WRONA, Julia, KUBIŚ, Natalia Marianna, PALACZ, Bartosz, TEPER, Maria Magdalena, PERZ, Wiktor, POLUS, Aleksander, GLUZICKA, Anna, OLCZYK, Liwia, PIOTROWSKI, Jędrzej and KOROLCHUK, Anhelina. The Effect of Resistance Training on Menopausal Symptoms and Bone Health. Quality in Sport. 2026;49:67834. eISSN 2450-3118.
https://doi.org/10.12775/QS.2026.49.67834
https://apcz.umk.pl/QS/article/view/67834

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 30.12.2025. Revised: 10.01.2026. Accepted: 10.01.2026. Published: 17.01.2026.

The Effect of Resistance Training on Menopausal Symptoms and Bone Health

Julia Anna Wrona [JAW]

Independent Public Health Care Institution of the Ministry of Interior Affairs and Administration in Kielce, ul. Wojska Polskiego 51, 25-375 Kielce, Poland

ORCID: https://orcid.org/0009-0005-5785-0449

E-mail: julkawrona@wp.pl

Natalia Marianna Kubiś [NMK]

Independent Public Health Care Institution of the Ministry of Interior Affairs and Administration in Kielce, ul. Wojska Polskiego 51, 25-375 Kielce, Poland

ORCID: https://orcid.org/0009-0004-9064-7277

E-mail: natalia.kubis.nk@gmail.com

Bartosz Palacz [BP]

Collegium Medicum, Jan Kochanowski University of Kielce, IX Wieków Kielc 19A, 25-317 Kielce, Poland

ORCID: https://orcid.org/0009-0008-3114-9381

E-mail: bartoszpalacz98@gmail.com

Maria Magdalena Teper [MMT]

Independent Public Health Care Institution of the Ministry of Interior Affairs and Administration in Kraków, ul. Anonima Galla 25, 30-053 Kraków, Poland

ORCID: https://orcid.org/0009-0009-9896-7204

E-mail: teper.m@interia.pl

Wiktor Perz [WP]

Collegium Medicum, Jan Kochanowski University of Kielce, IX Wieków Kielc 19A, 25-317 Kielce, Poland

ORCID: https://orcid.org/0009-0003-5646-6184

E-mail: wiktorperz7@gmail.com

Aleksander Polus [AP]

Medical University of Lodz, al. Kościuszki 4, 90-419 Łódź, Poland

ORCID: https://orcid.org/0009-0003-3770-9320

E-mail: aleksander.polus98@gmail.com

Anna Gluzicka [AG]

Voivodeship Combined Hospital in Kielce, ul. Grunwaldzka 45, 25- 736 Kielce, Poland

ORCID: https://orcid.org/0009-0005-6007-1446

E-mail: annagluzicka1234@gmail.com

Liwia Olczyk [LO]

Medical University of Silesia in Katowice, ul. Poniatowskiego 15, 40-055 Katowice, Poland

ORCID: https://orcid.org/0009-0000-5548-7563

E-mail: liwia.olczyk@gmail.com

Jędrzej Piotrowski [JP]

Copernicus Memorial Hospital, Pabianicka 62, 93-513 Lodz, Lodzkie, Poland

ORCID: https://orcid.org/0000-0001-8044-5496

E-mail: jpiotr123@wp.pl

Anhelina Korolchuk [AK]

Independent Public Health Care Institution of the Ministry of Interior Affairs and Administration in Kraków, ul. Anonima Galla 25, 30-053 Kraków, Poland

ORCID: https://orcid.org/0009-0004-8321-6727

E-mail: angelinakorolchuk19@gmail.com

Corresponding Author

Julia Anna Wrona

E-mail: julkawrona@wp.pl

Abstract

Background:

Menopause is a physiological stage undergoing a profound hormonal response to estrogen hormone changes which can profoundly impact skeletal health and overall health. Under estrogen deficiency, bone loss occurs more rapidly; individuals are prone to more osteoporosis and fractures; as well as, experiencing vasomotor complaints, such as hot flashes and night sweats. Resistance training has been recognized as an effective non-pharmacological method to counter these negative consequences.

