2024, Retos, 52, 647-656

Prescription of physical exercise for postmenopausal women with osteopenia or osteoporosis based on a systematic review of randomized clinical trials

Prescripción de ejercicio físico para mujeres posmenopáusicas con osteopenia u osteoporosis basada en una revisión sistemática de ensayos clínicos aleatorizados

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Abstract. Background: To analyze the methods of physical exercises that are efficient in improving the levels of bone mineral density (BMD)/T-score of postmenopausal women and to elaborate an exercise prescription model for women with low BMD and/or osteoporosis. Methods: We searched MEDLINE (via PubMed), ScienceDirect, Web of Science, and Scopus databases for randomized controlled trials (RCTs) that analyzed physical exercise methods that show efficiency for BMD in postmenopausal women with low BMD and/or osteoporosis. Results: Nine RCTs were selected. The most efficient exercises to improve the BMD were resistance, multicomponent, aerobic, and vibration training. The least efficient method was water training (hydrogymnastics). Conclusion: Exercises in normal gravity had the best effects on BMD compared to those performed in reduced gravity. Adequate training frequency should be 3 times/week or more. Intervention time should be around 12 months or more. The training intensity should be between moderate and high. Moreover, the exercise prescription proposal relates the T-score classification, level of physical activity, and use of medication, in addition to anamnesis, which considers the patients' previous fractures and risk factors for fractures.
Keywords: bone mineral density, osteoporosis, physical activity, older

Resumen. Antecedentes: Analizar los métodos de ejercicios físicos que son eficientes para mejorar los niveles de densidad mineral ósea (DMO)/T-score de mujeres posmenopáusicas y elaborar un modelo de prescripción de ejercicio para mujeres con baja DMO y/u osteoporosis. Métodos: Se realizaron búsquedas en las bases de datos MEDLINE (a través de PubMed), ScienceDirect, Web of Science y Scopus de ensayos controlados aleatorios (ECA) que analizaron métodos de ejercicio físico que muestran eficiencia para la DMO en mujeres posmenopáusicas con baja DMO y/u osteoporosis. Resultados: Se seleccionaron nueve ECA. Los ejercicios más eficientes para mejorar la DMO fueron el entrenamiento de resistencia, multicomponente, aeróbico y vibratorio. El método menos eficaz fue el entrenamiento acuático (hidrogimnasia). Conclusión: Los ejercicios en gravedad normal tuvieron los mejores efectos sobre la DMO en comparación con los realizados en gravedad reducida. La frecuencia de entrenamiento adecuada debe ser de 3 veces por semana o más. El tiempo de intervención debe ser de unos 12 meses o más. La intensidad del entrenamiento debe estar entre moderada y alta. Además, la propuesta de prescripción de ejercicio relaciona la clasificación T-score, el nivel de actividad física y el uso de medicación, además de la anamnesis, que considera las fracturas previas de los pacientes y los factores de riesgo de fracturas.
Palabras clave: Ejercicio, densidad ósea, osteoporosis, posmenopausia, envejecimiento.

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Introduction

Physical exercises are a set of musculoskeletal activities methodologically organized for a predetermined objective. Among the types of exercises are resistance training, multicomponent, aerobic, interval training, hydrogymnastics, and Tai Chi Chuan. These exercises are well studied and are shown to be a mechanism to help, to a greater or lesser extent, for the protection, prevention, and treatment of low bone mineral density (BMD) at all ages, especially in older people (Linhares et al., 2022; Razzak, Khan, & Farooqui, 2019; Souza, Almeida, Vale, Bello, & Borba Pinheiro, 2021).

In the elderly, the most serious cases of low BMD are directly associated with the loss of bone mass (osteoporosis), especially when there are fractures, which hinder the mobility of people with this problem. Furthermore, there is an increase in fear of falling, as muscle weakness, lack of balance, and low levels of flexibility increase the risk of falls and, consequently, fractures, a problem that deserves attention with greater concern in this age group (Swain, 2014; Tanaka, 2009).

In this sense, studies show that different exercise methods can be used for different treatments between them of cardiometabolic and osteomyoarticular diseases in elderly women, including the treatment of osteopenia or osteoporosis. This stems from the ability of exercises to promote an increase in muscle mass and bone metabolism, in which both are positively correlated (ACSM, 1998, 2021). These physiological changes stimulate osteoblastic activity, which helps build bone mass in a natural process without requiring medications (Linhares et al., 2022; Razzak et al., 2019; Souza et al., 2021).

However, in older women, studies show that exercises associated with medication contribute to potentiating BMD. Drug treatment specifically stimulates bone mass. Exercises, in addition to BMD, also help muscle strength, balance, flexibility, and agility, among other physical qualities and motor skills that are important to improve autonomy with functional independence. It is worth highlighting the importance of flexibility training in reducing the risk of falls, especially in the elderly. (Laiz et al., 2017; Linhares et al., 2022; Tanaka, 2009).

