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SYSTEMATIC REVIEW

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The effect of aerobic exercise on sleep disorder in menopausal women: a systematic review and meta-analyses

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Abstract

Objective This study systematically evaluated the effect of aerobic exercise on sleep disorders in menopausal women and proposed a practical program from the perspective of "what to practice," "how much to practice," and "how to practice." We proposed the program from the standpoint of training science.

Methods Up to March 20, 2023, a total of 16 articles and 19 RCT studies were retrieved from Web of Science, PubMed, Springer, Science Direct, China Knowledge Network, Wanfang, and VIP. The Cochrane Risk of Bias Assessment Tool was used to assess the quality of the literature, and We used RevMan5.3and STATA 16.0 software to provide a systematic review of included studies.

Results The overall effect of low- and moderate-intensity aerobic exercise interventions for sleep disorders in menopausal women had a moderate effect size (SMD = -0.52, $P < 0.001$), and the effect values between different intervention frequencies ($I^2 = 60\%$), intervention duration ($I^2 = 60$), intervention periods ($I^2 = 70$), exercise forms ($I^2 = 70$), and practice methods ($I^2 = 70$) had moderate heterogeneity. The most significant effect sizes were found for intervention frequency of 3 times/week (SMD = -0.57, $P < 0.001$); intervention duration of 70–90 min/session (SMD = -0.64, $P = 0.004$); intervention period of 8–10 weeks (SMD = -0.59, $P = 0.35$); and exercise form of static exercise (SMD = -0.55, $P = 0.003$); and the practice mode was an individual exercise with the most significant effect size (SMD = -0.66, $P < 0.01$).

Conclusion Low- and medium-intensity aerobic exercise intervention for sleep disorders in menopausal women has a good effect, but it is affected by training factors such as intervention frequency, intervention time, intervention period, exercise form, and practice mode; the best effect is achieved by adopting the dosage of 3 times/week, 70–90 min/times, and lasting for 8–10 weeks; aerobic intervention in the form of static exercise is the most effective; the best intervention effect is achieved by adopting the mode of individual exercise; but a group exercise approach improved exercise persistence in menopausal women.

Keywords Sleep disorders, Climacteric women, Aerobics, Systematic review

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Introduction

Sleep disorder refers to abnormal sleep–wake function caused by psychological or physiological factors, manifested as reduced sleep volume, increased awakenings, disturbed sleep rhythm, etc [1]. A 2021 World Health Organization (WHO) survey found that the prevalence rate of sleep disorders can reach 27% globally. It has become the second most common psychiatric disorder, which is prone to people engaged in high-stress occupations or suffering from underlying diseases, especially those who are affected by the decline of ovarian function and endocrine disease. Menopausal women with psychological or bodily conditions such as depression, anxiety, hot flashes [2], muscle aches and pains, and autonomic disorders due to ovarian failure and endocrine changes [3] are more likely to suffer from sleep disorders. Cross-sectional and prospective studies based on disease causation and prevalence have found that poor quality sleep not only exacerbates psychological and somatic symptoms, affects daily activities and quality of life of menopausal women, but also, more importantly, leads to an increased risk of cardiovascular disease, rectal cancer, thyroid cancer, Alzheimer's disease, and other diseases [4–8].

For a long time, many scholars have used subjective or objective sleep measurement tools such as the Pittsburgh Sleep Index and polysomnography to confirm that hormone therapy can significantly improve sleep disorders in menopausal women [9–12]. However, this therapy has the potential health risk of increasing the prevalence of diseases such as breast cancer and thrombosis [13, 14]. In recent years, to seek therapies that combine the characteristics of effectiveness, safety, economy, and foresight, some scholars have confirmed from the perspective of exercise health promotion that aerobic exercise not only improves the body's cardiorespiratory function and endocrine secretion but also improves the quality of sleep by decreasing neurosensitivity, improving anxiety and depression symptoms [15, 16],which has the advantages of high accessibility, operability, and fewer side effects. Particularly important is that it also seems to have a better ameliorative impact on sleep disorders in the menopausal female population. For example, Zong-Yan CAI et al. [17] found that the Pittsburgh Sleep Index Scale scores of the intervention group were significantly lower compared with both the baseline and the control group after a randomized controlled trial of 3times/week, 80–90 min/repetition for ten weeks in 19 menopausal women using pedal exercises as a form of aerobic exercise using group exercises; similarly, Tadayon et al. [18], Amalia et al. [19], and Carcelén-Fraile et al. [20] have reported that aerobic exercise in the form of walking, aerobic gymnastics, and Ba Duan Jin fitness qigong can significantly improve sleep disorders in menopausal women.

