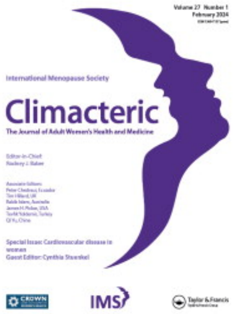

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ORIGINAL ARTICLE

Resistance training effects on healthy postmenopausal women: a systematic review with meta-analysis

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ABSTRACT

The aim of this systematic review with meta-analysis was to evaluate the effects of resistance training on physical fitness, physiological variables and body composition of postmenopausal women. The present systematic review was performed in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement and was registered in PROSPERO. A total of 12 studies were included. The literature search was performed in PubMed, Web of Science and EBSCO. Randomized control trials were included. Two blinded investigators performed the search, study selection and data collection, and assessed the quality and risk of bias. A random-effects model was used for all analyses. Compared to the control group, resistance training produced a significant improvement in maximal oxygen volume (standardized mean difference [SMD] = 2.32, $p < 0.001$), lower extremity strength (SMD = 4.70, $p < 0.001$) and upper extremity strength (SMD = 7.42, $p < 0.001$). The results obtained in the systematic review and meta-analysis confirm the benefits of resistance training on physical fitness in postmenopausal women, although there is more debate regarding its influence on bone mineral density, and anthropometric and derived variables. This work provides a solid starting point for promoting resistance training at a frequency of 3 days per week, in 60-min sessions, with the aim of improving parameters directly related to quality of life, functionality and disease prevention of postmenopausal women.

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Bone health; strength; health; exercise; training

Introduction

During menopause, women will experience major changes that affect them physically, psychologically and socially, causing a decline in their quality of life [1]. More specifically, during menopause many hormonal changes occur incrementally, such as a decrease in the production of estrogen, progesterone and growth hormone or increased levels of circulating androgens [2, 3]. Previous studies have suggested that estrogen and growth hormone deficiency is a key factor in the pathogenesis of bone mineral density (BMD) loss because they affect both the increased threshold of stress sensing by bone tissue to generate a stimulus for anabolism and the reduced conversion of mechanical to biochemical signals for bone tissue formation [4–6]. Muscle mass decreases in women from the third decade of age, showing an acceleration from the fifth decade and especially after the menopause period [7, 8]. This could be due to hormonal changes that occur during this stage [6], although other factors could affect this decline such as aging, physical inactivity, fitness level, dietary habits or oxidative stress [7]. Regarding fat, previous studies have shown that the hormonal changes that occur at this stage generate changes in lipid metabolism that lead to an increased tendency to accumulate intramuscular fat in the abdominal area [3, 7].

But the hormonal changes around the menopause do not only affect body composition. There are other associated symptoms such as changes in blood parameters [9] and an increase in blood pressure [10]; psychological and emotional disturbances, such as increased nervousness, anxiety, depression, insomnia, sadness, loneliness, isolation, lack of concentration, memory loss, irritability or bipolarity [11]; and a decline in social relations [12]. All of these changes are related to a loss of health quality of life, the onset of joint and muscle pain, and a decrease in health and well-being [12], together with the development of chronic diseases such as cardiovascular diseases, obesity, type 2 diabetes mellitus, hypertension and dyslipidemia, sarcopenia, osteopenia and osteoporosis, among others [13].

Systematic physical exercise may help reduce the adverse effects of menopause in women. More specifically, it has been shown that physical exercise could decrease fat accumulation; increase muscle development; control body weight, body mass index (BMI) and other obesity-related parameters such as waist girth or waist/hip ratio; and increase BMD, among others [14]. However, while the training of

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postmenopausal women has been classically and predominantly aerobic, in recent decades it has become apparent that postmenopausal women could also benefit from resistance training [15]. In fact, the mechanical load generated by this type of training could reduce the influence of sarcopenia to a greater extent, preventing the loss of muscle functionality and positively reversing the deterioration of the structure due to the aging of the person, resulting in a higher quality of life for postmenopausal women [16]. Also, the increase in the mechanical load in resistance training, with respect to other types of training, could increase BMD, with the corresponding reduction in the incidence of osteopenia, osteoporosis and osteoporotic fractures [17].

