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The impact of resistance training on bone mineral density in postmenopausal women with osteopenia and osteoporosis: a review

Dampak Latihan Resistensi terhadap Densitas Mineral Tulang pada Wanita Pascamenopause dengan Osteopenia dan Osteoporosis: Telaah Literatur

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ABSTRACT

Background: *Osteopenia and osteoporosis are common in postmenopausal women and increase fracture risk. Resistance training may positively influence bone mineral density (BMD), but optimal and safe recommendations based on FITT principles and the mechanisms underlying its effects remain uncertain.*

Objective: *To identify effective and safe resistance training regimens for postmenopausal women with osteopenia and osteoporosis and to clarify the mechanisms underlying its effects on BMD.*

Methods: *A systematic search was conducted in PubMed, Scopus, ScienceDirect, Cochrane, and Europe PMC up to September 2, 2025. Inclusion criteria were randomized controlled trials and quasi-experimental studies evaluating resistance training effects on BMD in postmenopausal women with osteopenia or osteoporosis, published between 2015-2025, with full-texts in English. Critical appraisal used the CEBM Oxford Critical Appraisal Tools for Therapy Study.*

Results: *From 111 articles identified, seven met the inclusion criteria. Resistance training improved BMD through mechanical stimulation of bone formation, with site-specific and dose–response effects. Moderate to high-intensity training (60% to >80% 1-RM), targeting wrist, trunk, hip, and lower limbs, performed 2–3 times weekly for 30–60 minutes over at least six months, produced greater BMD improvements at the lumbar spine and femoral neck compared to lower intensity, with no adverse events reported. Low to moderate intensity remained beneficial, particularly with higher frequency or longer duration.*

Conclusion: *Moderate to high-intensity resistance training is safe and most effective to increase BMD in postmenopausal women with osteopenia and osteoporosis. Professional supervision, gradual load progression, and individualized adjustments are essential to optimize outcome and ensure safety.*

Keywords*: bone mineral density, osteopenia, osteoporosis, postmenopausal women, resistance training*

ABSTRAK

Latar Belakang: Osteopenia dan osteoporosis sering dialami wanita pascamenopause dan meningkatkan risiko fraktur. Latihan resistensi berperan positif terhadap densitas mineral tulang (BMD), namun rekomendasi yang efektif dan aman berdasarkan prinsip FITT serta mekanisme pengaruhnya terhadap BMD masih belum jelas.

Tujuan: Mengidentifikasi regimen latihan resistensi yang efektif dan aman untuk wanita pascamenopause dengan osteopenia dan osteoporosis serta mengklarifikasi mekanisme pengaruhnya terhadap BMD.

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Metode: Pencarian sistematis dilakukan pada PubMed, Scopus, ScienceDirect, Cochrane, dan Europe PMC hingga 2 September 2025. Kriteria inklusi meliputi RCT atau studi quasi-eksperimen yang menilai efek latihan resistensi pada BMD wanita pascamenopause dengan osteopenia atau osteoporosis, terbit 2015–2025, berbahasa Inggris, dan tersedia teks lengkap. Penilaian kritis menggunakan CEBM Oxford Critical Appraisal Tools for Therapy Study.
Hasil: Dari 111 artikel, tujuh studi memenuhi kriteria inklusi. Latihan resistensi terbukti meningkatkan BMD melalui pembebanan mekanik pada tulang dengan respons spesifik sesuai area dan dosis latihan. Latihan intensitas sedang–tinggi (60%–>80% 1-RM), melibatkan otot pergelangan tangan, batang tubuh, panggul, dan tungkai bawah, dilakukan 2–3 kali per minggu selama 30–60 menit minimal 6 bulan, menghasilkan peningkatan BMD lebih baik di tulang belakang dan leher femur dibanding intensitas rendah, tanpa efek samping. Latihan intensitas rendah–sedang tetap bermanfaat bila dilakukan dengan frekuensi atau durasi lebih tinggi.
Kesimpulan: Latihan resistensi intensitas sedang–tinggi aman dan paling efektif meningkatkan BMD pada wanita pascamenopause dengan osteopenia dan osteoporosis. Supervisi profesional, progresivitas beban, dan penyesuaian individual penting untuk mengoptimalkan hasil dan keamanan latihan.

