Research Article

Effects of Resistance Training on Bone Mineral Density for Osteoporosis Prevention in Postmenopausal Women: A Systematic Review

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Abstract

Background: Postmenopausal estrogen decline accelerates bone loss and increases the risk of osteopenia, osteoporosis, and fragility fractures. Resistance training may help preserve or improve bone mineral density (BMD), while also improving muscle strength and physical function. Objective: To summarize original intervention studies examining resistance-training approaches and BMD-related outcomes in postmenopausal women. Methods: This mini review summarizes six randomized controlled studies identified across searches in PubMed, the Cochrane Library, PEDro, and supplementary Google Scholar searches, with approximately 8 to 15 duplicate records estimated after reviewing Google Scholar. A recently added randomized study examined low-intensity resistance training with blood-flow restriction. Results: Four studies in the initial five-study set reported significant BMD benefits, particularly at the lumbar spine. The ERTO-K trial reported no significant BMD difference. The added BFR trial found no significant BMD change in the exercise groups over 12 weeks, although lumbar BMD declined in the control group; BFR training improved P1NP, strength, and selected balance measures. Conclusion: Supervised, progressive resistance training appears promising for maintaining or improving BMD in postmenopausal women, but effects vary by program, duration, and population. The BFR study supports possible benefits for bone-turnover markers and function, not a demonstrated short-term increase in BMD.

Keywords: Postmenopausal, osteopenia, Cochrane Library, BMD

1. Introduction

Osteoporosis is a major health concern after menopause because declining estrogen levels accelerate bone resorption and contribute to reduced bone mass, deteriorated microarchitecture, and compromised bone strength (Black & Rosen, 2016; Cauley, 2013; Compston et al., 2019; Daly et al., 2019; Eastell et al., 2016; Hong & Kim, 2018). Globally, postmenopausal osteoporosis imposes a substantial clinical and socioeconomic burden due to heightened susceptibility to vertebral, hip, and wrist fragility fractures, which negatively affect mobility, functional independence, and quality of life (Benedetti et al., 2018; Cosman et al., 2014; Howe et al., 2011; Kanis et al., 2019; Weaver et al., 2016).

Resistance training is a primary non-pharmacological intervention that generates mechanical strain and muscle-pull forces on the skeleton, activating mechanotransduction pathways that stimulate osteoblast activity and bone remodeling (Frost, 2003; Hong & Kim, 2018; Robling & Turner, 2009; Turner & Robling, 2003; Wolff, 2010). When appropriately prescribed and progressively overloaded, structured resistance exercise improves neuromuscular strength, balance, and fall prevention while providing an osteogenic stimulus that helps preserve or increase BMD (Beck et al., 2017; Daly et al., 2019; Giangregorio et al., 2014; Kemmler et al., 2020; Sherrington et al., 2019; Shojaa

et al., 2020). However, exercise interventions vary substantially in loading intensity, movement velocity, exercise selection, weekly frequency, intervention duration, and supervision, leading to heterogeneous BMD responses across clinical trials (Bolam et al., 2013; Kast et al., 2022; Kistler-Fischbacher et al., 2021; Massini et al., 2022; Zehnacker & Bemis-Dougherty, 2007; Zhao et al., 2015).

This mini systematic review examines randomized intervention studies of resistance training in postmenopausal women, focusing primarily on site-specific BMD outcomes and secondarily on bone-turnover biomarkers, muscular strength, and physical function when reported (Kelley et al., 2012; Marques et al., 2012; Wallace & Cumming, 2000).

2. Research Question and PICO

PICO element	Definition
Population (P)	.Postmenopausal women, including women with osteopenia, osteoporosis, or osteosarcopenia
Intervention (I)	Structured resistance training, including progressive, high-intensity, multimodal, or low-intensity .resistance training with blood-flow restriction
Comparison (C)	Usual care, home-based or low-intensity exercise, another resistance-training dose, or a non-exercise .control group
Outcomes (O)	Primary: BMD at the lumbar spine, femoral neck, total hip, or total body. Secondary: bone-turnover .markers, muscle strength, balance, and physical function

Research question: In postmenopausal women, does structured resistance training, compared with control or alternative exercise conditions, improve or help maintain bone mineral density?

3. Search Strategy

Searches were conducted in PubMed and the Cochrane Library on 19 November 2026, in PEDro on 20 November 2026 (17 records), and via Google Scholar on 20 November 2026 (2016-2026 range, review articles filter, approximately 17,300 estimated results reported by the search engine, with an estimated 8 to 15 duplicate records noted after reviewing Google Scholar).