The growing importance of this issue has led to the proliferation of various literature reviews and systematic reviews with and without meta-analyses in recent years. Manaye et al. conducted a systematic review without meta-analysis on the importance of high-intensity, high-impact exercise (HIIT) on bone health in postmenopausal women [18]. Kitagawa et al. focused their systematic review with meta-analysis on the effects of HIIT training in people with osteoporosis, regardless of whether they were taking hormone replacement therapy [19]. Xi et al. analyzed the effect of combined aerobic and resistance training in postmenopausal women on blood pressure [20]. However, none of these systematic reviews examined the effects of specific resistance training, using other training methods [18–20].

Kemmler et al. [17] attempted a systematic review with meta-analysis of the effects of different types of physical exercise on BMD. However, they do not establish exclusion criteria based on some factors that could be affecting the results found, such as the intake of nutritional supplements or hormone replacement therapy, the inclusion of women with early menopause or the non-inclusion of postmenopausal women, the inclusion of populations with pathologies such as osteopenia or osteoporosis, the inclusion of studies that do not include resistance work or the inclusion of unsupervised exercise [21].

Loaiza-Betancur et al. analyzed the effects of resistance training on the very specific issue of C-reactive protein, mixing two different populations of menopausal women and postmenopausal women [22]. Sá et al. conducted a systematic review with meta-analysis to analyze the effects of resistance training on variables related to functionality, BMD and body composition. However, physical fitness was not analyzed [23].

Therefore, the aim of this systematic review with meta-analysis was to evaluate the effects of resistance training on physical fitness, physiological variables and body composition of postmenopausal women without hormone replacement therapy.

Methods

Protocol and registration

This study followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement Checklist [24] and the Handbook Cochrane Handbook for systematic reviews of interventions [25], and was registered in PROSPERO (CRD42022330633).

Information sources and search

The literature search was conducted in the electronic databases PubMed, Web Of Science and EBSCO. The search ended on 25 April 2022 and was carried out by two blinded authors (J.M.M.-T. and N.G.-G.). Studies evaluating the effect of a resistance training program on physical fitness, physiological variables and body composition of postmenopausal women were included.

The search strategy used was the following: ('force' OR 'Strength' OR 'energy' OR 'resistance') AND ('train*' OR 'prepare' OR 'preparation' OR 'exercise*' OR 'training' OR 'practice' OR 'physical activity' OR 'physical exercise' OR 'athletic') AND ('menopaus*' OR 'postmenopause' OR 'post-menopause' OR 'postmenopausal'). In addition, to find other studies that met the inclusion criteria, the reference lists from the articles found were screened manually.

Eligibility criteria and study selection

The inclusion criteria were: healthy postmenopausal women; randomized controlled trial design (experimental group vs. control group without training program or stretching program); resistance training exclusively (vigorous muscle contractions to overcome extreme loads) [26]; and written in English or Spanish. The exclusion criteria were: application of supplementation, hormone replacement or drugs; women with pathologies or diseases; and women over 70 years of age.

The articles found were reviewed independently by two authors (J.M.M.-T. and N.G.-G.). If there was any disagreement, the search was performed again. Cohen's κ was calculated to find the reliability between the two researchers, finding a high level of agreement ($\kappa = 0.870$) [27].

Quality assessment and risk of bias

To determine the individual quality of each of the selected articles and the overall quality of the systematic review, the scores established on the 'Physiotherapy Evidence Database' scale, also known as the 'PEDro Scale', were used [28]. A risk of bias summary graph was created to identify the authors' judgments, broken down according to each risk of bias criterion in all included studies.

Each study was assessed by two blinded authors (J.M.M.-T. and N.G.-G.) separately. Any disagreement over the assessed risk of bias of particular studies was resolved through discussion with a third author (R.V.-C.).