It should be noted that postmenopausal women diagnosed with low BMD will be prescribed medication for bone metabolism such as vitamin D, calcium supplements, and bisphosphonates. Thus, drugs should already be part of the treatment of postmenopausal women. Given this, women are more impacted by the aging process compared to men, which has a direct influence on menopause (Borba-Pinheiro et al., 2016; Tanaka, 2009). Hence, physical exercises should also be part of the strategic procedures for protecting the musculoskeletal structure of postmenopausal women, since their benefits are auxiliary and go beyond BMD (Laiz et al., 2017).

The prescription of physical exercises for people with low BMD is already highlighted in the scientific literature. The American College of Sports Medicine (ACSM) recommends, at least a weekly training frequency of three times, with intensities ranging from moderate to high, with a time of approximately 60 minutes per session, preferably with exercises that favor greater mechanical impact on bone structures, such as resistance training (ACSM, 1998, 2021; Borba-Pinheiro et al., 2016; Chodzko-Zajko et al., 2009; Swain, 2014). However, these recommendations do not establish which exercises may be more specifically recommended in the early or advanced stages of osteoporosis (ACSM, 1998, 2021; Cordeiro et al., 2023; Linhares et al., 2023; Swain, 2014).

In this perspective, BMD is a dynamic process that requires several components that stimulate bone formation and degradation. Therefore, they involve, among other factors, genetics, hormones, diet, and types of exercises that are important parts of this metabolic process. BMD is measured by Dual-energy X-ray absorptiometry (DXA), serving for the diagnosis, as well as for the control of osteopenia/osteoporosis and other risk factors for the disease (Krueger, Vallarta-Ast, Checovich, Gemar, & Binkley, 2012).

The BMD measurement, which is associated with the T-score, is widely used for disease classification and drug prescription. For this reason, it should also represent an important instrument for the prescription of physical exercises. Thus, we established the following research problem: which methods of physical exercise are most appropriate in the prescription to improve the BMD/T-score of postmenopausal women with osteopenia or osteoporosis?

Given these considerations, the aim of the present study was twofold: to analyze the physical exercise methods that are efficient in improving the BMD/T-score levels of postmenopausal women, and to elaborate an exercise prescription model for women with low BMD and/or osteoporosis.

Methods

This systematic review of randomized clinical trials (RCTs) was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria [10] and was approved by the International Prospective Register of Systematic Reviews (PROSPERO) under number CRD CRD42023391745.

Search strategies

Two independent reviewers performed an electronic search, from March 1st to 5th, 2023, without language or time filters, in the MEDLINE (via PubMed), Scopus, ScienceDirect, and Web of Science databases. Disagreements were solved by a third reviewer. The Medical Subject Headings (MeSH) and Health Sciences Descriptors (DeCS) metadata systems were used to identify the descriptors to be used in the present study. The Boolean operator AND was used between the descriptors and OR between the synonyms.

The descriptors were grouped into a single Boolean phrase as follows: **PubMed:** Search: ("exercise"[MeSH Terms] OR "exercise"[All Fields] OR ("physical"[All Fields] AND "exercise"[All Fields]) OR "physical exercise"[All Fields]) AND ("level"[All Fields] OR "levels"[All Fields]) AND ("bone diseases, metabolic"[MeSH Terms] OR ("bone"[All Fields] AND "diseases"[All Fields] AND "metabolic"[All Fields]) OR "metabolic bone diseases"[All Fields] OR "osteopenia"[All Fields] OR "osteopenias"[All Fields]) AND ("osteoporosis"[MeSH Terms] OR "osteoporosis"[All Fields] OR "osteoporoses"[All Fields] OR "osteoporosis, postmenopausal"[MeSH Terms] OR ("osteoporosis"[All Fields] AND "postmenopausal"[All Fields]) OR "postmenopausal osteoporosis"[All Fields]) AND ("postmenopausal"[All Fields] OR "postmenopausally"[All Fields] OR "postmenopausals"[All Fields] OR "postmenopause"[MeSH Terms] OR "postmenopause"[All Fields] OR "postmenopausic"[All Fields]); **Scopus:** TITLE-ABS-KEY ("physical exercise" AND "osteopenia" AND "osteoporosis" AND "menopause"); **ScienceDirect:** physical exercise and levels of osteopenia and osteoporosis and postmenopause; **Web of Science**: (((ALL=(physical exercise)) AND ALL=(osteopenia)) AND ALL=(osteoporosis)) AND ALL=(postmenopause).

Eligibility criteria

Inclusion criteria followed the Population, Intervention, Comparison, Outcome, Study Design (PICOS) strategy (Methley, Campbell, Chew-Graham, McNally, & Cheraghi-Sohi, 2014), as follows: Population: postmenopausal and/ or older women with low BMD and/or osteoporosis; Intervention: physical exercises; Comparison: other interventions, medicines, and/or control group (CG); Outcome: BMD, biomarkers (e.g., serum calcium; serum phosphorus; serum alkaline phosphatase) and physical fitness; Study design: RCTs. Studies with different populations or variables, with other interventions, and articles published in congresses, systematic review articles, and meta-analyses were excluded.