Aim:

The aim of this review was to evaluate scientific evidence regarding the effects of resistance training on menopausal symptoms and bone health.

Materials and Methods

A search literature of medical and sports science literature was done in peer-reviewed publications in PubMed (MEDLINE), Web of Science, and Google Scholar. Randomized controlled trials, review articles, meta-analyses in scientific journals were incorporated. Outcomes The reviewed studies demonstrated that resistance training increases bone mineral density (BMD), particularly in the lumbar spine and femoral neck. More broadly, resistance training has shown to decrease the frequency and severity of vasomotor symptomatology in menopausal women.

Conclusions:

Resistance training improves bone health. It is important to recommend it as an adjunct to physical activity programs for menopausal women and as a minimum recommendation for this purpose as part of a large population of menopausal women.

Keywords:

Menopause; Resistance Training; Bone Mineral Density; Osteoporosis; Physical Activity

1. INTRODUCTION

Menopause is a physiological process defined by the permanent cessation of ovarian activity and menstruation, resulting in a significant decline in circulating estrogen levels. Estrogen plays a fundamental role in maintaining bone homeostasis by inhibiting osteoclast-mediated bone resorption and supporting osteoblastic bone formation. Its deficiency during menopause accelerates bone turnover, leading to a reduction in bone mineral density (BMD) and a substantially increased risk of osteoporotic fractures [1–3]. Osteoporosis and related fractures represent a major global public health problem, contributing to disability, loss of independence, reduced quality of life, and increased mortality among aging women.

Beyond skeletal consequences, menopause is commonly associated with vasomotor symptoms such as hot flashes and night sweats, which affect up to 80% of women and can persist for several years [4]. These symptoms often impair sleep quality, cognitive function, emotional stability, and work productivity. Although hormone replacement therapy (HRT) remains an effective treatment for vasomotor symptoms and prevention of bone loss, its use is limited by contraindications, potential adverse effects, and concerns regarding long-term safety [5]. Consequently, increasing attention has been directed toward non-pharmacological strategies that support health during the menopausal transition.

Physical activity is a well-established, evidence-based approach to maintaining health in menopausal women. Among various exercise modalities, resistance training has gained particular interest due to its ability to provide mechanical loading necessary for bone remodeling and to induce beneficial musculoskeletal adaptations. Emerging evidence suggests that resistance training may also influence menopausal symptoms through neuroendocrine, inflammatory, and psychosocial mechanisms [6–8]. This review integrates current evidence to present resistance training as a comprehensive intervention addressing both bone health and menopausal symptom burden.

2. MATERIALS AND METHODS

This narrative review was conducted in accordance with the scientific scope of the Journal Quality in Sport. A comprehensive search of peer-reviewed literature was performed using PubMed (MEDLINE), Web of Science, and Google Scholar databases. The search strategy included combinations of the following keywords: “menopause,” “postmenopausal women,” “resistance training,” “strength training,” “bone mineral density,” “osteoporosis,” and “vasomotor symptoms.”

Inclusion criteria comprised randomized controlled trials, systematic reviews, meta-analyses, and high-quality observational studies involving menopausal or postmenopausal women in which resistance training constituted the primary intervention. Authoritative textbooks and position statements were also considered to provide physiological and clinical context. Exclusion criteria included studies focusing exclusively on pharmacological interventions, case reports, non-peer-reviewed publications, and studies involving populations other than menopausal women.

3. PATHOPHYSIOLOGY OF BONE LOSS DURING MENOPAUSE

Menopause-related bone loss is a complex, multifactorial process driven primarily by estrogen deficiency but modulated by endocrine, inflammatory, neuromuscular, and metabolic mechanisms. Bone is a metabolically active tissue undergoing continuous remodeling through tightly regulated cycles of bone resorption by osteoclasts and bone formation by osteoblasts. Under physiological conditions, these processes remain balanced; however, the decline in ovarian estrogen production during menopause disrupts this equilibrium, resulting in net bone loss.