Statistical analysis

The meta-analysis was performed with R software version 3.6.0 (© 2019; R Foundation for Statistical Computing) with the metacont package. The forest plots were created using the forestplot package. For continuous data, the change in mean and standard deviation between baseline and final (pre–post intervention) measurements of systolic and diastolic blood pressure values was used. Some studies had more than one experimental group and were treated as other subgroups in the analysis. We used the DerSimonian–Laird (Cohen's) clustering method, and assessed heterogeneity using Cochrane's Q test (χ^2), Higgins' I^2 statistic and significance (p-value) to determine the appropriateness of applying a fixed or random-effects model for the pooled analysis. If there was evidence of between-study heterogeneity ($I^2 > 50\%$, $p > 0.05$), random-effect estimates were described [29]. A pooled summary mean and 95% confidence interval were calculated for subgroups (intervention time: 12 weeks vs. >12 weeks) in order to compare the differences between groups. Random models using the restricted maximum likelihood method were utilized.

A meta-analysis with a random-effects model was performed to infer the pooled estimated standardized mean difference (SMD) [30]. The DerSimonian–Laird (Cohen's) mean difference was interpreted by Cohen as small (0–0.2), medium (0.3–0.7) or large (≥0.8) [31]. Significant differences were determined at $p < 0.05$.

Results

Study selection

A total of 542 studies were identified. Of these, 155 studies were excluded for duplication, while one study was excluded for language. After that, 200 studies were excluded after reading the title, 154 were excluded after reading the abstract and 20 were excluded after reading the full text for not meeting the inclusion and exclusion criteria. In the end, 12 studies were finally included in the systematic review with meta-analysis (Figure 1).

Risk of bias

Supplementary Table 1 shows the score obtained on the PEDro scale for each of the articles included. The score obtained showed a strong validity and inter-rater reliability of the assessment of randomized controlled trials with values from 5 to 9, with an average of 7.25 points. Supplementary Figure 1 shows the risk of bias summary graph.