Assessment of risk of bias and methodological quality in the studies

The Cochrane Collaboration tool, available at:

2024, Retos, 52, 647-656

<https://training.cochrane.org/handbook/>, was used to assess the risk of bias in the studies included in this systematic review. The domains that analyze the risk of bias in the RCTs followed the sequence: 1) random sequence generation; 2) allocation concealment; 3) blinding of evaluators and participants; 4) blinding of outcome evaluators; 5) incomplete outcomes; 6) reports of selective results; 7) report on other sources of bias. Each domain has the risk of bias classified as "high", "unclear", or "low". The final score is assigned with the highest classification among the domains evaluated in each study (Higgins et al., 2011).

The methodological quality of the studies was evaluated through the Tool for the assessment of Study quality and reporting in EXercise (TESTEX), a study quality and reporting assessment tool, constructed specifically for utilization in exercise training studies. The TESTEX scale uses 12 criteria. Some criteria may have more than one possible point, for a maximum score of 15 points. The first 5 points concern study quality, and the other 10 regard reporting. The scale is composed of the following criteria: 1) eligibility criteria specified; 2) randomization specified; 3) allocation concealment; 4) groups similar at baseline; 5) blinding of assessor (for at least one key outcome); 6) outcome measures assessed in 85% of patients (total possible: 3 points); 7) intention-to-treat analysis; 8) between-group statistical comparisons reported (total possible: 2 points); 9) point measures and measures of variability for all reported outcome measures; 10) activity monitoring in control groups; 11) relative exercise intensity remained constant; 12) exercise volume and energy expenditure. Each criterion receives 1 point and no point is attributed to the absence of this criterion (Smart et al., 2015).

Data extraction

To extract data from the included articles, an electronic spreadsheet was used, according to the eligibility criteria, in duplicate and independently. Thus, the data extracted from the articles were evaluated by two independent evaluators. A third evaluator was responsible for possible divergences and decisions for a consensus. The extracted variables were: authors, year of publication, country, characteristics of the study population (age, sex, sample size, height, body mass, and body mass index [BMI]), and intervention data, including general and specific exercises, duration of the intervention (weeks), training volume (duration of the training session, in minutes, and frequency, in times per week), evaluation, and results for physical exercises applied to postmenopausal women with low BMD or osteoporosis.

Results

A total of 413 publications were found by searching the databases (MEDLINE via PubMed = 244; Scopus = 13; ScienceDirect = 151; Web of Science = 5). After screening using selection criteria, 12 RCTs were included in this systematic review (Figure 1).

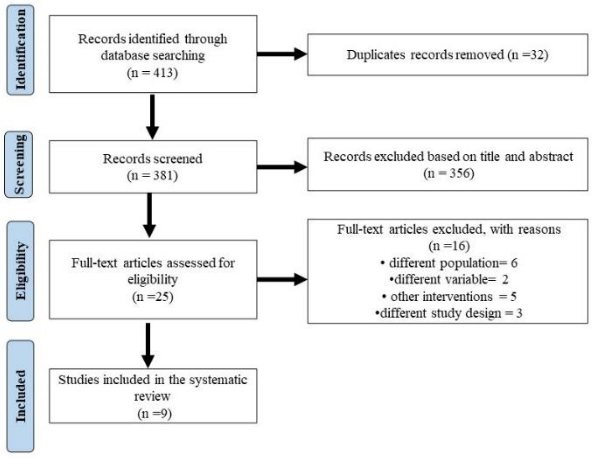

Figure 1. PRISMA Flow Diagram

Figure 2 shows the risk of bias in the included studies evaluated using the Cochrane Collaboration tool. All 12 studies included in this systematic review were classified as having a high risk of bias. The most common domains with bias were blinding of outcome assessment and blinding of participants and personnel, with percentages of 100% and 50%, respectively. It is noteworthy that a high-risk result among the seven domains used by the tool classifies the study as a high risk of bias. Therefore, the other domains of the tool should be carefully observed individually.

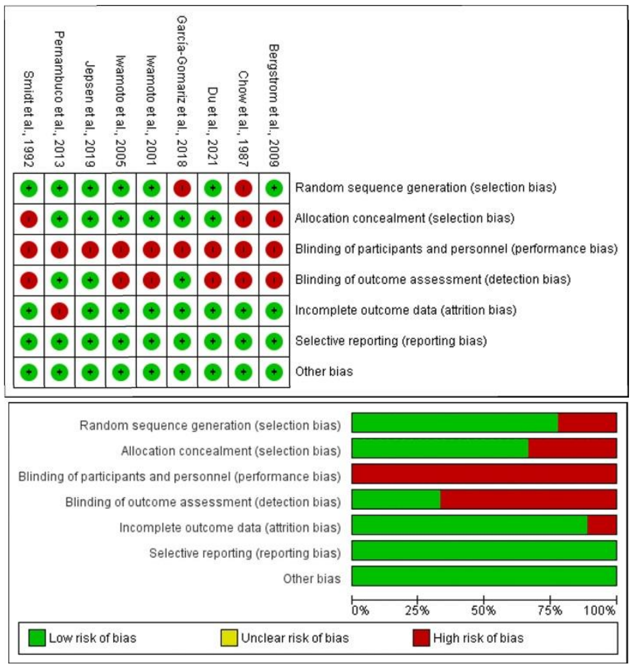

Figure 2. Cochrane Risk of Bias

Table 1 presents the methodological quality of studies by TESTEX. According to the TESTEX scale (0 to 15 points), the most sensitive points in the studies were blinding of evaluators and/or study participants, adverse events, punctual measures, and variability measures for all outcome measures, and the exercise volume and energy expenditure to be reported.