Nevertheless, there are still studies that concluded that aerobic exercise in the form of stationary equipment exercises (e.g., treadmill, stationary bicycle) has a weak effect on the improvement of sleep disorders in menopausal women [21] and even a study by Elavsky et al. [22] demonstrated that aerobic exercise interventions in the form of walking three times/week for 60 min/session for 16 weeks did not have a statistically significant. This apparent disagreement suggests that when aerobic exercise is adopted to intervene in sleep disorders in menopausal women, a series of unavoidable problems may be faced due to the interaction of variables such as population characteristics and training factors, as follows):1)whether the intervention effects of aerobic exercise remain accurate and effective for the menopausal female population; 2) what form of aerobic exercise is most effective; 3) what dosage of aerobic exercise is optimal; and 4) what type of exercises are most effective for aerobic exercise. Moreover, few studies systematize and explore their specific effects and trainological factors.

According to the "World Population Ageing Highlights (2020)" released by the World Health Organization, by 2025, the global elderly population (over 60 years old) will reach 2.2 billion, especially women will account for 55% of the worldwide population over 65 years old and 62% of the population over 80 years old, and in particular, by 2030, there will be more than 1.2 billion menopausal women in the global population. Because of this, this study adopts a systematic analysis method to review the existing literature, comprehensively evaluates the effectiveness of aerobic exercise in intervening sleep disorders in menopausal women, and, based on this study, explores the influence of different forms of exercise, exercise dosage, and exercise modes on the effectiveness of the interventions from the perspective of training, to provide evidence to support the scientific development of aerobic exercise programs for menopausal women in practice.

Objectives

Based on the principle of evidence-based medicine and the inherent research paradigm of the sports discipline, this study is oriented to the question of whether aerobic exercise can improve the sleep disorders of menopausal women and adopts a combination of quantitative assessment and qualitative research methods, such as data aggregation and heterogeneous research, to systematically review the effects of aerobic exercise on menopausal women's sleep disorders based on the evaluation of overall effects and the analysis of training. The aim is to evaluate the effect of aerobic exercise on sleep disorders in menopausal women and to propose specific practical programs from the perspective of "what to practice," "how to practice," and "how much to practice."

Methods

Search strategy

From October 2022 to March 20, 2023, the research team searched the databases of Web of Science, PubMed, Springer, Science Direct, China Knowledge Network, Wanfang, and VIP, using the following search strategy (see Table 1). The search was conducted from the date of construction of each database to the date of retrieval. In addition, the search was conducted retrospectively to ensure the completeness of the literature.

Eligibility criteria

(1)The experimental design was a randomized controlled trial; (2)The subjects were menopausal women who suffer from poor sleep quality; (3)The intervention was only aerobic exercise lasting no less than 15 min and lasting more than a week, and the specific forms included jogging, walking, taijiquan, Pilates, yoga, Ba Duan Jin, aerobic pedal exercise, cycling, etc.; (4)The control group did not receive any intervention in the form of physical exercise, only placebo or health education sessions and maintenance of routine daily activities; (5)The outcome indicators were scales that can evaluate sleep status such as the The Pittsburgh Sleep Quality Index(PSQI), the Insomnia Severity Index(ISI), the Kuperman Index(KMI), actigraphy(AG), or an objective assessment tool such as a polysomnogram (PSG); (6)Literature can provide sample sizes for both the experimental and control groups, mean and standard deviation of the experimental and control groups.

Exclusion criteria

(1)The type of literature is conference abstracts, academic papers, and non-Chinese and English literature; (2)The study subjects suffer from severe heart disease, diabetes, cancer, and other significant diseases or actively participate in sports and exercise in the last three months, or are receiving hormone replacement therapy; (3)The form of exercise intervention is not aerobic exercise, such as resistance training; (4)The intervention group is provided with a specific type of nutritional supplements but the control group is not provided with or provided with different nutritional supplements from the intervention group; (5)Incomplete presentation of data in the literature, with no "mean ± standard deviation" provided for pre- and post-intervention indicators or inability to calculate "change ± standard deviation" for pre- and post-intervention indicators.

Data extraction

We used Zotero software to manage the initial search. Based on the inclusion and exclusion criteria, two experienced researchers assessed and screened the literature that initially met the requirements in terms of five aspects: type of study, study population, interventions, controls, and outcome indicators; if there were any disagreements, we consulted third-party authors, and a consensus was reached after negotiation to complete the final inclusion of the literature.