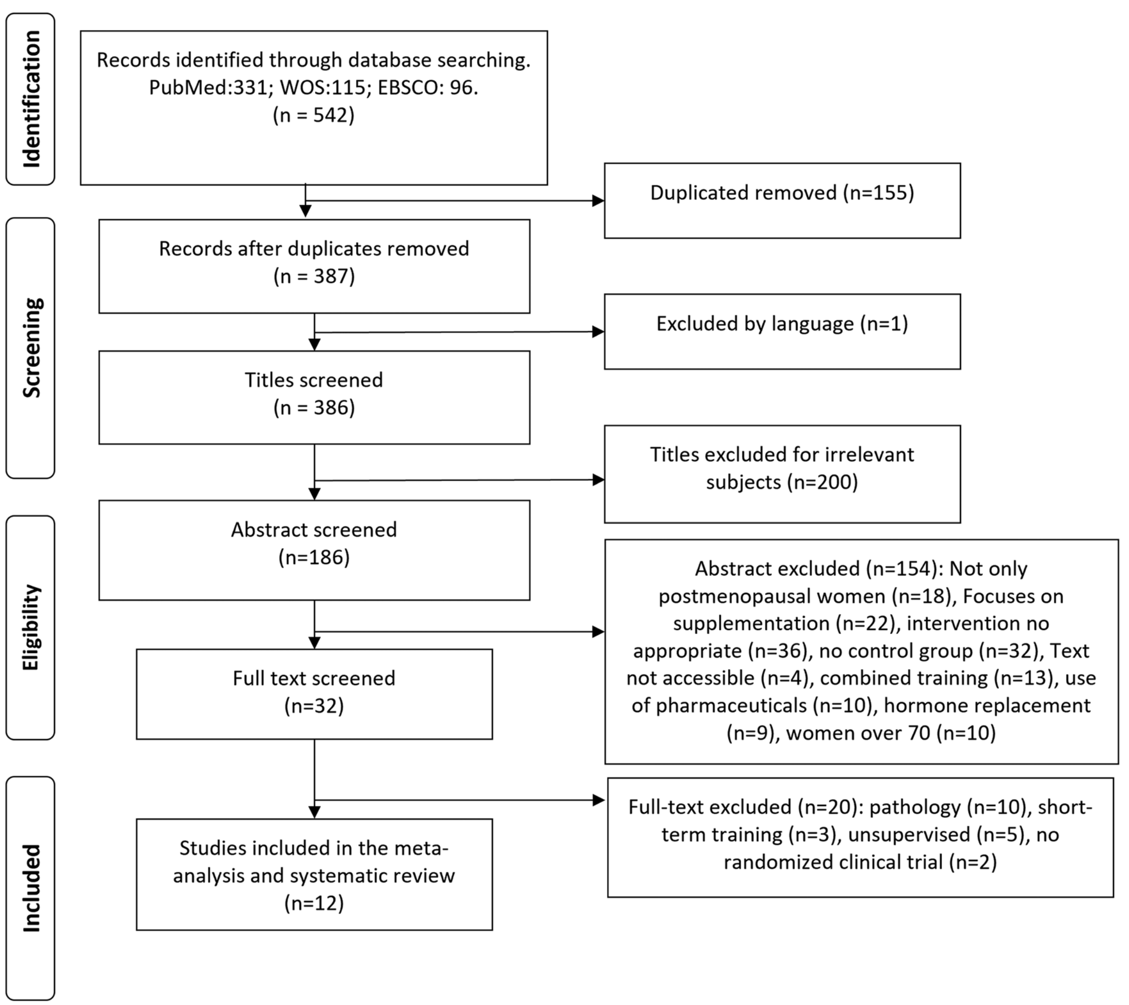

Figure 1. Flow diagram of the article selection process. WOS, Web of Science.

Study characteristics

Table 1 presents the characteristics of the studies included. In relation to the duration of the training program, a mean duration of 22 weeks (range 12–56 weeks) was observed, with a weekly frequency of training of 2–3 days (a mean of 2.8 days) and the duration of these training sessions lasting between 25 and 70 min. The work intensity ranged from 50% to 90% of the repetition maximum.

Summary of evidence

Qualitative synthesis

Regarding BMD, only one study of three showed a significative improvement in the experimental group after the application of strength training in the lumbar spine and hip [17].

In relation to maximal oxygen volume (VO_2max), only one study of three showed significative improvements in the experimental group after the application of strength training [17].

With respect to BMI, only one author of four showed significant differences between the pre-test and post-test values [32].

Regarding weight, one of four studies show significant improvement in the experimental group pre-test and post-test [33].

All of the studies except one showed significant differences in the pre-test–post-test measurements in lower body strength in the experimental group [34–37].

Likewise, all of the researchers who carried out measurement of the upper limb strength observed significant changes in strength between the pre-test and post-test for the experimental group [16, 17, 34, 35].

Quantitative synthesis

The meta-analysis showed a significant difference between the experimental group and the control group in relation to pre-test–post-test changes in VO_2max (Figure 2(b)) (SMD = 2.32; $p < 0.001$), lower body strength (Figure 2(e)) (SMD = 4.70; $p < 0.001$), lower limb strength (Figure 2(e)) (SMD = 4.7; $p < 0.001$) and upper limb strength (Figure 2(f)) (SMD = 7.42; $p < 0.001$). However, there were no significant differences in the rest of variables. When comparing the effect of the intervention programs between those applying durations of 12 weeks versus those applying durations of >12 weeks, the analysis shows that those applying longer durations show greater improvements in VO_2max and upper limb strength than those applying shorter intervention programs (Table 2).

Discussion

In the present systematic review with meta-analysis, resistance training was found to improve upper and lower limb strength, the improvement being higher after a program with duration >12 weeks. Numerous studies have debated what may be the causes of the strength gains achieved with resistance training [38, 39]. It seems that the increase in muscle size, for both muscle as a whole and of each of the individual fibers that compose them, had a significant influence on the strength produced. But it was also found that resistance training induced a series of neural adaptations that could increase muscle strength. Therefore, the increase in muscle strength in response to resistance training could be due to the combination of both muscle growth and mechanisms intrinsic to the muscle fibers [38], with the latter factor being especially important when considering the older adult population [38]. This finding is very relevant because postmenopausal women suffer a significant decrease in muscle strength, which is further increased by the aging process [40]. In addition, there is also evidence on the association between muscle strength and some aspects related to health, especially during aging, such as physical functionality, physical performance and fragility [41], BMD and bone quality, and therefore the prevention of osteoporosis and osteopenia [36], and other common diseases of postmenopausal women such as sarcopenia [42], cardiovascular diseases, respiratory diseases, cancer and overall mortality [43].

