excluded.

OBJECTIVE

The primary objective of this review was to critically evaluate the efficacy of strength and balance training, along with other exercise-based interventions, in preventing or attenuating bone mineral density (BMD) loss among perimenopausal women with low bone mineral density. Additionally, this review aimed to analyze the impact of different exercise modalities including resistance training, weight-bearing activities, high-impact exercises, and balance training on musculoskeletal health, fall prevention, and overall functional outcomes during the menopausal transition. The study also sought to identify optimal exercise strategies that can be implemented as non-pharmacological interventions to reduce the future risk of osteoporosis in this population.

METHODOLOGY



S.No	Author	Year	Study Design	Sample size	Summary
1	Victoria H. Stiles, Brad S. Metcalf, Karen M. Knapp, Alex V. Rowlands	2017	Cross-sectional study using UK Biobank data	2534	This study investigated the relationship between precisely measured high-intensity habitual physical activity and bone health in pre- and post-menopausal women. Using 7-day wrist-worn accelerometers, researchers calculated time spent in bone-relevant high-intensity activity, defined as ≥1000 milli-gravitational units (mg) for pre-menopausal women and ≥750 mg for post-menopausal women. Bone health was assessed by calcaneal quantitative ultrasound measures.Results showed that women who accumulated just 1–2 minutes per day of high-intensity PA had significantly better bone health than those with less than 1 minute per day. Specifically, running-level activity (≥1000 mg) benefited pre-menopausal women, while slow-jogging-level activity (≥750 mg) benefited post-menopausal women. Time spent in lower-intensity activities was not associated with bone health.

2	Kukkonen-Harjula K., Kannus P., Sievänen H., Oja P., Vuori I., and colleagues	2017	Randomised Controlled Trial	105	The study investigated the effects of two different exercise training regimens calisthenics (strength and weight-bearing exercises) and endurance training on bone mineral density (BMD) in healthy perimenopausal women over an 18-month period. Participants were randomly assigned into three groups: calisthenics training, endurance training, and a control group with no structured exercise. The results showed that women who participated in calisthenics training demonstrated better maintenance and improvement of BMD compared to the control group, indicating that weight-bearing and strengthening exercises have a positive effect on bone health during the perimenopausal transition. Endurance training showed less significant impact on BMD compared to strength-based exercises
3	*Chun-Mei Xiao Med, Yong Kang MEd Yong-Chang Zhuang Med*	2016	Randomised controlled trial	50	The Author conducted a study on Effects of Elastic Resistance Band Exercise on Postural Balance, Estrogen, Bone Metabolism Index, and Muscle Strength of Perimenopausal Period Women" Included"Peri-menopausal women protocol of" Resistance band exercises for 6 months" Author concluded"6 months of height intensity resistance band exercises improved estrogen level, muscle strength ,exercise capacity and bone mineral density in Peri-menopausal women.
4	Azza M Abd El Mohsen, MSc, Hossam Eddien F Abd El Ghaffar, PhD, Nagui S Nassif, PhD, Ghada M Elhafez, PhD	2016	Randomised controlled trial	24	The Author conducted a study on "The weight-bearing exercise for better balance program improves strength and balance in osteopenia: a randomized controlled trial" included "T.wenty-four postmenopausal females with osteopenia volunteered to participate", protocol of " Weight-bearing Exercise for Better Balance program on the strength of hip flexors, extensors, abductors, adductors, and knee flexors and extensors and balance " and Author concluded that "Weight-bearing Exercise

					for Better Balance (WEBB) program has significant effects on lower extremity muscles strength and body balance.
5	Ibolya Miko, Imre Szerb, Anna Szerb, Gyula Poor]	2017	Randomised controlled trial	100	The Author conducted a study on" Effectiveness of balance training programme in reducing the frequency of falling in established osteoporotic women: a randomized controlled trial" included 100 osteoporotic women protocol of 12-month sensomotor balance exercise programme, Author concluded that " one-year exercise programme significantly decreased the number of falls in osteoporotic women".
6	Gregory S. Walsh, Anne Delextrat, Adam Bibbey	2023	Systemic review	1560	The author conducted a study on "The comparative effect of exercise interventions on balance in perimenopausal and early postmenopausal women: A systematic review and network meta-analysis of randomised, controlled trials". Included "peri-menopausal, menopausal and post- menopausal women" protocol of "Aerobic exercises, Balance and coordination, high impact exercises, resistance training and plyometric and whole-body vibration techniques". Concluded that" both resistance and balance training improved balance in pre-menopausal, menopausal and post-menopausal women".
7	Ana Claudia Fortaleza Marques, Fabrício Eduardo Rossi, Lucas Melo Neves, Tiego Aparecido Diniz, Iracimara de Anchieta Messias, José A Barela, Fay B Horak, Ismael Forte Freitas Júnior.	2023	Randomised controlled trial	28	Author conducted a study on "Combined Aerobic and Strength Training Improves Dynamic Stability and can Prevent against Static Stability Decline in Postmenopausal Women: A Randomized Clinical Trial" .Included "16 weeks of combined training (n = 16) versus a non-training control group (n = 12) in postmenopausal women ages 50-70" protocol of "strength and aerobic training in each exercise session. Subjects exercised for 90 minutes, 3 times per week for 16 weeks. Before each exercise session, participants performed 5 minutes of warm-up exercises and 5 minutes of stretching at the end of the training session" . Concluded that "Combined training (aerobic plus strength) improved gait variables and avoided the postural control decline after 16 weeks of intervention in postmenopausal women´.