Kata kunci: densitas mineral tulang, latihan resistensi, osteopenia, osteoporosis, wanita pascamenopause.

INTRODUCTION

Osteoporosis is a metabolic bone disease characterized by reduced bone mineral density (BMD; T score ≤ −2.5) due to loss of bone matrix and mineral components, accompanied by microarchitectural deterioration that increases fracture risk.[1,2] Osteopenia refers to a decrease in BMD below normal values but not reaching the diagnostic threshold for osteoporosis (T score ≤ −1). Often described as the "silent epidemic of the 21st century," osteoporosis is a chronic and progressive condition that typically remains asymptomatic until fractures occur.[3] Globally, approximately 200 million people are affected, with a higher prevalence in women (23.1%) than men (11.7%).[3-5] In the Asia-Pacific region, including Indonesia, prevalence increases markedly with age, particularly among postmenopausal women.[6-9]

Osteoporotic fractures impose a substantial clinical and economic burden and are included among diseases covered by the Indonesian national health insurance system (BPJS). The World Health Organization estimated that osteoporotic fractures accounted for 2.6 million disability-adjusted life years (DALYs) lost in six major European countries in 2016, with disability contributing more than premature mortality.[10-11] Physical inactivity is a key modifiable risk factor for osteopenia and osteoporosis and is frequently accompanied by sarcopenia in older adults.[12] In Indonesia, 33.5% of populations have insufficient physical activity,[13] which is associated with reduced muscle mass, strength, and BMD, as well as increased bone resorption.[14-15]

Regular exercise, particularly resistance training, has been shown to maintain or improve BMD through mechanical stimulation of osteogenesis and to reduce fracture risk.[16-17] However, recommendations regarding safe and effective resistance training parameters based on FITT principles remain inconsistent, and the mechanisms underlying its effects on BMD in postmenopausal women with osteopenia or osteoporosis are not fully understood. Therefore, this study aims to identify effective and safe resistance training regimens for postmenopausal women with osteopenia and osteoporosis and to clarify the mechanisms by which resistance training influences BMD.

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METHODS

Study Design

This study is a systematic literature review conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. It aims to identify effective and safe resistance training regimens for postmenopausal women with osteopenia and osteoporosis and to clarify the mechanisms underlying its effects on BMD, through identification and synthesis of relevant literature from available current evidence.

Search Strategy

A systematic literature search was conducted until September 2nd, 2025 in five online databases: PubMed, Scopus, ScienceDirect, Cochrane, and Europe PMC. The search strategy was formulated using the PICO framework (Table 1), with keywords related to "postmenopausal women with osteopenia and osteoporosis," "resistance training," and "bone mineral density", combined with Boolean operators (AND,OR) and MeSH terms to make sure that relevant studies were retrieved.

Table 1. **PICO Framework**

P	I	C	O
Postmenopausal women with osteopenia and osteoporosis	Resistance training	Other exercises (aerobic, impact training, flexibility training	Bone mineral density

Eligibility Criteria

The inclusion criteria were: (1) studies evaluating the effects of resistance training on bone mineral density in postmenopausal women with osteopenia or osteoporosis; (2) randomized controlled trials or quasi-experimental designs; (3) publication years 2015–2025; (4) English language; and (5) full-text available. Exclusion criteria included: (1) mixed-gender studies or women without osteopenia/osteoporosis; (2) participants with conditions affecting bone metabolism; (3) review articles, observational studies, or case reports; and (4) non-English articles.

Study Selection Process

Search results were exported into Mendeley Desktop/Reference Manager for duplicate removal. Titles and abstracts were screened according to PICO criteria and year of publication, followed by full-text evaluation based on inclusion and exclusion criteria. The complete study selection process is illustrated in the PRISMA flowchart (Figure 1), from the initial 111 records identified to the final seven studies included in this review.