Another important result of the present systematic review with meta-analysis was that there was a significant effect of resistance training on VO_2max of postmenopausal women when training at least 3 days a week and this improvement is higher with a program of >12 weeks. Previous studies have pointed to the fact that VO_2max declination can affect both the physical condition, and the functionality and quality of life of older women [44]. This result is relevant since endurance training has been classically proposed for the improvement of VO_2max, as opposed to strength training [45]. Considering the results of the present meta-analysis, resistance training, with a minimum frequency of 3 days per week, could be defined as a suitable alternative.

The effects of resistance training on the other variables showed more discrepancies. Thus, regarding the effects of training on BMD, only one study shows an improvement after the application of resistance training [17], with no significant changes found in the other two articles [36, 37] or in the general model. The difference between the results of these studies could be due to the duration of the interventions carried out. More specifically, while the Kemmler et al. training program lasted 14 months [17], the other interventions did not exceed 24 weeks (~6 months) [36, 37]. Previous studies have already indicated the need for interventions that aim to modify BMD in women to be planned on a long-term basis, rather than as a one-off issue [17]. Therefore, given the importance of BMD in the health of postmenopausal women, as it is the most widely used variable for the prediction of osteopenia and osteoporosis [46], resistance training programs should be planned that last longer than one-off interventions in this population.

Regarding the effect of the practice of resistance training on anthropometric and derived variables, a great contradiction was found in the results from analyzing the significant effect of the interventions on BMI or body mass, with no significant effects found in any of the cases in the general model. Although body mass and BMI are frequently used tools for assessing body composition, it is not possible to distinguish between changes in fat and muscle masses using

Table 1. Characteristics of the studies included in the systematic review.