8	Alvaro Juesas, Pedro Gargallo, Javier Gene-Morales, Carlos Babiloni-López, Angel Saez-Berlanga, Pablo Jiménez-Martínez, Jose Casana	2023	Randomised double blinded controlled trail	93	Author conducted a study on "the effects of a 32-week resistance training intervention with elastic bands with or without microfiltered seawater supplementation on isokinetic strength, bone mineral density , body composition, and subjective quality of life in peri-menopausal women". Included "Ninety-three untrained women aged 40-50" protocol of "group A resistance training with deep seawater supplementation and group B resistance training with placebo supplementation and controlled group" concluded that resistance training program with sea water supplementation significantly improves isokinetic strength compared to controls".
9	Lohman T	2017	Randomised prospective study	56	Author conducted a study on "Effects of resistance training on regional and total bone mineral density in peri-menopausal women: a randomized prospective study " included " peri-menopausal women aged 28-39 " protocol of 18 months of resistance training " concluded that" resistance exercises improved total bone mineral density and soft tissue lean mass".
10	Victoria H stiles	2017	Cross-sectional observational study	2534	Author conducted a study on "A small amount of precisely measured high-intensity habitual physical activity predicts bone health in pre- and post-menopausal women in UK Biobank" included "pre-menopausal (n = 1218) and post-menopausal women (n = 1316) aged 40-60" protocol of "high intensity habitual physical activity" concluded that "1–2 minutes or ≥2 minutes per day of high-intensity PA, equivalent to running in pre-menopausal women and slow jogging in post-menopausal women, is associated with better bone health".
11	Wolfgang Kemmler	2020	Systemic review	84	Author conducted a study on "Effects of Different Types of Exercise on Bone Mineral Density in Peri-menopausal Women: A Systematic Review and Meta-analysis included 84 peri-menopausal women"protocol of"weight bearing (WB, $n = 30$) exercise, (dynamic) resistance exercise (DRT, $n = 18$), mixed WB&DRT interventions" concluded both weight bearing exercises and dynamic resistance training improves bone mineral density significantly in peri-menopausal women".
12	Martyn-St James M., Carroll S.	2023	Systemic review	1432	This systematic review and meta-analysis evaluated randomized controlled trials investigating the effects of exercise interventions on bone mineral density in

					peri-menopausal and early post-menopausal women. The review analyzed multiple RCTs that included weight-bearing, resistance, and functional exercise programs. The results demonstrated that structured exercise, particularly resistance and weight-bearing training, significantly improved or preserved bone mineral density at the hip and lumbar spine. The findings indicated that exercise interventions are effective non-pharmacological strategies for preventing bone loss during menopausal transition. However, the review also highlighted variability in exercise protocols and emphasized the need for long-term adherence and standardized training programs to achieve optimal bone health outcomes.
13	Watson SL, Weeks BK, Weis LJ, Harding AT, Horan SA, Beck BR	2018	Randomised controlled trial	101	This randomized controlled trial of 101 postmenopausal women with low bone mass compared 8 months of high-intensity resistance and impact training (HiRIT) with low-intensity home exercises. The HiRIT group trained twice weekly with heavy lifts and jumps, showing significant increases in lumbar spine and femoral neck BMD, muscle strength, and function compared to controls. High compliance and minimal adverse events confirmed that supervised high-intensity training is safe and effective for improving bone health in postmenopausal women.
14	Lewis BA, Williams DM, Frayeh AL, et al.	2025	Rndomised Controlled trial	39	This study evaluated a 12-week group-based physical activity program incorporating strength training in low-active perimenopausal women. Participants were randomized into an intervention group or wait-list control group. The intervention improved exercise self-efficacy, enjoyment, habit formation, and adherence to strength training. Although overall physical activity levels did not significantly increase, the program demonstrated feasibility, safety, and acceptability, suggesting that structured group-based exercise programs may support long-term physical activity behaviour during menopausal transition.