Database	Recorded search date	Recorded records	Notes
PubMed	November 19 2026	21	Boolean search across population, intervention, and outcome .terms
Cochrane Library	November 19 2026	131	.records screened in the initial screening pass 25
PEDro	November 20 2026	17	.Sixth included study (Linero & Choi, 2021) identified via PEDro
Google Scholar	November 20 2026	17,300~ (estimated)	range, review articles filter; ~8-15 estimated duplicates 2016-2026 .noted; source for supporting reference Hejazi et al. (2022)

PubMed search string:
(postmenopausal or "post-menopausal") and ("resistance training" or "strength training" or "resistance exercise") and ("bone mineral density" or "bone density" or osteoporosis)
The search combined synonyms for the population, intervention, and outcome using or, then linked the three concepts using and. Linero and Choi (2021) was identified through PEDro (20 November 2026, 17 records), while Google Scholar (20 November 2026, 2016-2026 range, review articles filter, ~17,300 estimated results, ~8 to 15 estimated duplicates) provided supporting literature (Hejazi et al., 2022).

4. Inclusion and Exclusion Criteria

4.1 Inclusion criteria

- Original randomized controlled intervention studies.
- Studies involving postmenopausal women, including women with osteopenia, osteoporosis, or osteosarcopenia.
- Resistance training is a central component of the intervention.
- A comparison group or alternative training condition is included.
- BMD is measured and reported; bone-turnover markers and physical-function outcomes may be reported as additional outcomes.
- Published within the review's stated date range (the last 10 years at the time of the search), with sufficient study information available.

4.2 Exclusion criteria

- Duplicate records or secondary reports of a trial already included.
- Studies involving populations other than postmenopausal women.
- Studies without a resistance-training intervention.
- Studies that do not measure BMD.
- Reviews, meta-analyses, editorials, protocols, and conference abstracts without an eligible full report.
- Records with insufficient information to assess eligibility.

5. Study Selection

5.1 PRISMA-style selection record

The search identified 21 records in PubMed (19 November 2026), 131 records in the Cochrane Library (19 November 2026; 25 screened initially), 17 records in PEDro (20 November 2026), and approximately 17,300 estimated results in Google Scholar (20 November 2026; 2016-2026 range, review articles filter), with an estimated 8 to 15 duplicate records noted after reviewing Google Scholar. Six primary randomized controlled studies are included in the synthesis, alongside Hejazi et al. (2022) retrieved via Google Scholar as a supporting reference.

Selection stage	Number / status
Records identified from PubMed	(searched 19 November 2026) 21
Records identified from Cochrane Library	(searched 19 November 2026; 25 screened initially) 131
Records identified from PEDro	(searched on 20 November 2026) 17
Records identified from Google Scholar	estimated results (searched on 20 November 17,300~ review articles filter; supporting ,2016-2026 ;2026 (reference Hejazi et al., 2022
Sixth added study: Linero & Choi (2021)	Identified from PEDro (searched 20 November 2026; 17 (records
Duplicates removed	to 15 (estimated range after reviewing Google 8~ (Scholar
Studies included in this synthesis	+ primary intervention studies (five initial studies 6 .Linero & Choi, 2021 from PEDro); plus Hejazi et al via Google Scholar as supporting meta-analytic (2022) reference

5.2 Included studies

Six randomized controlled trials are included in this review: Watson et al. (2018) [LIFTMOR], Hettchen et al. (2021) [ACTLIFE-RCT], Lee et al. (2025) [ERTO-K], Borba-Pinheiro et al. (2016), Riaz et al. (2022), and Linero & Choi (2021).