Table 1.
Analysis of the methodological quality of the included studies (TESTEX Scale).

Studies	1	2	3	4	5	Partial (0 to 5)	6a	6b	6c	7	8a	8b	9	10	11	12	Partial (0 to 10)	Total (0 to 15)
(Bergström et al., 2009)	1	1	0	1	0	3	1	1	1	1	1	1	0	1	1	0	8	11
(Chow et al., 1987)	1	1	0	1	0	3	1	0	1	1	1	1	0	0	1	0	6	9
(Du et al., 2021)	1	1	1	1	0	4	1	0	1	1	1	1	0	1	0	0	6	10
(García-Gomáriz et al., 2018)	1	1	1	1	1	5	1	1	1	1	1	1	1	0	1	0	8	13
(Iwamoto et al., 2001)	1	1	1	1	0	4	1	0	0	1	1	1	0	1	1	1	7	11
(Iwamoto et al., 2005)	1	1	1	1	0	4	1	0	0	1	1	1	0	1	1	1	7	11
(Jepsen et al., 2019)	1	1	1	1	1	5	1	0	1	1	1	1	0	1	1	0	7	12
(Pernambuco et al., 2013)	1	1	1	1	0	4	1	1	1	1	1	1	1	1	1	0	9	13
(Smidt et al., 1992)	1	1	0	1	0	3	1	0	0	1	1	1	0	0	1	0	5	8

1 = eligibility criteria specified; 2 = randomization specified; 3 = allocation concealment; 4 = groups similar at baseline; 5 = blinding of assessor (for at least one key outcome); 6 = outcome measures assessed in 85% of patients (6a = 1 point if more than 85% completed; 6b = 1 point if adverse events were reported; 6c = if exercise attendance was reported); 7 = intention-to-treat analysis; 8 = between-group statistical comparisons reported (8a = 1 point if between-group comparisons are reported for the primary outcome variable of interest; 8b = 1 point if statistical comparisons between groups are reported for at least one secondary measure); 9 = point measures and measures of variability for all reported outcome measures; 10 = activity monitoring in control groups; 11 = relative exercise intensity remained constant; 12 = exercise volume and energy expenditure were reported.

Table 2 presents the characteristics of the studies by author, year, country of the study, number of participants and groups, and the values (mean ± standard deviation) of age, height, body mass, and BMI. The year of publication of the studies varied between 1987 and 2021. Regarding the country of origin, the studies were conducted in the United States of America (USA) (1 study), Japan (2 studies), Denmark (1 study), Brazil (1 study), Sweden (1 study), Canada (1 study), China (1 study), and Spain (1 study). The mean age of the experimental group (EG) and CG was 61 and 64 years, respectively. The average number of participants in the EG was 22 and, in the CG, 25 participants. Only female participants were included. The total number of participants was 471 (241 in the EG and 227 in the CG).

Table 3 reports the assessment instruments, data on the assessment variables, and the outcome of the included studies. Among the types of physical exercises evidenced in this systematic review, aerobic training, and resistance training appeared more frequently (12 studies). The duration of the intervention varied between 12 and 96 weeks with a mean of 51 weeks. The training volume had an average of 47 minutes per session with an average frequency of 3 times a week. The variables BMD, biomarkers, and physical fitness were investigated.

The results presented in this research showed that the different types of exercises presented diverse results for BMD and biochemical markers of bone metabolism in postmenopausal women (Table 3). However, physical fitness variables, such as strength, balance, and functional autonomy, showed positive statistical effects in most studies, regardless of the types of exercises. Given these findings, a proposal was made for the prescription of physical exercises (Figure 3) for elderly women with low BMD and osteoporosis, based on the DXA assessment, which provides a T-Score/BMD classification: normal BMD, osteopenia, osteoporosis, and severe osteoporosis (with fractures) (Radominski et al., 2017).

Table 2.
Characteristics of studies by author/year, country of origin, number of participants, and studied groups.