Table 1 The list of search strategy

Number	Search content
#1	exercise[Mesh]
#2	exercise[Title/Abstract] aerobic training[Title/Abstract] OR Physical Activity[Title/Abstract] OR Physical Exercise[Title/Abstract] OR Acute Exercise[Title/Abstract] OR Exercise, Isometric[Title/Abstract] OR endurance exercise[Title/Abstract] OR Treadmill[Title/Abstract] OR walking[Title/Abstract] OR Jogging[Title/Abstract] OR Swimming[Title/Abstract] OR Dancing[Title/Abstract] OR Cycling[Title/Abstract] OR Taijiquan[Title/Abstract]
#3	#1 OR #2
#4	perimenopause[Mesh]
#5	menopause[Mesh]
#6	climacteric[MeSH]
#7	perimenopause[Title/Abstract] OR perimenopause syndrome[Title/Abstract] OR perimenopause symptoms[Title/Abstract] menopause[Title/Abstract] OR menopause syndrome[Title/Abstract] OR menopause symptoms[Title/Abstract] climacteric[Title/Abstract] OR climacteric syndrome[Title/Abstract] OR climacteric symptoms[Title/Abstract]
#8	#4 OR #5 OR #6 OR #7
#9	sleep[Mesh]
#10	sleep[Title/Abstract] OR Insomnia[Title/Abstract] OR chronic Insomnia[Title/Abstract] OR sleep disorder[Title/Abstract] OR sleep complaint[Title/Abstract] OR sleep disturb[Title/Abstract] OR sleep quality[Title/Abstract] OR sleep problem[Title/Abstract]
#11	#9 OR #10
#12	#3 AND #8 AND #11

Data items were extracted and merged by the above two researchers using Excel software, and we contacted the authors by e-mail to obtain the corresponding data if the data were missing or ambiguous. The extracted data mainly included the first author, the year of publication, the sample size, the age of the subjects, the form of aerobic exercise, the training indexes (the content of the intervention, the number of interventions, the duration of the intervention, the intervention period, the intensity of the exercise, the mode of exercise, etc.), and the outcome indexes (the mean and standard deviation of the pre-and post-tests of relevant indexes of the intervention group and the control group), and so on. In case of multiple outcome indicators in a single study, one of them will be chosen by two researchers after consultation.

Assessment study risk of bias

We used the Cochrane risk of bias assessment tool to assess the risk of bias in the included literature, including selection bias (randomized sequence generation and allocation concealment), implementation bias (single- and double-blind trials), measurement bias (blinding of outcome indices), follow-up bias (structural integrity of data), reporting bias (selective reporting of study results), and other bias (other risks). We assessed risks as low, unclear, and high in ascending order.

Statistical analysis

Software RevMan5.3 and State16.0 were used to evaluate the literature's quality, combine effect sizes, test for heterogeneity, subgroup analysis, forest plot, and funnel plot, and perform sensitivity and publication bias tests on the data. (1) Model selection. Cochran's Q test was used to determine the heterogeneity between studies, taking $P<0.1$ as the level of significance and quantitatively evaluating the heterogeneity by the I^2 value, in which 0%, 25%, 50%, and 75% indicated no heterogeneity, mild heterogeneity, moderate heterogeneity, and high heterogeneity, respectively [23]. The fixed-effects model was applied when there was no significant heterogeneity ($I^2<50\%$);otherwise,the random-effects model was used. (2) Effect size indicators. Because the ending indicators of the literature data are continuous variables and the measurement units are different, standard mean difference (SMD) and 95% confidence interval were chosen as the effect size indicators, in which $SMD<0.2$ is infinitesimal effect size, $0.2\leq SMD\leq 0.5$ is a small effect size, $0.5\leq SMD\leq 0.8$ is a medium effect size, and $SMD\geq 0.8$ is a large effect size [24]. (3) Data encoding and conversion. First, because of multiple test indicators for assessing sleep disorders in some RCT experiments, to avoid the increase of weights caused by double calculation [25], we selected the commonly used indicators for benefit merging [26]. Second, we coded the intervention time of aerobic exercise across the literature. Specifically, we kept the original value if the intervention time was fixed. If it was an interval range (e.g., 50 min to 60 min), the average of the range was taken [27, 28] (the converted intervention time was 55 min). Finally, because there is a possibility of interference of baseline differences between studies in the combined analysis using the post-test data of the intervention and control groups, which leads to errors in the analysis results [29], the study used the Cochrane Handbook's recommendation of the change score data as a data index, i.e., the mean (Mean) and standard deviation (SD) of the pre-and post-test differences between the intervention and control groups), calculated by the formula:

$$\mathrm{SD}_{\mathrm{variation}} = \sqrt{\mathrm{SD}^2\mathrm{pre} + \mathrm{SD}^2\mathrm{post} - (2 \times \mathrm{R} \times \mathrm{SDpre} \times \mathrm{SDpost})} \quad (1)$$

$$\mathrm{Mean}_{\mathrm{variation}} = \mathrm{Mean}_{\mathrm{post}} - \mathrm{Mean}_{\mathrm{pre}} \quad (2)$$