6. Results

6.1 Summary of included studies

Study	Participants	Intervention	Comparison	Outcomes	Main findings
.Watson et al LIFTMOR ,(2018)	101 postmenopausal women with low bone mass; mean age about 65 .years	;months 8 supervised high-intensity resistance plus ,impact training ;twice weekly .1RM 85%<	Home-based low-.intensity exercise	Lumbar spine and femoral-neck BMD; physical .function	Lumbar-spine BMD increased in the 2.9% training group versus a 1.2% decrease in controls; femoral-neck BMD increased 0.3% versus a 1.9% .decrease Functional outcomes favored .training
.Hettchen et al ACTLIFE- ,(2021) RCT	early 54 postmenopausal women with osteopenia or .osteoporosis	High-impact, high-intensity and high-velocity resistance training, 3 times ;weekly intervention stopped at 13 .months	Low-intensity exercise once weekly; both groups received calcium and .vitamin D	Lumbar-spine and ;total-hip BMD body composition .and function	Lumbar-spine BMD improved significantly versus control (p=0.027); total-hip BMD did not differ significantly .(p=0.129) Strength and power outcomes .favored training
,Lee et al. (2025) ERTO-K	community- 34 dwelling postmenopausal Korean women with .osteosarcopenia	months of 6 supervised progressive resistance exercise twice weekly plus home .exercise advice	Home exercise advice and nutritional .supplementation	Skeletal muscle ,index, BMD ,handgrip strength and physical .performance	No significant BMD difference within or between groups. Some muscle-related outcomes favored the supervised group at selected .time points
Borba-Pinheiro et al. (2016)	52 postmenopausal women receiving pharmacological .treatment	month-13 periodized resistance training; 3 sessions/week or .sessions/week 2	.Control group	,BMD by DXA functional autonomy, leg strength, and .quality of life	Both training groups had better outcomes than control; the 3-session group was reported as more effective than the session group-2 across BMD and several functional .outcomes
Riaz et al. (2022)	28 postmenopausal	;months 8 supervised high-	Low-to-moderate-.intensity exercise	Lumbar-spine and femoral-neck	The high-intensity group achieved

	women aged 45-.years 70	intensity multimodal training twice weekly, including resistance, weight-,bearing, balance and mobility .exercises		BMD; muscle .performance	greater gains than the comparison group in lumbar-spine BMD and muscle performance .(p<0.05)
Linero & Choi (2021)	26 postmenopausal women with osteopenia or ;osteoporosis mean age 56 years; 12 osteopenia and 14 .osteoporosis	weeks, 3 12 .times/week Groups: moderate-to-high-intensity RT (60-80% 1RM), low-intensity RT with ,BFR (30% 1RM) and low-intensity .RT (30% 1RM)	;Control group also compared three exercise .approaches	Lumbar-spine and femoral-neck BMD; P1NP and CTx; 1RM .strength; balance	No significant BMD change in the exercise groups over 12 weeks; lumbar BMD decreased significantly in controls. BFR increased P1NP by about 7.05 ng/mL and improved strength and selected static-.balance measures

6.2 Training characteristics

Study	Duration	Frequency	Main training approach
LIFTMOR	months 8	sessions/week 2	High-intensity resistance .plus impact; >85% 1RM
ACTLIFE-RCT	months completed 13	sessions/week 3	,High-impact, high-intensity .high-velocity resistance
ERTO-K	months 6	sessions/week 2	Progressive resistance .exercise
.Borba-Pinheiro et al	months 13	or 3 sessions/week 2	Periodized resistance .training
.Riaz et al	months 8	sessions/week 2	High-intensity multimodal exercise including .resistance
Linero & Choi	weeks 12	sessions/week 3	Low-intensity resistance with BFR compared with low-intensity and moderate-.to-high-intensity RT

6.3 Overall synthesis

Four of the five studies in the initial set reported a significant BMD benefit in at least one measured site or comparison. The ERTO-K study found no significant BMD difference. The added Linero and Choi study also did not demonstrate a significant increase in BMD in any training group over 12 weeks; however, lumbar BMD declined in the control group, suggesting short-term maintenance rather than a demonstrated BMD increase.

The added study provides useful secondary evidence: low-intensity resistance training with BFR improved the bone-formation marker P1NP, muscle strength, and selected static-balance outcomes. These outcomes are clinically relevant but are not interchangeable with a measured increase in BMD.