Author	*Sample size (n), age (years)*	*Inclusion criteria*	*Intervention*	*Time (min), frequency (weeks), duration, intensity, repetitions and series*	*Outcome*	*Equipment*
Thompson et al. (1997) [37]	Sample: E = 20; C = 20 Age: E = 65 ± 3; C = 65 ± 3	Healthy, no metabolic disorder, no hormone therapy or supplementations	C = dietary program of 500 kcal less than their usual intake E = training	T = 60, F = 2, D = 24, I = 80%, R = 10, S = 1	BMD, strength and VO_2max	X-ray absorptiometry, indirect calorimetry and 1RM
Bonganha et al. (2012) [34]	Sample: E = 16; C = 16 Age: E = 65 ± 3; C = 58.2 ± 4.6	Healthy, postmenopausal 12 months, no regular PA	C = normal life E = upper and lower limb strength training	T = 60, F = 3, D = 16, I = 70–85%, R = 10, S = 3	BMI, weight and strength	Platform scale and 1RM
Kemmler et al. (2003) [17]	Sample: E = 86; C = 51 Age: E = 55.1 ± 3.3 C = 55.8 ± 3.1	No hormone therapy or supplementations	C = normal life E = strength-endurance, jumping and flexibility training	T = 60–70, F = 2, D = 60, I = 50–60–65%, R = 20–15–12, S = 2 + 2	BMD, VO_2max, strength	DXA, stepwise treadmill test and maximum voluntary isometric contraction
Rodrigo et al. (2008) [33]	Sample: E = 40; C = 23 Age: E = 54.3 ± 2.5; C = 53.1 ± 1.9	Healthy, no hormone therapy or supplementations	C = normal life E = strength-resistance protocol	T = 60, F = 2, D = 28, I = 80%, R = 20, S = 2	Weight	Anthropometry
Ferreira Alves de Oliveira et al. (2015) [49]	Sample: E = 12; C = 10 Age: E = 65 ± 4.2; C = 65 ± 4.2	Healthy, no hormone therapy or supplementations	C = normal life E = strength training	T = 50–60, F = 3, D = 12, R = 12–10–8, S = 3,	Strength	Dynamometer, manual oscillometer
de Oliveira-Junio et al. (2021) [39]	Sample: E = 38; C = 20 Age: E > 50; C ≥ 50	No PA, no hormone therapy or supplementations, non-drinkers, non-smokers, no smokers	C = normal life E = strength training and maximal isometric contraction	F = 3, D = 12, I = 50–60%, R = 8–12, S = 6	Strength	X-ray absorptiometry and maximum voluntary isometric contraction
Nunes et al. (2017) [50]	Sample: E = 22; C = 11 Age: E = 64.2; C = 59.4	No PA, no hormone therapy or supplementations, non-drinkers, non-smokers, no smokers	C = stretching E = full body strength	T = 60, F = 3, D = 16, I = 70%, R = 8–12, S = 3–6	Strength	1RM
Gerage et al. (2013) [35]	Sample: E = 15; C = 14 Age: E = 65.5 ± 5.0; C = 66.2 ± 4.1	Healthy, no medications, no hormone therapy or supplementations, no smokers, no regular PA within the last 6 months	C = stretching E = strength-endurance training	T = 50–60, F = 3, D = 12, I = 50%, R = 10–15, S = 2	BMI, weight and strength	Mercury sphygmomanometer and stethoscope, scale and 1RM
Mosti et al. (2013) [36]	Sample: E = 10; C = 11 Age: E = 61.9 ± 5.0; C = 66.7 ± 7.4	Healthy, more than 2 years menopause, younger than 75 years old, BMD between 21.5 and 24.0, no hormonal therapy or supplementations	C = normal life E = strength training	T = 25, F = 3, D = 12, I = 85–90%, R = 3–5, S = 4	BMD, VO_2max, weight and strength	DEXA, gas analyzer and 1RM
Orsatti et al. (2008) [16]	Sample: E = 22; C = 21 Age: E = 57.8 ± 8.0; C = 59.3 ± 6.2	Healthy, no hormone therapy or supplementations in previous 6 months	C = normal life E = upper and lower body strength training	T = 50–60, F = 3, D = 16, I = 60–80%, R = 8–12, S = 3	BMI, weight and strength	Bioelectrical impedance, stadiometer, balance beam scale and 1RM
Gelecek et al. (2012) [51]	Sample: E = 24; C = 21 Age: 53.16 ± 4.73	44–65 years old, no hormone therapy or vitamin supplements, non-smokers	C = normal life E = strength training	F = 3, D = 12, I = 60%, R = 8–12, S = 2	BMI and VO_2max	Balance beam scale and 6-minute walk test
Saucedo-Rodrigo et al. (2008) [33]	Sample: E = 40; C = 23. Age: E = 54.3 ± 2.5; C = 53.1 ± 1.9	Health, 45–59 years old, no hormonal therapy or supplementations	C = normal life E = strength training	F = 2–3, D = 24, R = 20/min, S = 2	BMI and weight	Balance beam scale

BMD, bone mineral density; BMI, body mass index; C, control group; D, duration; DEXA, dual-energy X-ray absorptiometry; E, experimental group; F, frequency; I, intensity; PA, physical activity; 1RM, one repetition maximum; R, repetitions; S, series; T, time; VO_2max, maximal oxygen volume.