Note: In formula (1), the R coefficient is 0.5 [30].

Pre means pre-intervention, Post means post-intervention

Results

Study selection

A total of 1458 documents were obtained by searching databases such as Web of Science, PubMed, Springer, Science Direct, China Knowledge Network, Wanfang, and VIP. Subsequently, the resulting literature was subjected to duplicate screening, title screening, abstract screening, experimental design screening, data index screening, etc. A total of 16 articles and 19 RCT studies that met the requirements of the systematic analysis were finally included (see Fig. 1).

Characteristics of the studies included in the meta-analysis

The sample size of the 19 studies totaled 1867, with 885 and 982 subjects in the experimental and control groups, respectively. The subjects were menopausal women with age range of 47.8–69.7 years, a baseline PSQI of 5.51–12.69, an ISI of 14.1–16.9, and a KMI of 2.65–3.1. The intervention modalities were all aerobic exercise, including yoga, Pilates, walking, muscle stretching, aerobic dance, aerobic pedal exercise, and Baduanjin. The weekly interventions ranged from 1 to 7 times/week, with 2 to 3 times/week predominating. The range of intervention time was 15 min ~ 90 min/session, with 60 min/session being the most common—the intervention period they have spanned from 6 to 20 weeks, with 12 weeks predominating. The control group maintained their daily activity habits or received relevant health education. Indicators used in the literature to evaluate sleep disorders included