Author	Year	Country	Sample (n)	Age (years)	BMI (kg/m^2)	T-score (g/cm^3)
(Bergström et al., 2009)	2009	Sweden	Postmenopausal with osteoporosis EG: 48 CG: 44	EG: 58.8 ± 4.2 CG: 59.4 ± 3.6	EG: 24.4 ± 2.5 CG: 25.0 ± 2.2	NI
(Chow et al., 1987)	1987	Canada	Postmenopausal with osteoporosis EG1: 17 EG2: 16 CG: 15	EG1: 56–69 ± 0.83 EG2: 55–77 ± 1.02 CG: 56–33 ± 0.85	NI	NI
(Du et al., 2021)	2021	China	Postmenopausal EG: 33 CG: 30	EG: 59.8 CG: 59.7	EG:26.4 CG:25.8	EG: Whole body: - 0.13 ± 0.97; Femoral neck: - 0.62 ± 1,00; Lumbar spine: - 0.13 ± 1,45 CG: Whole body: -0.20 ± 0.91; Femoral neck: - 0.54 ± 1,04; Lumbar spine: - 0.15 ± 1,53
(García-Gomáriz et al., 2018)	2018	Spain	Postmenopausal EG: 17 CG: 17	CG: 56.5 ± 6.7 EG: 60.3 ± 5.4	NI	CG: Femural neck: - 0.84 ± 0.94; Lumbar spine: - 1.83 ± 1.09 EG: Femural neck: - 0.76 ± 0.81; Lumbar Spine: - 1.93 ± 1.16
(Iwamoto et al., 2001)	2001	Japan	Postmenopausal with osteoporosis CG: 20 EG1: 8 EG2: 7	CG: 64.9 ± 5.7 EG1: 65.3 ± 4.7 EG2: 64.3 ± 3.0	CG: 19.9 ±2.1 EG1: 19.7 ± 1.3 EG2: 20.5 ± 2.6	NI
(Iwamoto et al., 2005)	2005	Japan	Postmenopausal with	CG: 70.6 ± 8.7	CG: 20.8 ± 3.3	NI

			osteoporosis EG: 25 CG: 25	EG: 71.9 ± 8.1	EG: 21.6 ± 3.3	
(Jepsen et al., 2019)	2019	Denmark	Postmenopausal with osteoporosis EG: 15 GC: 18	GC: 69 ± 8 EG: 69 ± 5	NI	EG: Lumbar spine: − 3.4 ± 0.9 CG: Lumbar spine − 2.9 ± 1.2
(Pernambuco et al., 2013)	2013	Brazil	Postmenopausal with low BMD EG: 36 CG: 31	EG: 66.8 ± 4.2 CG: 66.9 ± 3.2	EG: 29.3 ± 2.7 CG: 23.9 ± 3.4	Femur: EG: Femur: - 1.84 ±1.2; Lumbar L2-L4: - 2.53 ± 0.51; CG: Femur: - 2.11 ± 0.32; Lumbar: - 2.61 ± 0.68
(Smidt et al., 1992)	1992	USA	Postmenopausal EG: 22 CG: 27	EG: 56.6 ± 6.6 CG: 55.4 ± 8.0	NI	NI

EG = experimental Group; CG = control Group; USA: United States of America; BMD = bone mineral density; BMI = body mass index; NI = not informed.

Table 3.
Analyzed variables and outcomes of the included studies.

Study	Evaluation instrument	Intervention	VT (DT; FT; duration of intervention)	Results
(Bergström et al., 2009)	Anthropometric measurements and biomarkers	EG: warm-up (5 min walk); RT (upper and lower limbs); aerobics (walking) (50 min); cool-down (relaxation 5 min) CG: continued with daily activities without intervention	60 min/session 1–2 ×/week 12 months	EG: ↔ BMI; ↔ waist circumference; ↔ triglycerides; ↔ cholesterol; ↔ LDL-C; ↔ HDL-C; ↔ ApoB; ↔ ApoA-1; ↔ ratio ↔ ApoB/ApoA-1; ↔ systolic blood pressure; ↔ diastolic blood pressure; ↔ hs-CRP CG: ↔ BMI; ↔ waist circumference; ↔ triglycerides; ↔ cholesterol; ↔ LDL-C; ↔ HDL-C; ↔ ApoB; ↔ ApoA-1; ↔ ratio ↔ ApoB/ApoA-1; ↔ systolic blood pressure; ↔ diastolic blood pressure; ↔ hs-CRP
(Chow et al., 1987)	Biomarkers and cardiorespiratory fitness	EG1: warm-up (5–10 min of stretching and calisthenics), 30 min of aerobic exercise EG2: warm-up (5–10 min stretching and calisthenics), 30 min exercise + extra 10–15 min of RT CG: no exercises	35–60 min/session 3 ×/week 12 months	EG1: ↑ calcium body index; ↑ VO_{2max} EG2: ↑ calcium body index; ↑ VO_{2max} CG: no difference (p>0.05)
(Du et al., 2021)	BMD: lumbar and femur	EG: warm-up (5 min), Nordic walking (20–50 min), cool-down (5 min) 60–70% VO_{2max} CG: no exercises	30–60 min/session 2–3 ×/week 6 months	EG: ↔ whole-body; ↔ total-femur; ↔ femoral neck; ↔ lumbar spine CG: ↔ whole-body; ↓ total-femur; ↔ femoral neck; ↓ lumbar spine
(García-Gomáriz et al., 2018)	BMD: lumbar e femur (T-score)	EG: high-impact training CG: high-intensity walking (15 min), workout (35 min), cool-down (10 min)	60 min/session 2–5 ×/week 12 months	EG × CG (post-intervention): ↑ femoral neck; ↔ lumbar spine
(Iwamoto et al., 2001)	BMD lumbar: DXA. Calcium, phosphorus, and alkaline phosphatase: blood analysis	EG1 (2 years) and EG2 (1 year + 1 year of detraining): daily walk with step count from an individual average value with increments of 30% and RT with 2 daily sets of 15 reps (hip flexion with knee extended, squat, strengthening of abdominal and lumbar muscles). Daily 2g of calcium lactate and 1μg of 1α-hydroxyvitamin D3 CG: daily 2g of calcium lactate and 1μg of 1α-hydroxyvitamin D3	NI 7 ×/week 24 months	1 year: EG1: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase EG2: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase CG: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase 2 years: EG1: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase EG2: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase CG: ↔ BMD; ↔ serum calcium; ↔ serum phosphorus; ↔ serum alkaline phosphatase
(Iwamoto et al., 2005)	BMD lumbar: DXA. Calcium, phosphorus, and alkaline phosphatase: blood analysis	EG: 5 mg daily of alendronate + body vibration exercise using Galileo at 20 Hz intensity CG: 5 mg daily of alendronate	4 min/session 1 ×/week 12 months	6 months: EG: ↑ BMD; ↔ serum calcium; ↔ serum phosphorus; ↓ serum alkaline phosphatase 1 year: EG: ↑ BMD; ↔ serum calcium; ↔ serum phosphorus; ↓ serum alkaline phosphatase