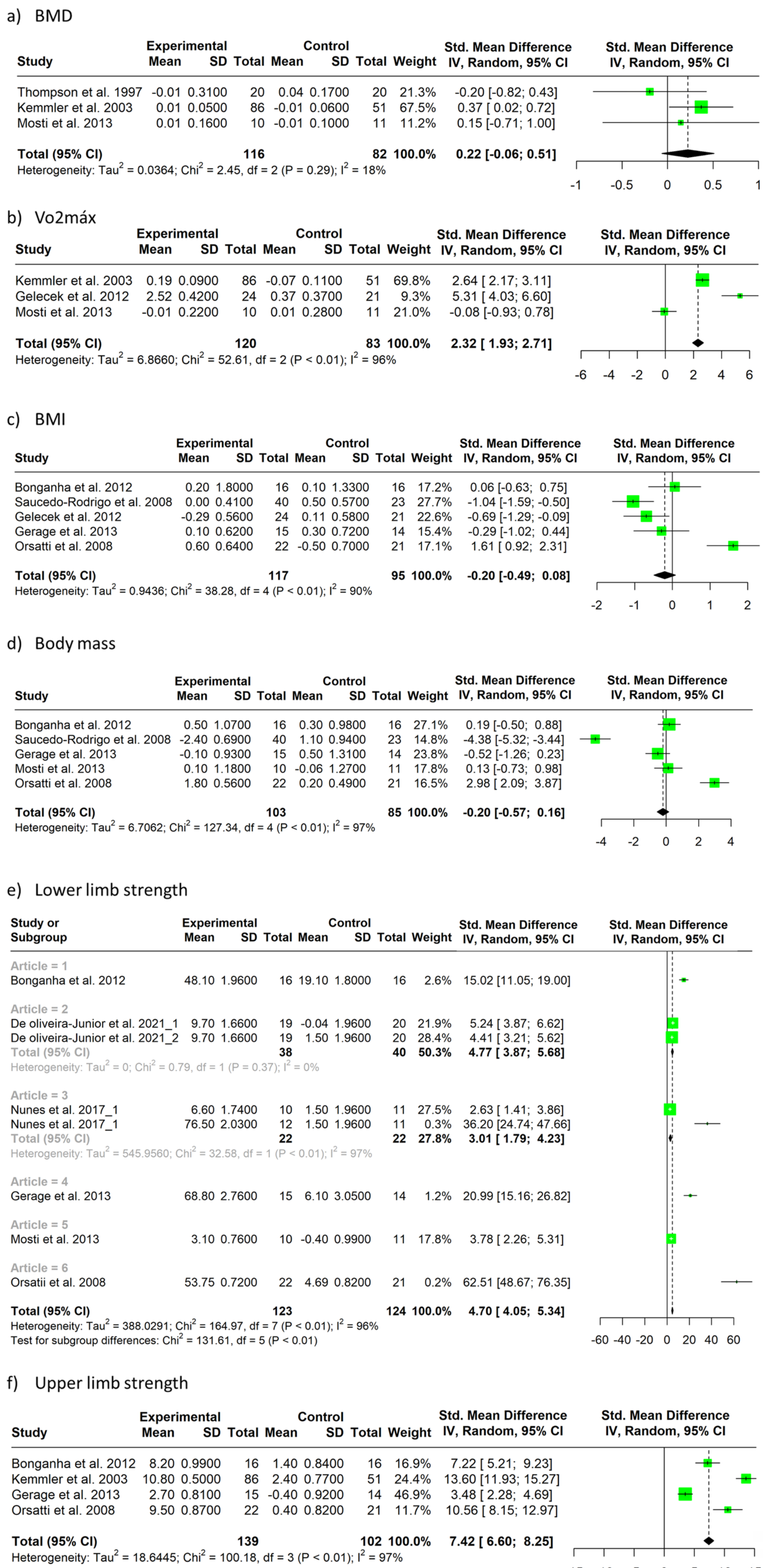

Figure 2. Forest plots: (a) bone mineral density (BMD), (b) maximal oxygen volume (VO_2max), (c) body mass index (BMI), (d) body mass, (e) lower limb strength and (f) upper limb strength. CI, confidence interval; SD, standard deviation.

Table 2. Analysis of the effect of resistance training on physical fitness, physiological variables and body composition of postmenopausal women according to weeks of duration.