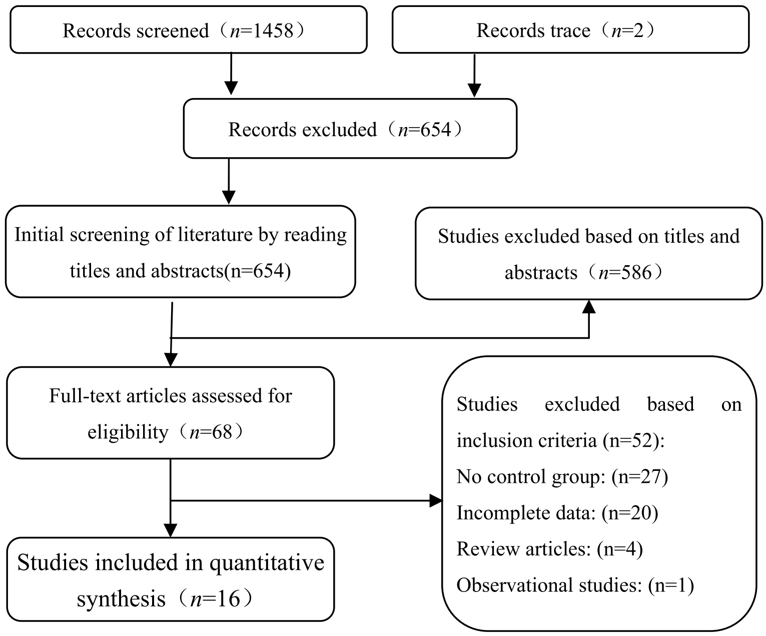

Fig. 1 Literature screening flow chart

polysomnography, insomnia severity index, Pittsburgh Sleep Index Scale, Sleep Activity Recorder, and Cooperman Scoring Index, with the Pittsburgh Sleep Index Scale being the most prevalent (see Table 2). To systematically analyze and explore the effects of aerobic exercise on the sleep quality of menopausal women from the perspective of motor skill learning and control, the aerobic exercise programs included in the literature were categorized into dynamic exercise (e.g., walking, stepping, etc.), static exercise (e.g., yoga, muscle stretching, etc.), and combination of dynamic and static exercise (e.g., Ba Duan Jin fitness qigong, etc.). Among them, static exercise refers to the form in which a single movement pattern is characterized by active or passive elongation or contraction of muscles, ligaments, etc., to the maximum range of motion of the joints and maintained for a particular time; Dynamic exercise is based on the structure of periodic or non-periodic single or set movements in the form of repetitive muscle "contraction-diastole," involving many skeletal and muscular systems. In contrast, the combination of active and static exercise forms has the characteristics of both dynamic and static exercise forms. It may be characterized by a soft, stretching, and static-kinetic combination in the pattern of movements. In addition, according to the organization of aerobic exercise interventions, practice sites, and the interaction and communication status of the subjects, aerobic exercise is classified into three types of practice modes: individual exercise, group exercise, and mixed exercise (a combination of group and personal). Among them, the particular exercise mode was characterized by the lack of unified exercise such as curriculum teaching; the exercise rhythm could be adjusted according to the psychological and physiological conditions of the subjects. The exercise content and site had flexibility characteristics, such as autonomy and selectivity. The prominent feature was the lack of interactive communication between subjects in the social scene. On the other hand, collective practice is manifested in the organization of course teaching, with the practice process led by coaches and with vital stipulations in practice content, practice rhythm, etc. Its prominent feature is that it can provide many social interaction scenarios for the subjects in the practice process. Mixed practice combines the two, such as a short individual practice at home after participating in a program intervention.

Risk of bias within studies

To assess the quality of research evaluations, a bias risk assessment was conducted on 19 included studies. The results showed that 18 studies used random allocation, 17 studies had no selective reporting bias, and 7 implemented allocation concealment before the experimental grouping. Only 4 studies were assessed as low risk of bias in imposing blinding of participants and researchers, as most studies had signed informed consent forms with participants before the experiment, which might have revealed information about the study. However, during the experiment, most studies used exercise interventions conducted by coaches or

Table 2 List of basic information of the included literature ($n = 19$)

Author/year	Sample size		Age ($M \pm SD$) /y	Sports format	intervention time	Intervention Frequency	Intervention period	Exercise Methods	Evaluation indicators
	EG	CG							
Afonso[a] 2012 [31]	15	15	50～65	yoga	60 min\times	2times/week	16 week	GT	PSG; ISI
Afonso[b] 2012 [31]	14	15	50～65	muscle stretching	60 min\times	2times/week	16 week	GT	PSG; ISI
Aibar-Almazán 2019 [32]	55	52	EG:69.9 ± 7.83 CG:66.7 ± 10.1	Pilates	60 min\times	2times/week	12 week	GT	PSQI
Amalia 2021 [19]	12	12	EG:53.0 ± 4.8 CG:53.2 ± 5.7	body movement	90 min\times	2times/week	12 week	NR	PSQI
Buchanan [a]2017 [33]	52	80	EG:55.3 ± 3.9 CG:54.2 ± 3.7	yoga	90 min\times	1times/week	12 week	GT&PT	AG
Buchanan [b]2017 [33]	54	80	EG:55.6 ± 3.5 CG:54.2 ± 3.7	Treadmill;Elliptical; Stationary Bike	50 min\times	3times/week	12 week	PT	AG
Carcelén-Fraile 2022 [20]	57	60	EG:69.7 ± 6.1 CG:69.7 ± 6.7	eight pieces of brocade brocadebrocade	60 min\times	2times/week	12 week	GT	PSQI
Elavsky[a] 2007 [22]	63	39	EG:50.5 ± 3.4 CG:48.6 ± 3.5	walk	60 min\times	3times/week	16 week	PT	PSQI
Elavsky[b] 2007 [22]	61	39	EG:50.0 ± 3.7 CG:48.6 ± 3.5	yoga	90 min\times	2times/week	16 week	GT	PSQI
Innes 2012 [34]	8	10	EG:58.4 ± 6.3 CG:58.9 ± 9.1	yoga	90 min\times	3times/week	8 week	GT&PT	PSQI
Jing Zhang 2014 [35]	54	57	EG:47.8 ± 4.5 CG:48.6 ± 5.2	walk	30 min\times	3times/week	12 week	GT&PT	KMI
Newton 2014 [36]	95	131	EG:54.3 ± 3.9 CG:54.2 ± 3.5	yoga	45 min\times	2times/week	12 week	GT&PT	PSQI; ISI
Serrano-Guzmán 2016 [37]	35	32	EG:69.0 ± 4.4 CG:69.4 ± 3.2	aerobic dance	50 min\times	3times/week	8 week	GT	PSQI; Sleep Diary
Sternfeld 2014 [21]	79	131	EG:55.8 ± 3.6 CG:54.2 ± 3.5	Treadmill;Elliptical;Stationary Bike	50 min\times	3times/week	12 week	PT	ISI; PSQI
Susanti 2022 [38]	95	92	EG:52.3 ± 4.2 CG:52.5 ± 3.9	yoga	75 min\times	3times/week	20 week	PT	PSQI
Tadayon 2016 [18]	56	56	EG:52.30 ± 1.6 CG:52.48 ± 1.7	walk	NR	7times/week	12 week	PT	PSQI
ZONG-YAN CAI 2014 [17]	10	9	EG:57.6 ± 0.6 CE:59.3 ± 1.1	Group Aerobic Pedal Exercise	85 min\times	3times/week	10 week	GT	PSQI
Jing Hao et al. 2013 [39]	55	58	EG:49.9 ± 3.7 CG:49.6 ± 4.3	eight pieces of brocade	45 min\times	3times/week	10 week	GT	KMI
Avis 2014 [40]	15	14	EG:53.5 ± 2.9 CG:52.8 ± 3.0	yoga	90 min\times	1times/week	10 week	GT&PT	PSQI