2024, Retos, 52, 647-656

				CG: ↑ BMD; ↔ serum calcium; ↔ serum phosphorus; ↓ serum alkaline phosphatase	CG: ↑ BMD; ↔ serum calcium; ↔ serum phosphorus; ↓ serum alkaline phosphatase
(Jepsen et al., 2019)	Lumbar and hip BMD: DXA	EG: 20 μg daily subcutaneous therapy + Power Plate with 30Hz intensity CG: 20 μg daily subcutaneous therapy	12 min/session 3 ×/week 12 months	6 months: EG: ↑ lumbar BMD; ↔ hip BMD CG: ↑ lumbar BMD; ↔ hip BMD	12 months: EG: ↑ lumbar BMD; ↔ hip BMD CG: ↑ lumbar BMD; ↔ hip BMD
(Pernambuco et al., 2013)	Lumbar and femoral BMD: DXA; Osteocalcin: electrochemiluminescence; Functional autonomy: GDLAM	EG: water activities (stationary running, hip flexion, trunk rotation, elbow flexion, short jumps, jumps with hyperextension, and walking) CG: no exercises	50 min/session 2 ×/week 8 months	EG: ↔ femur BMD; ↔ L2–L4 lumbar BMD; ↑ osteocalcin CG: ↔ femur BMD; ↔ L2–L4 lumbar BMD; ↔ osteocalcin EG × CG: ↑ EG: osteocalcin	
(Smidt et al., 1992)	Lumbar and femoral BMD: DPA	EG: 70% of maximum strength load and increment of 2–5% each month. 3×10 of the 3 exercises performed as a home program: trunk flexion (sit-up); hip flexion in supine position (double leg raise); trunk extension in prone position (prone trunk extension) CG: encouraged to continue their current lifestyle	NI 3–4 ×/week 10 months	6 months: EG: ↔ L2; ↔ L3; ↔ L4; ↔ L2–L4; ↓ femur neck; ↔ trochanteric region CG: ↔ L2; ↔ L3; ↓ L4; ↓ L2–L4; ↓ femur neck; ↔ trochanteric region	1 year: EG: ↔ L2; ↔ L3; ↓ L4; ↔ L2–L4; ↔ femur neck; ↔ trochanteric region CG: ↓ L2; ↓ L3; ↔ L4; ↓ L2–L4; ↔ femur neck; ↔ trochanteric region

EG = experimental Group; CG = control Group; DT = duration of training; FT = frequency of training; DXA = dual-energy X-ray absorptiometry; DPA = Dual photon absorptiometry; COP = center of pression; RT = resistance training; reps = repetitions; BMD = bone mineral density; VO_{2max} = maximum volume of oxygen; BMI = body mass index; LDL = low-density lipoprotein; HDL= high-density lipoprotein; hs-CRP= high-sensitivity C-reactive protein; ApoB = apolipoprotein B; ApoA-1= apolipoprotein A; ×/week = times per week.

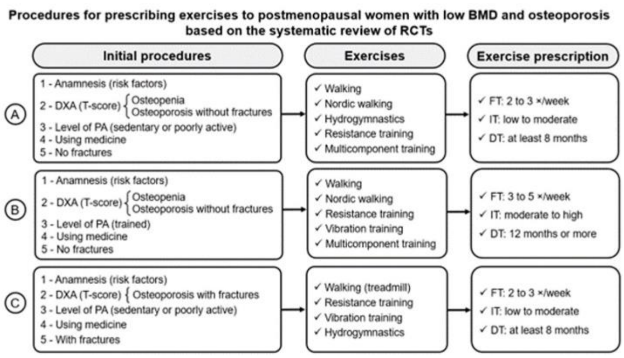

Figure 3. Procedures for prescribing. A = indicates a prescription for sedentary or inactive older women with a T-score referring to osteopenia/osteoporosis without fractures; B = indicates a prescription for active older women with a T-score for osteopenia/osteoporosis without fractures; C = indicates a prescription for sedentary or inactive older women with a T-score referring to osteoporosis with fractures. RCTs = randomized clinical trials; DXA = dual-energy X-ray absorptiometry; PA = physical activity; FT = frequency of training; IT = intensity of training; DT = duration of training; ×/week = times per week.