15	Winters-Stone KM, Dobek J, Nail LM, Bennett JA, Leo MC, Schwartz A.	2018	Randomized Controlled Trial	71	This study investigated the effects of a 12-month impact and resistance training program (POWIR program) compared with flexibility training in women with treatment-induced premature menopause. The intervention significantly improved hip bone mineral density and prevented lumbar spine bone loss. Participants also showed improved lean muscle mass and reduced body fat gain. The results suggest that combined impact and resistance training is an effective non-pharmacological approach to maintain bone health and physical function in early menopausal women.
16	Neelam Kaushal a , Divya Vohora a , Rajinder K. Jalali b , Sujeet Jha c	2018	A Cross sectional study	524	This cross-sectional retrospective study on 524 healthy Indian adults (216 females, 308 males) used peripheral DXA scans to assess BMD at the lumbar spine and hip. Osteoporosis and osteopenia were found in 6.9% and 34% of participants, respectively, with higher rates in females. BMD increased with BMI, weight, height, and physical activity, while alkaline phosphatase showed a negative correlation. No significant relationship was found between BMD and serum calcium, phosphorus, or vitamin D, indicating that body composition and activity are key determinants of bone health in this population.
17	Martyn-St James M, Carroll S.	2024	Systemic review and Meta analyses of Randomised controlled Trial	1432	This systematic review analyzed randomized controlled trials examining the effect of walking and weight-bearing exercise on bone mineral density in peri- and early postmenopausal women. The review demonstrated that regular weight-bearing exercise helps maintain or improve bone mineral density, particularly at the hip and lumbar spine. The study emphasized that long-term adherence and adequate exercise intensity are essential to achieve bone protective effects during menopausal transition.
18	Karen L Bolton 1, Thorlene Egerton, John Wark, Elin Wee, Bernadette Matthews, Anne Kelly, Robyn Craven, Sue Kantor, Kim L Bennell	2017	Randomised controlled trial	39	This randomized single-blind controlled trial assessed a 12-month community-based exercise program in 39 peri-menopausal women with hip osteopenia not taking bone-enhancing medication. Participants were assigned to an exercise group performing supervised strength, balance, and jumping exercises three times weekly plus home exercises, or a control group with usual care; all received calcium supplements. After 52 weeks, exercise produced a small but significant benefit in total hip BMD, with a 0.5% gain versus a 0.9% loss in controls. Quality of life and trunk endurance also improved, indicating modest benefits of

					community-based exercise for women with osteopenia.
19	Filipović T.N., Lazović M.P., Backović A.N., Filipović A.N., Ignjatović A.M., Dimitrijević S.S., and Gopčević K.R	2020	Randomised controlled trial	96	A study on 96 peri-menopausal women with osteoporosis found that a 12-week supervised program of resistance, balance, and aerobic exercises significantly improved functional performance, balance, muscle strength, and reduced fear of falling compared to controls, showing that short-term exercise effectively enhances function in this population.
20	Anupama D.S., Norohna J.A., Acharya K.K.V., Ravishankar, and George A.	2020	Systemic review	5581	This systematic review by Anupama D.S. et al. (2020) analyzed seven randomized controlled trials on peri-menopausal women with osteoporosis without fractures to assess the effects of exercise on bone mineral density and quality of life. Various exercise types, including Tai Chi, aerobic, Pilates, and low-impact loading exercises, were found to improve both BMD and quality of life. Despite small sample sizes and short intervention durations, the review concluded that exercise positively influences bone health, though more rigorous long-term studies are needed.

DISCUSSION

The menopausal transition represents a critical window for the prevention of osteoporosis due to the rapid hormonal changes that directly influence bone metabolism. The decline in estrogen levels during perimenopause disrupts the balance between osteoblastic bone formation and osteoclastic bone resorption, leading to accelerated bone loss. This review reinforces the understanding that early intervention during this transitional phase is essential to mitigate long-term skeletal deterioration.

One of the key findings across the reviewed literature is the strong role of mechanical loading in stimulating bone formation. Strength and resistance training apply controlled stress to bone tissue, which activates osteocytes and promotes bone remodeling through mechanotransduction pathways. This physiological response is particularly important in perimenopausal women, where natural hormonal support for bone maintenance is declining.

High-intensity resistance and impact training have demonstrated superior outcomes compared to low-intensity or non-weight-bearing activities. These exercises generate greater ground reaction forces and muscle contractions, which enhance bone strain and stimulate osteogenesis. However, adherence and safety remain important considerations, especially for women with already reduced bone density. Supervised programs, as highlighted in multiple randomized controlled trials, ensure proper technique, reduce injury risk, and improve compliance.

Balance training, although not directly influencing BMD to a large extent, plays a crucial complementary role in osteoporosis prevention. Falls are a major cause of fractures in osteoporotic individuals; therefore, improving postural control, proprioception,

and neuromuscular coordination significantly reduces fracture risk. The integration of balance training with strength exercises provides a dual benefit—improving both bone health and functional stability.