			Intragroup effect			Differences between groups		
Outcome	*Time duration (weeks)*	*Author*	*MD*	*95% CI*	p-*Value*	*MD*	*95% CI*	p-*Value*
BMD	12	Mosti et al. (2013) [36]	0.15	−0.71, 1.00	0.12	0.22	−0.06, 0.51	0.85
	>12	Thompson et al. (1997) [37] , Kemmler et al. (2003) [17]	0.23	−0.07, 0.54	–			
VO_2max	12	Gelecek et al. (2012) [51], Mosti et al. (2013) [36]	1.58	0.87, 2.29	<0.01	2.32	1.93, 2.71	0.01
	>12	Kemmler et al. (2003) [17]	2.64	2.17, 3.11	–			
BMI	12	Gelecek et al. (2012) [51], Gerage et al. (2013) [35]	−0.53	−0.99, −0.06	0.41	−0.20	−0.49, 0.08	0.08
	>12	Bonganha et al. (2012) [34], Saucedo-Rodrigo et al. (2008) [33], Orsatti et al. (2008) [16]	−0.01	−0.37, 0.36	<0.01			
Body mass	12	Gerage et al. (2013) [35], Mosti et al. (2013) [36]	−0.24	−0.80, 0.32	0.27	−0.20	−0.57, 0.16	0.86
	>12	Bonganha et al. (2012) [34], Saucedo-Rodrigo et al. (2008) [33], Orsatti et al. (2008) [16]	−0.18	−0.65, 0.30	< 0.01			
Lower limb strength	12	de Oliveira-Junior et al. (2021_1) [39], de Oliveira-Junior et al. (2021_2) [39], Gerage et al. (2013) [35], Mosti et al. (2013) [36]	4.80	4.03, 5.58	<0.01	4.70	4.05, 5.34	0.63
	>12	Bonganha et al. (2012) [34], Nunes et al. (2017_1) [50], Nunes et al. (2017_1) [50], Orsatii et al. (2008) [16]	4.46	3.30, 5.00	<0.01			
Upper limb strength	12	Bonganha et al. (2012) [34], Kemmler et al. (2003) [17], Orsatti et al. (2008) [16]	3.48	2.28, 4.69	<0.01	7.42	6.60, 8.25	<0.01
	>12	Gerage et al. (2013) [35]	10.90	9.76, 12.03	–			

BMD, bone mineral density; BMI, body mass index; CI, confidence interval; MD, mean difference; VO_2max, maximal oxygen volume.

just these parameters [47], so the lack of change in body mass and BMI does not mean that the resistance programs did not have a positive effect on health or did not change body composition [47]. The contradictions between the results found in the present study could be due to differences in sample characteristics or training programs, which may influence the results, so further studies on the current topic are recommended. It is particularly important that futures studies include direct measurements of body composition due to the relation between muscle, bone and fat components with numerous metabolic and chronic diseases [13, 38].

During the systematic review and meta-analysis, some limitations were observed in the available scientific literature. Firstly, the tests and protocols used to assess the different variables were different. In addition, the sample sizes used in some of the articles were small. Moreover, the samples used in the research included postmenopausal women with diverse characteristics, making it difficult to draw conclusions for postmenopausal women as a whole. Also, some of the included studies included nutritional aspects in addition to physical exercise in the intervention, and these could be a contaminating aspect with respect to the independent effects of the training program. Finally, a limitation of the study was that no corrections were made based on weight, BMI or obesity. These issues need to be addressed in future research. However, the studies analyzed also had strengths, among which we must underline that they obtained scores between 4 and 10 on the PEDro scale, with an average of 7.2 points, and are therefore considered of 'high quality' [48].

The results obtained in the systematic review and meta-analysis confirm the benefits of resistance training on the physical fitness of postmenopausal women, although there is more debate regarding its influence on BMD and anthropometric and derived variables. This work provides a solid starting point for promoting resistance training at a frequency of 2–3 days per week, to improve parameters directly related to quality of life, functionality and disease prevention of postmenopausal women, and a duration of >12 weeks reports better results for cardiorespiratory fitness and upper limb strength. However, future research is needed to further analyze more variables that could be affected by resistance training; the interaction with some factors that could also affect physical fitness, physiological variables and body composition, such as aging, dietary habits, sporting experience and hormone replacement therapy use; or to continue to expand our knowledge on the optimal training frequency.

This study was necessary to obtain conclusions backed by statistical values with which to raise awareness among all agents related to healthy aging on the importance of resistance training for postmenopausal women.

Potential conflict of interest No potential conflict of interest was reported by the authors.

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Data availability statement

Data available on request from the authors.

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