Discussion

The first objective of this systematic review was to analyze the physical exercise methods that are efficient in improving BMD levels/T-score in postmenopausal women. The results showed that planned physical exercise is an auxiliary method that should be part of care strategies for women with low BMD and osteoporosis. The exercise methods selected in this study showed that BMD or biochemical markers that stimulate bone metabolism benefit from the improvement of the evaluated bone structures, mainly the lumbar spine, femur, and hip. The results of this study corroborate what the scientific literature has robustly shown, that is, that physical exercise promotes improvements in BMD (Borba-Pinheiro et al., 2016; D.G. Linhares et al., 2022; Souza et al., 2021; Swain, 2014).

The studies selected in this systematic review pointed out that exercise programs involving walking, Nordic walking, vibrating platform, strength training, hydrogymnastics, and training with exercises performed at home, in addition to the training that involves multiple exercise methods, called multicomponent training, are efficient to improve BMD.

The second objective of this study was to elaborate an exercise prescription model for women with low BMD and/or osteoporosis based on the results of the studies included in this systematic review. Although there are recommendations for the practice of physical exercises by numerous organizations, and international medical and sports associations (Cheng, Wentworth, & Shoback, 2020; Swain, 2014; Vos et al., 2015), these still require refinement because they do not specifically indicate which exercises may be more suitable for a given T-score classification.

These recommendations (Cheng et al., 2020; Swain, 2014; Vos et al., 2015) deal specifically with weekly training frequency, intervention time, and effort intensity. The model suggested in the present study allows us to go further, that is, it indicates exercise methods that can be better recommended for the individual's BMD status, based on important information, such as anamnesis, state, and level of physical activity, association of medications with exercise, fracture history, and T-score of postmenopausal women (Cheng et al., 2020; Kistler-Fischbacher, Weeks, & Beck, 2021; Swain, 2014).

The results found in the present study indicate that the methods of physical exercises that have a greater mechanical shock or overload on the joints (Xu et al., 2015) are those that showed increases in BMD ($p<0.05$). These studies used vibrating platform exercises, simple or Nordic walking, resistance training, and multi-component training. This last method seems to be the alternative that promotes better general conditioning in postmenopausal women because, in addition to improving BMD, it also improves functional autonomy, muscle strength, and body balance, among other important factors that reduce the risk of falls and, consequently, fractures (Cheng et al., 2020; Kistler-Fischbacher et al., 2021; Mofid et al., 2022; Swain, 2014).

The prescription of an exercise program needs to consider the weekly frequency, which can be at least twice a week according to the results presented in this review. However, data from studies included in this systematic review indicate that three times a week is the frequency that best translates into increased BMD (Cheng et al., 2020; Wang et al., 2023). Training intensity is another factor that deserves to be highlighted because the greatest increases in general physical fitness and BMD are attributed to intensities above 70% of the maximum load (Swain, 2014), either for aerobic or resistance exercises (Kistler-Fischbacher et al., 2021; Wang et al., 2023). Intervention time is a reference that should be considered important, as an exercise program for women with low BMD and/or osteoporosis is long. This is justified by the bone metabolism cycle in the elderly population showing positive responses in the long term. In this sense, the results showed that 12 months of planned exercises should be recommended (Borba-Pinheiro et al., 2016; Cheng et al., 2020; Wang et al., 2023).

In the practical application of the exercise prescription proposal, based on the present systematic review, initially, the need for exercise for sedentary/low-active elderly women was analyzed, that is, those who did not perform regular physical exercise and with osteopenia/osteoporosis T-score without fractures (Figure 3A). In this context, the recommendation should be to start with any type of exercise that stimulates mobility, regardless of weekly frequency, mechanical shock on the joints, and intensity, but with a minimum intervention time of 8 months (Kistler-Fischbacher et al., 2021; Swain, 2014; Wang et al., 2023; Xu et al., 2015). It is understood that, at this moment, there is a greater need to improve physical fitness skills and abilities related to health, in addition to maintaining BMD and biochemical markers of bone metabolism. Based on these characteristics, any method of controlled exercise can contribute to these objectives (Wang et al., 2023). Walking exercises, water aerobics, sports for the elderly, and home exercise programs (Bergström, Lombardo, & Brinck, 2009; Chow, Harrison, & Notarius, 1987; Du et al., 2021; Iwamoto, Takeda, & Ichimura, 2001; Iwamoto, Takeda, Sato, & Uzawa, 2005; Pernambuco et al., 2013) can be indicated. Additionally, at the initial moment of entering an exercise program, the motivation of these people must also be strongly considered (Wang et al., 2023; Weeks, Purvis, & Beck, 2016), to maintain adherence to a future, longer program.