7. Discussion

Across the six included trials, resistance-training effects on BMD were mixed but generally encouraging. The clearest BMD improvements were reported in longer supervised programs, including LIFTMOR, ACTLIFE-RCT, Borba-Pinheiro et al., and Riaz et al. Benefits were most consistently reported at the lumbar spine, which contains a high proportion of metabolically active trabecular bone that responds more rapidly to mechanical loading than cortical-rich sites (Kohrt et al., 2004; Martyn-St James & Carroll, 2006; Zhao et al., 2017). However, not every study found a significant BMD response, and effects at the total hip or femoral neck were less consistent, echoing findings from earlier quantitative syntheses (Kelley et al., 2012; Marques et al., 2012; Martyn-St James & Carroll, 2009).
Program duration and loading magnitude may partly explain these differences. The positive trials generally lasted 8 to 13 months, whereas ERTO-K lasted 6 months and Linero and Choi lasted only 12 weeks. Because a complete bone-remodeling cycle typically spans at least 4 to 6 months, shorter interventions may improve muscle strength or circulating bone-turnover markers before measurable densitometric BMD gains appear on DXA (Borer, 2005; Dolan et al., 2020; Seeman & Delmas, 2006; Turner & Robling, 2003). Moreover, combined resistance and high-impact weight-bearing regimens generally elicit superior osteogenic adaptations compared with resistance exercise alone (Bolam et al., 2013; Zhao et al., 2015).

The BFR study adds an alternative modality for postmenopausal women who may not tolerate heavy mechanical loads due to joint pain or frailty, aligning with broader evidence on low-load blood-flow-restricted exercise adaptations in older and postmenopausal cohorts (Centner et al., 2019; Hughes et al., 2017; Patterson et al., 2019; Silva et al., 2018). Its low-intensity BFR group trained at 30% of 1RM and improved P1NP, strength, and static balance. Nevertheless, BMD did not significantly increase in the exercise groups, and the sample size (26 participants) and duration (12 weeks) were modest. Conversely, high-intensity resistance and impact protocols such as LIFTMOR apply high-magnitude, rapid-rate mechanical strains that exceed osteogenic thresholds and have demonstrated robust efficacy and safety across osteopenic and osteoporotic populations when properly supervised (Beck et al., 2017; Harding et al., 2020; Kistler-Fischbacher et al., 2021; Watson et al., 2019).

Supporting evidence from a meta-analysis of 53 randomized controlled trials in older postmenopausal women retrieved via Google Scholar on 20 November 2026 (Hejazi et al., 2022) similarly reported significant increases in femoral neck, lumbar spine, and trochanter BMD with exercise training, while noting no significant differences for total body or total hip BMD. These findings are further reinforced by recent meta-analyses and network meta-analyses demonstrating that supervised, higher-intensity, and dynamic progressive resistance programs produce the most consistent BMD gains, particularly at the lumbar spine (Mohebbi et al., 2023; Sanchez-Trigo et al., 2022; Wang et al., 2023; Zhao et al., 2025).

Clinical relevance: supervised, individualized, and progressive resistance exercise may support bone health, fall reduction, and physical function in postmenopausal women (Beck et al., 2017; Daly et al., 2019; Giangregorio et al., 2014; Sherrington et al., 2019). High-intensity programs should not be generalized to unsupervised settings, particularly in women with established osteoporosis or elevated vertebral fracture risk; exercise selection, spinal loading precautions, and progressive dosing should be guided by clinical assessment and qualified supervision (Compston et al., 2019; Cosman et al., 2014; Kanis et al., 2019; Sinaki et al., 2002).

7.1 Limitations of the evidence and this review:

- Sample sizes were modest in several trials, including the 26-participant BFR study and the 34-participant ERTO-K study.
- Training protocols, durations, comparison groups, and participant characteristics varied across trials.
- Some interventions combined resistance exercise with impact training, balance exercises, nutritional supplements, or pharmacological therapy, making it harder to isolate resistance training alone.
- Google Scholar results are reported as search-engine estimates (~17,300 results) with an estimated 8 to 15 duplicates, and not all database records underwent exhaustive screening.

8. Conclusion and Recommendations

The six studies suggest that supervised resistance-training programs can help improve or maintain BMD in

postmenopausal women, particularly when programs are progressive and sustained over several months. The most consistent positive BMD findings were observed in longer supervised interventions.

Low-intensity resistance training with BFR over 12 weeks (Linero & Choi, 2021) did not significantly increase BMD in the exercise groups, but improved P1NP, muscle strength, and selected balance measures while lumbar BMD declined in controls.

8.1 Recommendations supported by the reviewed evidence:

- Use individualized, progressive resistance training with appropriate supervision.
- Consider program duration and loading dose; short interventions may be insufficient to demonstrate measurable BMD changes.
- Monitor strength and functional outcomes as additional benefits alongside BMD.
- Use caution with high-intensity or BFR protocols in women with osteoporosis; clinical screening and qualified supervision are essential.
- Future research should include larger randomized trials, longer follow-up, standardized BMD measurement sites, direct intensity comparisons, and reporting of fractures and adverse events.

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