[a] EG is the intervention group; CG is the control group; GT is group practice; PT is individual practice; GT&PT is group and individual practice

[b] NR indicates that no definitive data were reported

temporary workers unrelated to the research, and for some interventions conducted by researchers, methods with a blinding setting role were also used, thus reducing the risk of implementation bias. Additionally, 5 studies blinded the evaluators during the data processing phase of the results; one study presented other sources of bias risk (see Fig. 2).

Results of syntheses

Overall effectiveness of aerobic exercise intervention for sleep disorders in menopausal women

To systematically evaluate the overall effect of aerobic exercise in improving sleep disorders in menopausal women, effect size tests were performed on the 19 included RCT studies. The studies had moderate heterogeneity ($I^2 = 70\%$, $P < 0.001$), so the random-effects model

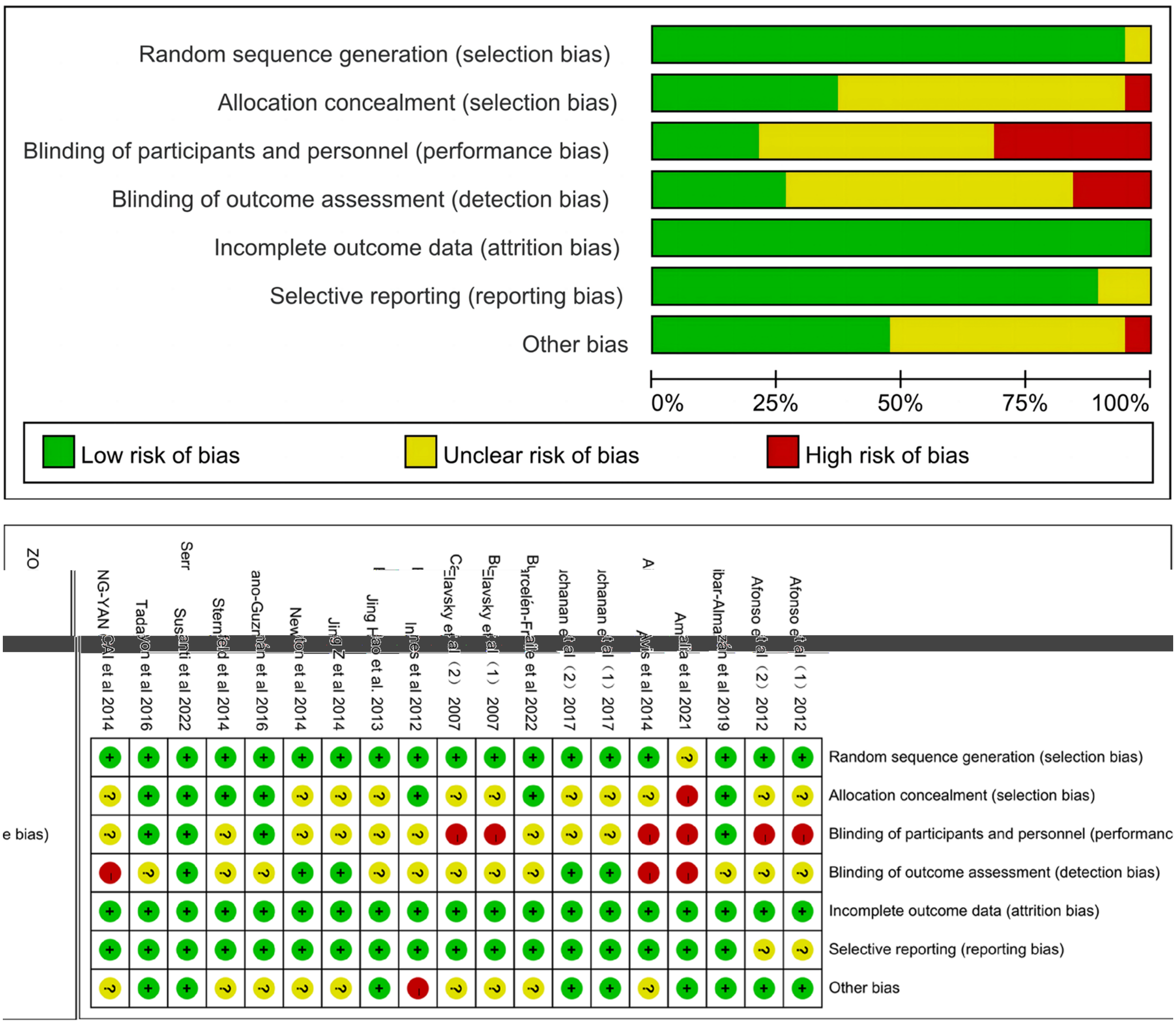

Fig. 2 Schematic diagram of the cochrane risk of bias assessment

combined effect sizes. The results of the study showed that the combined effect size of aerobic exercise intervention for sleep disorders in menopausal women was equal to -0.52(95% CI: -0.71, -0.34, $P<0.001$), and the 95% CI was located on the left side of the null vertical line, suggesting that aerobic exercise can effectively improve sleep disorders in menopausal women (see Fig. 3).