In a prescription for active older women with osteopenia/osteoporosis T-score without fractures, that is, who already performed regular physical exercises (Figure 3B), the recommendation is to practice exercises of greater mechanical shock with moderate to high intensities, according to studies selected in this research. These studies showed the best osteogenic effects ($p<0.05$) on BMD with a weekly frequency of 3 to 5 times/week and with 12 months or more of intervention, including resistance training, vibrating platform, multicomponent training, and aerobic training (García-Gomáriz, Blasco, Macián-Romero, Guillem-Hernández, & Igual-Camacho, 2018; Jepsen et al., 2019; Smidt, Lin, O'dwyer, & Blanpied, 1992). Other studies reinforce the efficiency of these exercise methods with similar prescriptions for women of advanced age and postmenopausal women. Still in this sense, the patient's motivation should also be considered when choosing the exercises. It is noteworthy that, for active women with low BMD T-score and/or osteoporosis without fractures, exercises in water, such as hydrogymnastics, would not be the best indication, because they do not offer the best results for BMD. In these cases, the professional together with the patient should evaluate the best exercise method option and the patient's T-score classification (Borba-Pinheiro et al., 2016; Diego Gama Linhares et al., 2022; Pernambuco et al., 2013; Souza et al., 2021).

For the last case of this prescription suggestion, older women with severe osteoporosis who have previous fractures, the recommendations should be for greater patient care. Thus, they should not perform exercises with complex methods that require an advanced degree of mobility and prefer conservative methods, such as resistance training and vibrating platforms (Bergström et al., 2009; Chow et al., 1987; Du et al., 2021; Iwamoto et al., 2001, 2005). In these activities, the control of volume and intensity components should be privileged, associated with exercises in reduced gravity, such as hydrogymnastics (Pernambuco et al., 2013), to protect the joints and, above all, possible recurring fractures. The intensities must be light to moderate and a minimum time of 8 months for the interventions. In these cases, the professional must be aware of the patient's evolution, because it is necessary to increase the intensities in a new training cycle when the patient presents improvements in BMD, strength, balance, and functional autonomy. Regarding the motivational issue already mentioned (Ura, Taga, Yamazaki, & Yatomi, 2011), at this time of prescription, given the complexity of the T-score classification and the presence of antecedent fractures, the choice of training method should be left to the professional.

Another important issue within this proposal is the use of medications already prescribed by the patient's physicians, as it is natural that elderly women with low BMD and osteoporosis should already be using medication. Studies that associate drugs for low BMD associated with physical exercise seem to potentiate the effects of both on BMD, highlighting that the increase and maintenance of BMD in postmenopausal women depends on the regularity of exercise associated or not with medication. Therefore, in a physical exercise program, it is fundamental that the professional identifies this information in the initial anamnesis of the patients, before starting an exercise program for this population (Iwamoto et al., 2001, 2005). It should be noted that women with normal BMD also need attention to maintain muscular strength and BMD with regular exercise practices and this includes this lifestyle habit (ACSM, 2021)

Within this perspective, the present study can help the population of postmenopausal women with low BMD and osteoporosis, in addition to providing a more refined prescription proposal for exercise professionals who care for this specific population of women. This is in line with international recommendations for the care of these patients (Kistler-Fischbacher et al., 2021; Swain, 2014; Wang et al., 2023; Weeks et al., 2016).

The limitations observed in this research refer to some experimental studies not having CG. Furthermore, the lack of standardization of the prescription of physical exercises for the same method must also be considered. Another important factor was the different drug treatments, which also promote effects on BMD.

Conclusion

This study concluded that the physical exercises selected in this systematic review, planned for postmenopausal women, are shown to be effective to some extent for the maintenance and/or effective improvement of BMD, in addition to other physical fitness variables that are important for the maintenance of functional autonomy with independence focused on carrying out activities of daily living. The exercises that stood out as the most efficient were resistance training, aerobics, multicomponent, and vibrating platform; and the least efficient was hydrogymnastics. For best effects, the appropriate weekly frequency should be three times/week or more, the intervention time should be around 12 months or more, and the intensities should be between low, moderate and high according to the relationship between the severity of bone mass loss (T score), the level of physical activity and the indication/prescription that can best meet the clinical condition.

Moreover, the exercise prescription proposal based on the results of this systematic review can be implemented in physical activity centers for this population, as it relates to the T-score classification, level of physical activity, and use of medication, in addition to anamnesis, which considers the patient's previous fractures and risk factors for fractures.

Limitations exist in the scientific literature, especially the general recommendations of official health bodies and health-oriented exercises that motivated this research, showing that this study can bring an expansion of practical application in the area of physical exercise with multiple possibilities, using new methods of approach with therapeutic exercises that consider the complexity and severity of bone mass loss for better health care.

Finally, a future line of research could evaluate the effectiveness of this model developed and suggested for exercise prescription at the three levels proposed for BMD care in women.

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Data availability

All data used in this review is appropriately cited.

Author contributions

C.J.B.P.; D.G.L; A.O.B.S.; L.L.S and R.G.S.V: contributed to study design, data collection and analysis, interpretation, and wrote the manuscript.

G.C.P.S.M.S. and N.M.A.F: contributed to data collection and analysis, interpretation, and revising the manuscript.

E.E.J.S. and J.B.P.C: contributed to data acquisition. S.M. contributed to the conception and interpretation, revising the manuscript, and supervised the study. All the authors read and approved the manuscript.

Conflict of interests

None

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