Data Extraction

Data were extracted from each included study and presented in a structured table (Table 2). The extracted information included author name, publication year, study design, population characteristics, intervention details, control conditions, outcomes, and conclusions

Quality Assessment

Critical appraisal was performed using the CEBM Oxford Critical Appraisal Tool for Therapy Studies to assess validity, important results, and applicability of each included study (Table 3). The level of evidence of each study was determined using the Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.

Data Synthesis

Data from the seven included studies were synthesized narratively, as the heterogeneity in training protocols, populations, and outcome measures precluded meta-analysis. Findings were organized and interpreted based on resistance training parameters (frequency, intensity, duration, and type) and their effects on BMD at different skeletal sites.

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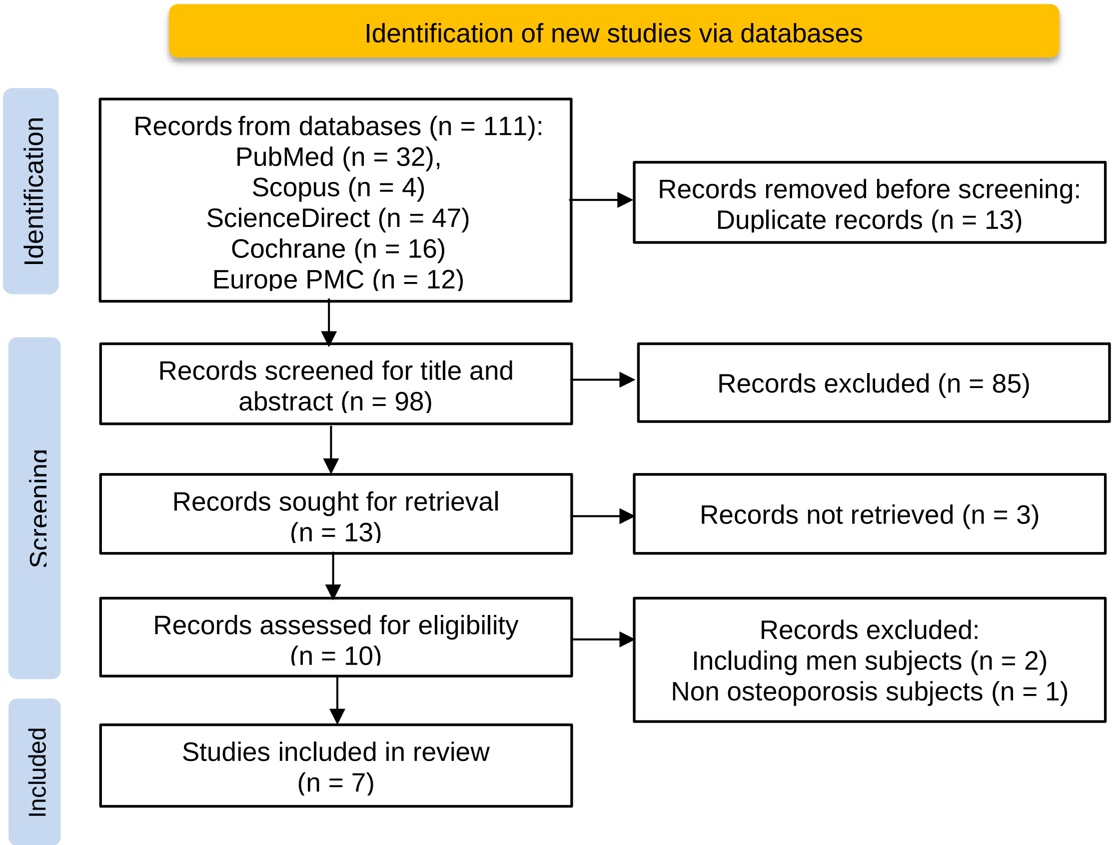