Terminological analysis of the effect of aerobic exercise improving sleep disorder in climacteric women

Even though aerobic exercise was found to be effective in improving sleep disorder in menopausal women, the combined effect sizes were moderately heterogeneous ($I^2=70\%$, $P<0.001$), suggesting that several moderating variables may influence the effect of the intervention. Because of this, based on the components of athletic training, the exercise characteristics of the female population, and the characteristics of the included data, subgroups were set up to analyze the five training elements of aerobic exercise: intervention frequency, intervention time, intervention period, exercise form, and exercise mode (see Table 3), aiming to explore the source of heterogeneity and to address the training issues of "what to practice," "how much to practice," and "how to practice."

Subgroup analyses

Intervention frequency subgroups

Subgroup analyses by intervention frequency revealed no heterogeneity in the 1-time/week subgroup ($I^2=0\%$, $P=0.86$), mild heterogeneity in the 2-time/week subgroup ($I^2=25\%$, $P=0.24$), and high heterogeneity in the

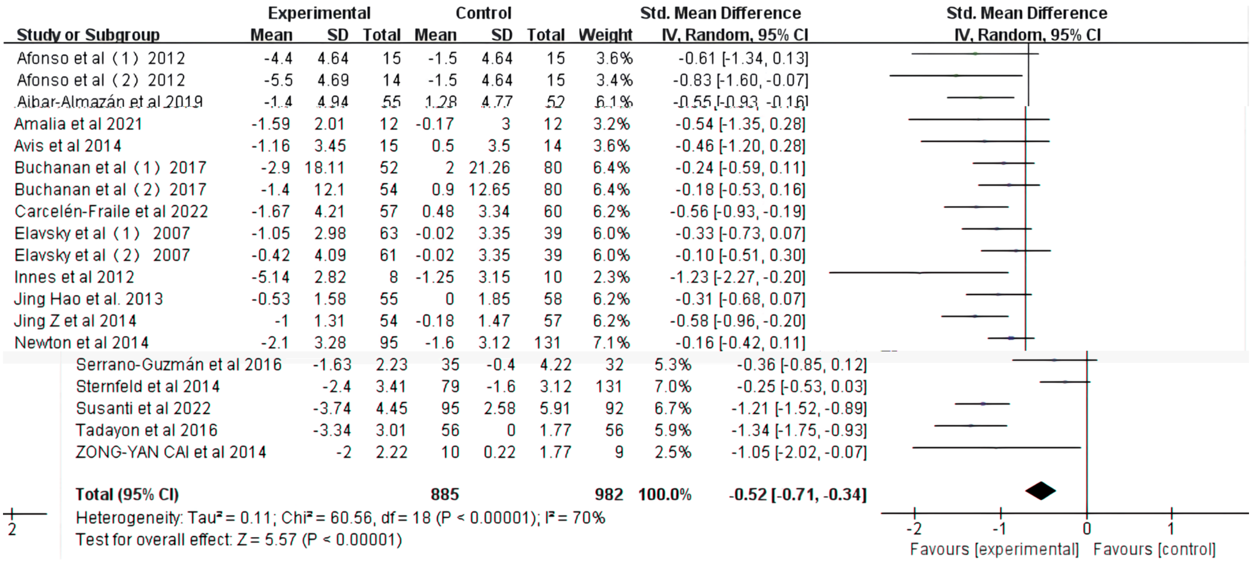

Fig. 3 Forest Graph of the overall effect of aerobic exercise intervention on sleep disorders in menopausal women