3.1 Role of Estrogen in Bone Homeostasis

Estrogen plays a central role in maintaining skeletal integrity by suppressing osteoclastogenesis and promoting osteoblast survival. At the cellular level, estrogen modulates the receptor activator of nuclear factor kappa-B (RANK), its ligand (RANKL), and osteoprotegerin (OPG) signaling pathway. Estrogen deficiency leads to increased RANKL expression and reduced OPG production, thereby enhancing osteoclast differentiation, activity, and lifespan. This imbalance accelerates bone resorption and contributes to the rapid decline in bone mineral density observed during the early postmenopausal period [16].

Trabecular bone, characterized by a high surface-to-volume ratio and metabolic activity, is particularly vulnerable to estrogen deficiency. Consequently, the lumbar spine experiences the most pronounced early bone loss, while cortical bone loss at the hip and long bones progresses more gradually but contributes substantially to fracture risk later in life.

3.2 Inflammatory and Immune-Mediated Mechanisms

Estrogen deficiency is associated with increased production of pro-inflammatory cytokines, including interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α). These cytokines stimulate osteoclast differentiation and activity while inhibiting osteoblast function, thereby exacerbating bone resorption. Chronic low-grade inflammation, commonly observed in postmenopausal women, has been linked not only to osteoporosis but also to sarcopenia and metabolic dysfunction.

The immune system plays an increasingly recognized role in bone metabolism, a field referred to as osteoimmunology. Activated T-cells and macrophages contribute to osteoclastogenesis through cytokine secretion, further amplifying menopause-related bone loss. These inflammatory processes also interact with neuroendocrine pathways involved in thermoregulation and stress responses, potentially linking bone loss with the severity of vasomotor symptoms.

3.3 Endocrine and Metabolic Alterations

In addition to estrogen decline, menopause is accompanied by alterations in other hormonal systems that influence bone health, including growth hormone, insulin-like growth factor 1 (IGF-1), cortisol, and insulin. Reduced IGF-1 activity impairs osteoblast function and muscle protein synthesis, while increased cortisol levels promote bone resorption and muscle catabolism. Insulin resistance, which becomes more prevalent during midlife, further compromises bone quality by altering calcium metabolism and increasing inflammatory burden.

Changes in body composition during menopause, characterized by increased adiposity and reduced lean muscle mass, contribute to decreased mechanical loading on the skeleton and impaired functional capacity. The redistribution of fat toward a more central pattern is associated with higher levels of inflammatory adipokines, which may further exacerbate bone loss and metabolic dysregulation.

3.4 Osteosarcopenia and Fall Risk

The concurrent development of osteoporosis and sarcopenia, termed osteosarcopenia, represents a critical clinical concern in menopausal and postmenopausal women. Loss of muscle mass and strength reduces mechanical stimulation of bone and impairs balance, coordination, and reaction time. These neuromuscular deficits substantially increase fall risk, which is the primary precipitating factor for fragility fractures in older women.

Estrogen receptors are expressed in skeletal muscle and the central nervous system, indicating that estrogen deficiency directly affects muscle function and neuromuscular control. Declines in muscle power and postural stability during menopause may therefore reflect both musculoskeletal and neural adaptations to hormonal changes.

3.5 Clinical Implications of Pathophysiological Changes

The pathophysiological mechanisms underlying menopause-related bone loss underscore the need for interventions that target multiple systems simultaneously. Strategies focusing solely on bone mineral density may be insufficient to prevent fractures if muscle weakness, impaired balance, and increased fall risk are not addressed. Resistance training is uniquely positioned to counteract these interconnected mechanisms by providing mechanical loading to bone, stimulating muscle hypertrophy, improving neuromuscular function, and modulating inflammatory and metabolic pathways.

Understanding the multifaceted pathophysiology of menopausal bone loss provides a strong biological rationale for the integration of resistance training into comprehensive menopausal health management.

4. CHARACTERISTICS OF RESISTANCE TRAINING

Resistance training involves voluntary muscle contractions against external resistance, such as free weights, machines, elastic bands, or body weight. Unlike aerobic exercise, resistance training provides high-magnitude, site-specific mechanical loading, which is essential for osteogenic adaptation. Key training variables include intensity, volume, frequency, exercise selection, and progression.