Figure 1. PRISMA Flowchart

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RESULTS

The study characteristic of selected articles is explained in Table 2 below:

Table 2. Study Characteristic of Selected Articles

Study	Population (P)	Intervention (I)	Control (C)	Outcome (O)	Conclusion
Borba-Pinheiro et al., 2016 (RCT, Brazil).[18]	N=52; ♀=52 Mean age: ≥55 years; purposive sampling with random allocation Postmenopausal women with osteopenia (n=32) and osteoporosis (n=20)	F: 3x/week (RT3), 2x/week (RT2) I: 60%-90% of 10RM = 45%-70% 1-RM (low-moderate) T: 13 months, 60 min/session T: Supervised RT: 3x10 leg press, knee extension, plantar flexion, squats, hip adduction, glutes, elbow flex/extension, shoulder adduction	No exercise intervention Both groups received Vit D3 5600 IU/d ± Alendronate 70 mg/w	BMD change in RT3 group: • ↑ LS-BMD +0.07% • ↑ FN-BMD +0.12% • ↑ Trochanter BMD +0.09% • ↑ Total femur BMD +0.12% • ↑ Total BMD +0.10% • p<0.05 (pre-post RT3) Total BMD change: RT3 +0.10%, RT2 +0.06%, Control: ~0; p<0.05	Low-moderate RT 3x/week showed greater BMD improvements than 2x/week; 2x/week was superior vs control.
Watson et al., 2018 (RCT, Australia).[19]	N=110; ♀=110 Mean age: 65±5 years; purposive sampling with random allocation Postmenopausal women with osteopenia (n=57) and osteoporosis (n=44)	F: 2x/week I: >85% 1-RM (high) T: 8 months, 30 min/session T: Supervised HiRIT (high-intensity resistance and impact training): 5x5 deadlift, squat, overhead press + jump chin up and drop landing	F: 2x/week I: <60% 1-RM (low) T: 8 months, 30 mins/session T: Home-based RT: 10-15 reps lunges, calf raises, forward raise, shrugs (bodyweight+3kg)	BMD change in intervention: • ↑ LS-BMD +2.9±2.8% vs –1.2±2.8%; p<0.001 • ↑ FN-BMD: +0.3±2.6% vs –1.9±2.6%; p=0.004 • ↑ FN-BMC: +7.7±21.3% vs –6.2±21.3%; p=0.028 • ↑ FN cortical thickness: +13.6±16.6% vs –6.3±16.6%; p=0.027	HiRIT safely improved BMD, BMC and cortical thickness vs control.
Holubiac et al., 2022 (Quasi-experimental, Romania).[20]	N=29; ♀=29 Mean age: 56.5±2.8 years; purposive sampling	F: 2x/week I: 50%-70% 1-RM (low-moderate) T: 6 months, 60 min/session	No exercise intervention Both groups received	↑ LS-BMD +1.82% (p=0.018); not significant vs control	Low-moderate RT improved BMD pre vs post intervention, but not significant vs control.

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Study	Population (P)	Intervention (I)	Control (C)	Outcome (O)	Conclusion
	Postmenopausal women with osteopenia and osteoporosis	T: Supervised RT: 2x12 hip abduction, machine dip, back extension, hip flex/ext, hip adduction, leg press, hamstring curls, knee extension, biceps curls, squats	Alfacalcidol 0.5 μg/day		
Eslamipour et al., 2023 (RCT, Iran).[21]	N=45; ♀=45 Mean age: ≥53 years; purposive sampling with random allocation Postmenopausal women with osteopenia	HiIRT: F: 3x/week I: 80% 1-RM (high) T: 6 months, 60 min/session T: Supervised RT: 3x8 reps squat, lunge, side lunge, deadlift, thigh abd/adduction, thigh extension, spine extension, knee extension, single leg press, bridge LIRT: F: 3x/week I: 40% 1-RM (low) T: 6 months, 60 min/session T: Supervised RT: 3x16 reps (same regiment as HIRT)	No exercise intervention	LS-BMD: • HIRT: 1.06 ± 0.03 • LIRT: 0.95 ± 0.03 • Control: 0.78 ± 0.03 • p<0.001 FN-BMD: • HIRT: 0.82 ± 0.02 • LIRT: 0.75 ± 0.02 • Control: 0.69 ± 0.02 • P 0.001 Inter-group comparisons showed significant differences (p<0.05)	High-intensity RT more effective to improve BMD and BMC than low-intensity RT or control
Lee et al., 2025 (RCT, South Korea).[22]	N=34; ♀=34 Mean age: ≥75 years: purposive sampling with random allocation	F: 2x/week I: Non-RM intensity, started with max 8-15 reps, progressed to 7-10 reps T: 6 months	Unsupervised home exercise 2-3x/weeks All group received nutritional support	No significant difference for LS, FN, TH-BMD between exercise and control group.	Progressive RT without precise 1-RM prescription did not lead to significant BMD improvements