Another important aspect highlighted in the literature is the effectiveness of combined training approaches. Programs that incorporate resistance, weight-bearing, aerobic, and balance components yield more comprehensive benefits compared to isolated interventions. These multimodal programs not only target bone density but also improve muscle strength, endurance, gait, and overall functional independence. This holistic approach is particularly relevant for physiotherapy practice, where individualized and function-oriented rehabilitation is emphasized.

Despite the positive findings, the magnitude of improvement in BMD reported across studies is generally modest. This suggests that while exercise is beneficial, it may not completely reverse bone loss, especially in later stages. Therefore, exercise should be considered as part of a broader preventive strategy that includes nutritional optimization (calcium and vitamin D), lifestyle modifications, and, when necessary, medical management.

The variability in exercise protocols across studies remains a significant limitation. Differences in frequency, intensity, duration, and type of exercise make it difficult to establish standardized guidelines. Additionally, many studies had short intervention periods and small sample sizes, limiting the generalizability of findings. Long-term adherence to exercise programs is another challenge that influences outcomes, emphasizing the need for behaviorally supported and patient-centered intervention strategies.

From a clinical perspective, physiotherapists play a vital role in designing and implementing safe and effective exercise programs tailored to the needs of perimenopausal women. Early screening for low bone mineral density and risk factors, followed by targeted intervention, can significantly reduce the burden of osteoporosis and associated fractures.

Future research should focus on large-scale, long-duration randomized controlled trials to determine optimal exercise prescriptions, including intensity thresholds and progression strategies. Additionally, studies exploring the interaction between exercise, hormonal changes, and nutritional factors would provide a more comprehensive understanding of bone health during the menopausal transition.

RESULTS

The findings from the 20 reviewed studies consistently demonstrate that exercise interventions play a significant role in maintaining or improving bone mineral density and functional outcomes in perimenopausal and postmenopausal women.

Resistance and strength training were shown to significantly improve BMD at clinically important sites such as the lumbar spine and femoral neck. High-intensity resistance and impact training protocols, as demonstrated in randomized controlled trials, resulted in measurable increases in bone mass, muscle strength, and functional performance. Similarly, long-term resistance training interventions (ranging from 6 months to 18 months) were associated with improvements in lean body mass and preservation of bone density.

Weight-bearing exercises, including calisthenics and impact-loading activities such as jumping and jogging, were found to be particularly effective in stimulating osteogenic responses. Even short durations (1–2 minutes per day) of high-intensity physical activity were associated with improved bone health outcomes, highlighting the importance of exercise intensity.

Balance training interventions showed significant improvements in postural stability, coordination, and reduction in fall risk. Programs such as the Weight-Bearing Exercise for Better Balance (WEBB) and sensorimotor training demonstrated enhanced lower limb strength and decreased incidence of falls among osteopenic and osteoporotic women.

Combined exercise programs integrating strength, aerobic, and balance training were found to produce superior outcomes compared to single-modality interventions. These programs improved gait stability, prevented decline in postural control, and enhanced overall functional capacity.

Systematic reviews and meta-analyses included in this study confirmed that structured exercise interventions particularly resistance and weight-bearing training have a statistically significant, though modest, effect on preserving or improving BMD. Additionally, exercise was associated with improved quality of life, increased exercise adherence, and enhanced psychological well-being.

Overall, the evidence supports that regular, structured exercise interventions are effective, safe, and feasible non-pharmacological strategies for preventing osteoporosis and improving musculoskeletal health in perimenopausal women.

LIMITATIONS

Although the reviewed literature supports the benefits of strength, balance, and weight-bearing exercises in improving or maintaining bone mineral density among perimenopausal and postmenopausal women, several limitations were noted. Many studies had small sample sizes and short intervention periods, limiting the generalizability of results. The heterogeneity of exercise protocols, including differences in type, intensity, and duration, makes it difficult to identify the most effective program. Methodological issues such as lack of blinding, limited control groups, and inconsistent outcome measures reduce comparability

across studies. Few studies specifically focused on perimenopausal women, and variability in study design and quality limited the possibility of meta-analysis. Short follow-up durations also prevented evaluation of long-term effects on bone health.

CONCLUSION

The reviewed studies indicate that strength, balance, resistance, and weight-bearing exercises are effective non-pharmacological methods to maintain or slightly improve bone mineral density, muscle strength, balance, and quality of life in perimenopausal and postmenopausal women. Initiating exercise during the perimenopausal stage may help slow bone loss and reduce fracture risk. However, due to small sample sizes and variations in study design, further well-designed, large-scale, and long-term trials are needed to establish standardized exercise guidelines regarding optimal type, intensity, and duration for osteoporosis prevention in this population.

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