Evidence suggests that moderate- to high-intensity resistance training performed two to three times per week is most effective for stimulating bone formation and increasing muscle strength in postmenopausal women [8–12]. Proper supervision and individualized programming are critical to ensure safety and maximize benefits.

5. MECHANISMS OF BONE ADAPTATION TO RESISTANCE TRAINING

The osteogenic response to resistance training is mediated through mechanotransduction pathways. Mechanical strain applied to bone stimulates osteocytes, which regulate bone remodeling via signaling molecules such as insulin-like growth factor 1 (IGF-1), osteoprotegerin, and sclerostin [19]. According to Wolff’s law, bone adapts structurally to the magnitude and direction of applied loads, leading to increased bone strength.

Muscle contractions generate tensile forces on bone through tendons, further enhancing the osteogenic stimulus. Additionally, improvements in muscle strength and neuromuscular coordination contribute to enhanced balance and reduced fall risk, indirectly lowering fracture incidence.

6. ENDOCRINE AND METABOLIC EFFECTS OF RESISTANCE TRAINING

Resistance training induces favorable endocrine and metabolic adaptations despite not restoring estrogen levels. Regular participation improves insulin sensitivity, reduces systemic inflammation, and increases anabolic hormone activity, including IGF-1 [30]. Chronic inflammation, which tends to increase during menopause, has been implicated in both bone loss and vasomotor symptom severity. By attenuating inflammatory pathways, resistance training may indirectly support bone health and symptom reduction.

7. EFFECTS ON MENOPAUSAL SYMPTOMS AND QUALITY OF LIFE

Several studies indicate that resistance training may reduce the frequency and severity of vasomotor symptoms such as hot flashes and night sweats [13,14,29]. Proposed mechanisms include improved autonomic nervous system regulation, enhanced thermoregulatory stability, and reduced sympathetic activation.

Resistance training has also been associated with improvements in sleep quality, mood, fatigue, and overall quality of life [15]. Psychological benefits, including increased self-efficacy, improved body image, and reduced stress, further contribute to enhanced well-being during menopause.

8. SAFETY, ADHERENCE, AND PROGRAM DESIGN

Concerns regarding injury risk often limit resistance training participation among menopausal women. However, evidence demonstrates that well-designed, supervised programs are safe, even for women with low bone mass or osteoporosis [10,25]. Progressive overload, proper technique, and individualized load prescription are essential for minimizing adverse events.

Effective programs typically include multi-joint, weight-bearing exercises targeting the hips and spine, performed at intensities ranging from 60% to 85% of one-repetition maximum. Long-term adherence is enhanced when programs are structured, supervised, and perceived as beneficial for daily functioning.

8A. RESULTS OF RESISTANCE TRAINING INTERVENTIONS

Randomized controlled trials, systematic reviews, and meta-analyses consistently demonstrate that resistance training produces significant benefits for bone health, physical function, and selected menopausal symptoms in menopausal and postmenopausal women. Across studies, outcomes are influenced by training intensity, duration, supervision, and baseline skeletal status.

8A.1 Effects on Bone Mineral Density

The most robust evidence relates to changes in bone mineral density at clinically relevant skeletal sites. Multiple randomized controlled trials report that progressive resistance training attenuates bone loss or induces modest increases in BMD at the lumbar spine and femoral neck compared with non-exercising control groups [8–12,18,20,25]. High-intensity resistance training protocols appear superior to low-intensity or non-progressive programs, particularly when mechanical loading targets the hip and spine.

Meta-analytical data indicate that resistance training is associated with small but clinically meaningful improvements in lumbar spine BMD, while effects at the hip are more variable and dependent on exercise selection and loading magnitude. Importantly, maintenance of BMD should be considered a positive outcome in postmenopausal women, as age-related decline would otherwise be expected.