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Study	Population (P)	Intervention (I)	Control (C)	Outcome (O)	Conclusion
	Postmenopausal women with osteosarcopenia.	T: Supervised RT: 1-2 sets x 7-10 reps (leg press, leg abductor, leg flexor, leg extension, chest press, row, dips, back extension)	(protein complex powder)		
Hettchen et al., 2021 (RCT, Germany).[23]	N=54; ♀=54 Mean age: ≥53 years; convenience sampling with random allocation Early postmenopausal women with osteopenia	F: 3x/week I: 80-85% 1-RM (high) T: 13 months, 60 min/session T: Supervised RT with impact and aerobic (calf raise, lunges, leg press, squats, deadlifts, back extension, lat pulldown, dips, bench press, jump, dance)	F: 1x/week I: Low intensity T: 13 months, 15-45 min/session T: walking, stability, stretching exercises Both groups received Vit D3 2500 IU/d and calcium 1000 mg/d	BMD change in intervention: • ↑ LS-BMD +0.002±0.018 mg/cm2 vs –0.009±0.018 mg/cm2; p=0.027	Long-term HiRIT significantly improved BMD at lumbar spine vs control.
Kistler-Fischbacher et al., 2021 (RCT, Australia).[24]	N=115; ♀=115 Mean age: 63.6±0.7 years; convenience sampling with random allocation Postmenopausal women with osteopenia on or off antiresoptive medication	F: 2x/week I: 80-85% 1-RM (high) T: 8 months, 40 min/session T: Supervised HiRIT (high-intensity resistance and impact training): 5x5 deadlift, squat, overhead press + progressive height jump drop	F: 2x/week I: low intensity T: 8 months, 40 min/session T: BB (Buff Bones movement): 6-10x stretching exercises and body weight RT	BMD change in intervention: • ↑ LS-BMD +1.9±0.3% in HiRIT vs 0.1±0.4% in BB; p<0.001 • ↑ FN-BMD +5.1±1.1% in HiRIT-med vs -0.1±0.4% in HiRIT; p<0.001 • ↑ TH-BMD +2.3±0.6% in HiRIT-med vs -0.5±0.3% in HiRIT; p<0.001	HiRIT improved BMD; combination with medication (HiRIT-med) resulted a significant FN-BMD and TH-BMD improvement

Note: N: Total number of subjects; ♀: women; RT: resistance training; FITT: frequency, intensity, time, type; 1-RM: 1-repetition maximum; HIRT: high intensity resistance training; LIRT: low intensity resistance training; LS-BMD: lumbar spine bone mineral density, FN-BMD: femoral neck bone mineral density, TH-BMD: total hip bone mineral density; BMC: bone mineral content; SGA: sub-group analysis.

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Selected studies were critically appraised using Critical Appraisal Tool for Therapy Studies from CEBM Oxford as explained in Table 3 below:

Table 3. Critical Appraisal for Therapy Studies

CEBM Appraisal Question	Borba et al., 2016.[18]	Watson et al., 2018.[19]	Holubiac et al., 2022.[20]	Eslamipour et al., 2023.[21]	Lee et al., 2025.[22]	Hettchen et al., 2021.[23]	Kistler-Fischbacher et al., 2021.[24]
Are the results of the trial valid? (Internal Validity)							
1a. Was the assignment of patients to treatments randomised?	Yes	Yes	No	Yes	Yes	Yes	Yes
1b. Were the groups similar at the start of the trial?	Yes, except BMI	Yes	Yes	Yes	Yes	Yes	Yes
2a. Aside from the allocated treatment, were groups treated equally?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2b. Were all patients who entered the trial accounted for and analysed in the groups to which they were randomised?	No (8 dropout patients are not analyzed)	No (1 dropout participant is not analyzed	Yes	Yes	Yes	Yes	Yes
3. Were measures objective or were patients and clinicians kept “blind” to treatment allocation?	Unclear (blinding not mentioned)	Yes (BMD assessor blinded)	Unclear (blinding not mentioned)	Yes (patients blinded)	Yes (BMD assessor blinded)	Yes (assessor and test assistant blinded)	Yes (investigator blinded)
What were the results? (Importance)							

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CEBM Appraisal Question	Borba et al., 2016.[18]	Watson et al., 2018.[19]	Holubiac et al., 2022.[20]	Eslamipour et al., 2023.[21]	Lee et al., 2025.[22]	Hettchen et al., 2021.[23]	Kistler-Fischbacher et al., 2021.[24]
How large was the treatment effect?	Total BMD change: RT3: 0.10%, RT2: 0.06%, Control: ~0; p<0.05	LS-BMD +2.9±2.8%, vs Control: –1.2±2.8%; p<0.001 FN-BMD +0.3±2.6% vs -1.9±2.6%; p=0.004	LS-BMD +1.82% (p=0.018); not significant vs control	Moderate BMD and BMC gains favoring HIRT (ES LS-BMD 0.525; ES FN-BMC 0.605)	No significant BMD improvement	LS-BMD +0.002±0.018 mg/cm2 vs control –0.009±0.018 mg/cm2; p=0.027	LS-BMD +1.9±0.3% in HiRIT vs 0.1±0.4% in control; p<0.001
How precise was the estimate of the treatment effect?	CI not stated	CI not stated	CI not stated	Narrow CI shows more precise results.	CI not stated	Narrow CI shows more precise results.	Narrow CI shows more precise results.
Will the results help me in caring for my patient? (External Validity/ Applicability)							
Is my patient so different to those in the study that the results cannot apply?	No	No	No	No	No	No	No
Is the treatment feasible in my setting?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Will the potential benefits of treatment outweight the potential harms of treatment for my patient?	Yes	Yes (no adverse events or fractures reported)	Yes	Yes	Yes	Yes	Yes
Level of Evidence	2	2	3	2	2	2	2

Note: ES: effect estimate; BMD: bone mineral density; BMC: bone mineral content; CI: confident interval.

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DISCUSSION

This literature review from current evidence supports that resistance training serves as a safe and effective non-pharmacological treatment to improve bone mineral density (BMD) in postmenopausal women with osteopenia and osteoporosis. Improvements were observed in lumbar spine and femoral neck, with gains more pronounced when training programs applied adequate intensity, frequency, and progression.[19]

The frequency and intensity of training seemed to be crucial to induce significant BMD improvements. Programs with moderate-to-high intensity (60%->80% 1-RM) and performed at least two to three times per week showed superior osteogenic effects compared to lower-intensity protocols.[18,19,21,23,24] A longer duration of consistent training was also important, with programs performed beyond six months showed more reliable benefits. [18,19] In contrast, lower-intensity training or programs without precise 1-RM prescription and progressive overload were less effective in improving BMD despite increases in muscle strength and mass. [20,22] This strongly reinforces that for resistance training to have a significant effect on BMD, it must be performed with specific program and progressive overloads, as the bone response to mechanical load is site-specific and dose-response effect.[25]