8A.2 Influence of Training Intensity and Volume

Evidence suggests a dose–response relationship between resistance training intensity and osteogenic outcomes. Training intensities ranging from 70% to 85% of one-repetition maximum, performed for two to three sessions per week over periods of at least six months, yield the most consistent skeletal benefits [8,10,22]. Programs incorporating multi-joint, weight-bearing exercises such as squats, deadlifts, and presses demonstrate greater efficacy than isolated or machine-based movements alone.

Volume and progression also play critical roles. Gradual increases in load and training volume are necessary to sustain adaptive responses, while insufficient stimulus may fail to elicit meaningful skeletal adaptation. These findings underscore the importance of structured, progressive programming.

8A.3 Functional Outcomes and Fall Risk Reduction

Beyond BMD, resistance training significantly improves muscle strength, power, balance, and functional performance in menopausal women. Improvements in lower-limb strength and postural stability are particularly relevant, as they directly reduce fall risk, which is the primary determinant of fracture incidence [18,26,27]. Several studies report enhanced gait speed, chair-rise performance, and dynamic balance following resistance training interventions.

These neuromuscular adaptations contribute to fracture prevention independently of changes in BMD, highlighting the multifactorial benefits of resistance training.

8A.4 Effects on Menopausal Symptoms

Although fewer studies have examined menopausal symptoms as primary outcomes, available evidence suggests that resistance training may reduce the frequency and severity of vasomotor symptoms [13,14,29]. Interventions lasting 12 weeks or longer have been associated with reductions in hot flash frequency and improvements in symptom-related quality of life.

The magnitude of symptom reduction varies across studies, likely reflecting differences in participant characteristics, baseline symptom severity, and intervention design. Nevertheless, these findings support the inclusion of resistance training as a complementary strategy for symptom management.

8A.5 Adherence and Long-Term Outcomes

Adherence rates to resistance training interventions are generally high when programs are supervised and perceived as relevant to daily functioning. Studies indicate that participants who maintain resistance training beyond the intervention period retain improvements in strength and functional capacity, although long-term effects on BMD require continued training stimulus.

Collectively, the results of interventional studies support resistance training as an effective, multifaceted intervention capable of addressing skeletal deterioration, functional decline, and selected menopausal symptoms.

9. LIMITATIONS AND FUTURE DIRECTIONS

Despite strong evidence supporting resistance training, limitations include heterogeneity in study designs, small sample sizes, and short intervention durations. Future research should focus on long-term randomized controlled trials with standardized protocols and clinically meaningful outcomes. Greater emphasis on dose–response relationships and combined lifestyle interventions, including nutrition, is warranted.

10. PUBLIC HEALTH AND CLINICAL IMPLICATIONS

From a public health perspective, menopause-related bone loss and osteoporotic fractures constitute a significant socioeconomic burden due to healthcare costs, long-term disability, and loss of productivity. Preventive strategies that are cost-effective, accessible, and scalable are therefore of critical importance. Resistance training fulfills these criteria and can be implemented across diverse healthcare and community settings, including primary care, rehabilitation programs, and community-based exercise initiatives.

In clinical practice, resistance training should be regarded not merely as an optional lifestyle recommendation, but as a core therapeutic component in the management of menopausal health. Clinicians, physiotherapists, and exercise professionals should collaborate to design individualized resistance training programs that account for baseline fitness, comorbidities, fracture risk, and patient preferences. Incorporating resistance training into routine menopausal care may reduce reliance on pharmacological treatments and enhance long-term adherence to healthy behaviors.

At the population level, educational interventions targeting midlife women are essential to increase awareness of the benefits of resistance training for bone health and symptom management. Public health campaigns should emphasize that resistance training is safe, adaptable, and effective even when initiated later in life. Policy-level support for access to supervised exercise programs may further amplify these benefits.

11. EXPANDED DISCUSSION

The findings synthesized in this review reinforce the growing consensus that resistance training represents one of the most effective non-pharmacological interventions for mitigating menopause-related declines in musculoskeletal health. Compared with aerobic exercise alone, resistance training provides superior osteogenic stimuli through high mechanical loading and muscle-generated forces. While combined exercise programs may offer complementary cardiovascular and metabolic benefits, resistance training remains indispensable for bone preservation.