During resistance training, bones are exposed to various mechanical strains, such as compression, tension, torsion, and shear, that may occur at the same location.[26] These mechanical loads induce mechanotransduction, where osteocytes convert mechanical stimuli into biochemical signals, activating the Wnt/β-catenin pathway that promotes osteogenesis and reduces apoptosis by osteoblast.[25,26] Parathyroid hormone (PTH) released during exercise, further increase osteoblast activity by reducing sclerostin expression, while osteocytes secrete osteoprotegerin (OPG) to inhibit osteoclast differentiation, balancing bone formation with reduced resorption.[26] Bone adaptation to exercise is site-specific and dose-response relationship with greater formation in the area exposed to higher strain. Effective adaptive responses require sufficient load magnitude, speed, and frequency, with high-intensity training needs fewer repetitions to stimulate bone remodeling. To prevent osteocyte desensitization from repetitive loading, resistance training performed in shorter bouts with rest intervals is more effective than continuous loading with the same volume.[25]

According to available recent studies, there is no clear definition of FITT for resistance training in postmenopausal women with osteopenia and osteoporosis. Current literature review concluded that supervised moderate to high-intensity (60% up to >80% 1-RM) resistance training is the most optimal protocol to improve BMD in this population. This training should be performed 2-3 times per week, with sessions lasting between 30-60 minutes, for a minimum of six months duration. The exercises should specifically target muscle groups in the wrist, trunk, hips, and lower extremities using free weight or machine. On the other hand, lower-moderate intensity of resistance training can still be beneficial to improve BMD with higher training frequency and longer duration of training (>12 months). A minimum of six months training program is also crucial to be kept in

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mind, as though the microstructural changes in bone begin around the fourth month, they can only be reliably detected by BMD scans after six months.[19]

To ensure the safety and effectiveness of high-intensity resistance training, strict supervision with professionals and proper technique implementation is the basic rule to be performed. The gradual load progression, 5-10% every 2-4 weeks if the exercises become easier, should be carefully tailor made to each individual's capacity. Furthermore, monitoring individual response to exercise, such as using Rating of Perceived Exertion (RPE) or Repetitions in Reserve (RIR) is important to prevent overtraining. In conclusion, progressive resistance training, whether as a standalone therapy or combined with impact training, is a safe, effective, and evidence based non-pharmacological treatment option to increase BMD in postmenopausal women with osteopenia or osteoporosis.

This review has several strengths. The studies included are all recent and specifically involved postmenopausal women with osteopenia and osteoporosis, so the findings are truly relevant for this population and not mixed with other gender or healthy postmenopausal women. The use of the last ten years of evidence also gives a clearer picture of current resistance training approaches and its clinical impact on BMD. In addition, the articles were carefully selected using clear PICO criteria and critically appraised with the CEBM Oxford tool. However, there are limitations, especially the small number of eligible studies and the variation in training protocols, intensity, and duration, which makes it difficult to determine one exact FITT recommendation. Even so, this review supports the growing evidence that supervised, progressive, moderate-to-high intensity resistance training is safe and beneficial for improving bone health in postmenopausal women, and these findings may help guide clinicians and exercise professionals in prescribing appropriate resistance exercise programs for this group.

CONCLUSION

This study concluded that resistance training is safe and effective to increase BMD in postmenopausal women with osteopenia and osteoporosis, even with a history of osteoporotic fracture within ten years. Its effect on BMD is site-specific and follows a clear dose-response relationship with area exposed to greater load, showing greater bone formation as detected in greater BMD improvement. Based on this literature review, the FITT of resistance training for this population is 2-3 times per week of moderate to high (60% up to >80% 1-RM) resistance training involving muscle groups in the wrist, trunk, hips, and lower extremities using free weight or machine, for at least 6 months or beyond with 30-60 minutes for each session. The use of higher intensity is safe, with strict supervision by professionals, correct technique, and gradual increases in load (e.g., 5-10% per set every 2 to 4 weeks if the weight feels light) that are tailored to each individual's capacity.

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