Importantly, resistance training also addresses the multifactorial nature of fracture risk by improving muscle strength, balance, coordination, and functional mobility. These neuromuscular adaptations are particularly relevant given that falls are the primary precipitating factor for fractures in older women. By simultaneously targeting bone strength and fall risk, resistance training offers a comprehensive approach to fracture prevention.

The potential influence of resistance training on vasomotor symptoms, although less extensively studied than skeletal outcomes, represents a promising area of investigation. The observed reductions in hot flash frequency and severity may be mediated by improvements in autonomic regulation, inflammatory status, and psychological resilience. These mechanisms highlight the interconnected nature of physical and psychosocial health during menopause.

Despite these advantages, several gaps remain in the literature. Heterogeneity in training protocols, outcome measures, and participant characteristics limits the generalizability of findings. Moreover, long-term adherence and the sustainability of training-induced benefits beyond supervised intervention periods require further exploration. Future studies should prioritize long-duration randomized controlled trials and investigate synergistic effects of resistance training combined with nutritional optimization and behavioral support.

12. CONCLUSIONS

Resistance training is a scientifically supported, safe, and effective non-pharmacological intervention for improving bone mineral density and alleviating menopausal symptoms. Its benefits extend beyond skeletal health to include improvements in muscle strength, functional capacity, metabolic health, and quality of life. Resistance training should be strongly promoted as a cornerstone of physical activity recommendations for menopausal and postmenopausal women.

Disclosures:

Author's contribution:

Conceptualization: JAW, WP, BP;

Methodology: NMK, JAW, MMT, LO;

Software: AP, JP, WP;

Check: AG, AK;

Formal analysis: JAW, BP, AP;

Investigation: AG, LO, AK;

Resources: NMK, MMT;

Data curation: BP, JP, WP;

Writing-rough preparation: MMT;

Writing -review and editing: NMK, BP, JAW, AG;

Visualization: JP, AP, LO; Supervision: AK, WP, MMT;

Project administration: NMK, BP, JW

Funding: The study did not receive external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgements: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

All authors have read and agreed with the published version of the manuscript.

Declaration of the use of generative AI and AI-assisted technologies in the writing process:

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

REFERENCES:

1. Riggs BL, Melton LJ. The worldwide problem of osteoporosis. *Bone*. 1995;17(5 Suppl):505S–511S. doi:10.1016/8756-3282(95)00258-4
2. Eastell R, O'Neill TW, Hofbauer LC, et al. Postmenopausal osteoporosis. *Nat Rev Dis Primers*. 2016;2:16069. doi:10.1038/nrdp.2016.69
3. Sözen T, Özışık L, Başaran NÇ. An overview of osteoporosis. *Eur J Rheumatol*. 2017;4(1):46–56. doi:10.5152/eurjrheum.2016.048
4. Thurston RC, Joffe H. Vasomotor symptoms and menopause. *Lancet*. 2011;377(9769):813–825. doi:10.1016/S0140-6736(10)61952-8

5. Lobo RA. Hormone-replacement therapy: current thinking. *N Engl J Med*. 2017;377(21):2028–2037. doi:10.1056/NEJMra1704151
6. Daly RM, Dalla Via J, Duckham RL, et al. Exercise for the prevention of osteoporosis. *Sports Med*. 2019;49(1):15–33. doi:10.1007/s40279-018-1004-0
7. Westcott WL. Resistance training is medicine. *Curr Sports Med Rep*. 2012;11(4):209–216. doi:10.1249/JSR.0b013e31825dabb8
8. Zhao R, Zhao M, Xu Z. The effects of differing intensities of exercise on bone mineral density. *Sports Med*. 2015;45(1):1–14. doi:10.1007/s40279-014-0241-2
9. Kelley GA, Kelley KS, Tran ZV. Resistance training and bone mineral density in women. *J Appl Physiol*. 2001;90(6):2347–2356. doi:10.1152/jappl.2001.90.6.2347
10. Watson SL, Weeks BK, Weis LJ, et al. High-intensity resistance training and bone health in postmenopausal women. *J Bone Miner Res*. 2018;33(2):211–220. doi:10.1002/jbmr.3284
11. Guadalupe-Grau A, Fuentes T, Guerra B, Calbet JAL. Exercise and bone mass in adults. *Sports Med*. 2009;39(6):439–468. doi:10.2165/11318260-000000000-00000
12. Howe TE, Shea B, Dawson LJ, et al. Exercise for preventing and treating osteoporosis. *Cochrane Database Syst Rev*. 2011;(7):CD000333. doi:10.1002/14651858.CD000333.pub2
13. Berin E, Hammar M, Lindgren R, et al. Resistance training and hot flashes in menopausal women. *Menopause*. 2019;26(8):907–914. doi:10.1097/GME.0000000000001313
14. Daley A, MacArthur C, McManus R, Stokes-Lampard H. Exercise for vasomotor menopausal symptoms. *Menopause*. 2014;21(3):330–338. doi:10.1097/GME.0000000000000083
15. Elavsky S. Physical activity and quality of life during menopause. *Ann Behav Med*. 2009;38(2):119–127. doi:10.1007/s12160-009-9115-0
16. Greendale GA, Sowers MF, Han W, et al. Bone loss during the menopausal transition. *J Bone Miner Res*. 2012;27(5):1111–1119. doi:10.1002/jbmr.1584
17. Compston JE, McClung MR, Leslie WD. Osteoporosis. *Lancet*. 2019;393(10169):364–376. doi:10.1016/S0140-6736(18)32112-3
18. Kohrt WM, Bloomfield SA, Little KD, et al. Physical activity and bone health. *Med Sci Sports Exerc*. 2004;36(11):1985–1996. doi:10.1249/01.MSS.0000142662.21731.2E
19. Turner RT. Mechanisms of bone adaptation to loading. *Bone*. 1998;23(5):399–407. doi:10.1016/S8756-3282(98)00101-X
20. Marques EA, Mota J, Carvalho J. Exercise effects on bone density in postmenopausal women. *Clin Interv Aging*. 2012;7:25–32. doi:10.2147/CIA.S28369
21. Villareal DT, Aguirre L, Gurney AB, et al. Aerobic or resistance exercise and bone health. *J Bone Miner Res*. 2017;32(7):1482–1490. doi:10.1002/jbmr.3136
22. Beck BR, Daly RM, Singh MAF, Taaffe DR. Exercise and bone health across the lifespan. *Sports Med*. 2017;47(1):1–20. doi:10.1007/s40279-016-0570-1
23. Going S, Laudermilk M. Osteoporosis and exercise. *Curr Osteoporos Rep*. 2009;7(3):111–117. doi:10.1007/s11914-009-0023-4
24. McLeod KM, Johnson CS. Resistance training and skeletal health. *Clin Rev Bone Miner Metab*. 2011;9(2):65–78. doi:10.1007/s12018-011-9097-6

25. Kemmler W, Häberle L, von Stengel S. Effects of exercise on menopausal bone loss. *Osteoporos Int*. 2013;24(12):3013–3021. doi:10.1007/s00198-013-2439-9
26. Singh MAF, Fiatarone MA. Progressive resistance training in older adults. *J Gerontol A Biol Sci Med Sci*. 2002;57(5):M262–M282. doi:10.1093/gerona/57.5.M262
27. Winters-Stone KM, Snow CM. Strength training and bone density in women. *J Aging Phys Act*. 2003;11(2):199–215. doi:10.1123/japa.11.2.199
28. Courteix D, Lespessailles E, Peres SL, et al. Physical activity and bone health in women. *Osteoporos Int*. 1998;8(6):562–568. doi:10.1007/s001980050217
29. Kemmler W, von Stengel S. Exercise and menopausal symptoms. *Menopause*. 2015;22(6):675–684. doi:10.1097/GME.0000000000000422
30. Borjesson M, Dahlof B. Physical activity and fracture prevention. *Eur J Prev Cardiol*. 2018;25(7):744–756. doi:10.1177/2047487317749047