Table 3 The effect of training factors on aerobic exercise intervention in menopausal women with sleep disorders

subgroup	Criteria for grouping	Literature and sample size	heterogeneity test			Effect size and 95% confidence interval	two-tailed test	
			x^2	*P*	I^2		*Z*	*P*
Intervention Frequency	1times/week [33, 39, 40]	3(274)	0.29	0.86	0%	-0.29(-0.53, -0.05)	2.38	0.02
	2times/week [19, 20, 22, 31, 32, 36]	7(633)	8.00	0.24	25%	-0.35(-0.51, -0.20)	4.37	< 0.001
	3times/week [17, 21, 22, 33, 35, 37, 38]	8(848)	Pre:30.14 Post:7.62	Pre: < 0.001 Post:0.27	Pre:77% Post:21%	-0.57(-0.89, -0.26) -0.36(-0.52, -0.20)	3.56 4.48	< 0.001 < 0.00001
Intervention Time	30 ~ 50 min [21, 33, 35–37, 39]	6(861)	3.77	0.58	0%	-0.27(-0.41, -0.14)	3.93	< 0.001
	60 min [20, 22, 31, 32]	5(385)	1.66	0.80	0%	-0.52(-0.73, -0.32)	4.97	< 0.001
	70 ~ 90 min [17, 19, 22, 33, 34, 38, 40]	7(509)	Pre:26.59 Post:6.83	Pre: < 0.001 Post:0.23	Pre:77% Post:27%	-0.64(-1.08, -0.21) -0.33(-0.56, -0.11)	2.88 2.88	0.004 0.004
Intervention Period	8 ~ 10 week [17, 34, 37, 40]	4(133)	3.26	0.35	8%	-0.58(-0.93, -0.22)	3.21	0.001
	12 week [18–21, 32, 33, 35, 36]	9(772)	Pre:29.18 Post:7.63	Pre: < 0.001 Post:0.37	Pre:73% Post:8%	-0.47(-0.70, -0.23) -0.33(-0.45, -0.20)	3.93 5.19	< 0.001 < 0.00001
	16 ~ 20 week [22, 31, 38, 39]	6(561)	Pre:24.87 Post:3.44	Pre: < 0.001 Post:0.49	Pre:80% Post:0%	-0.55(-0.96, -0.14) -0.32(-0.53, -0.11)	2.66 3.03	< 0.01 0.002
Exercise form	static motion [22, 31, 33, 34, 36, 38, 40]	8(751)	Pre:34.61 Post:7.87	Pre: < 0.001 Post:0.25	Pre:80% Post:24%	-0.55(-0.92, -0.18) -0.27(-0.44, -0.10)	2.94 3.12	0.003 0.002
	dynamic movement [17–19, 21, 22, 32, 33, 35, 37]	9(886)	Pre:24.90 Post:5.95	Pre:0.002 Post:0.55	Pre:68% Post:0%	-0.53(-0.79, -0.28) -0.37(-0.52, -0.23)	4.09 5.07	< 0.001 < 0.00001
	Combination of dynamic [20, 39]	2(230)	0.93	0.33	0%	-0.43(-0.70, -0.17)	3.25	0.001
Practice mode	Personal exercise [18, 21, 22, 33, 38]	5(745)	Pre:40.38 Post:0.28	Pre: < 0.001 Post:0.87	Pre:90% Post:0%	-0.66(-1.15, -0.17) -0.25(-0.44, -0.05)	2.64 2.52	< 0.01
	group exercise [17, 19, 20, 22, 31, 32, 37, 39]	8(582)	6.78	0.56	0%	-0.44(-0.60, -0.28)	5.31	< 0.001
	Individual and group exercises [33–36, 40]	5(516)	6.63	0.16	40%	-0.32(0.50, -0.14)	3.54	< 0.001

[a] Pre stands for before exclusion; Post stands for after exclusion

[b] Subgroups analyzed were those with more than 1 article in the literature and complete data

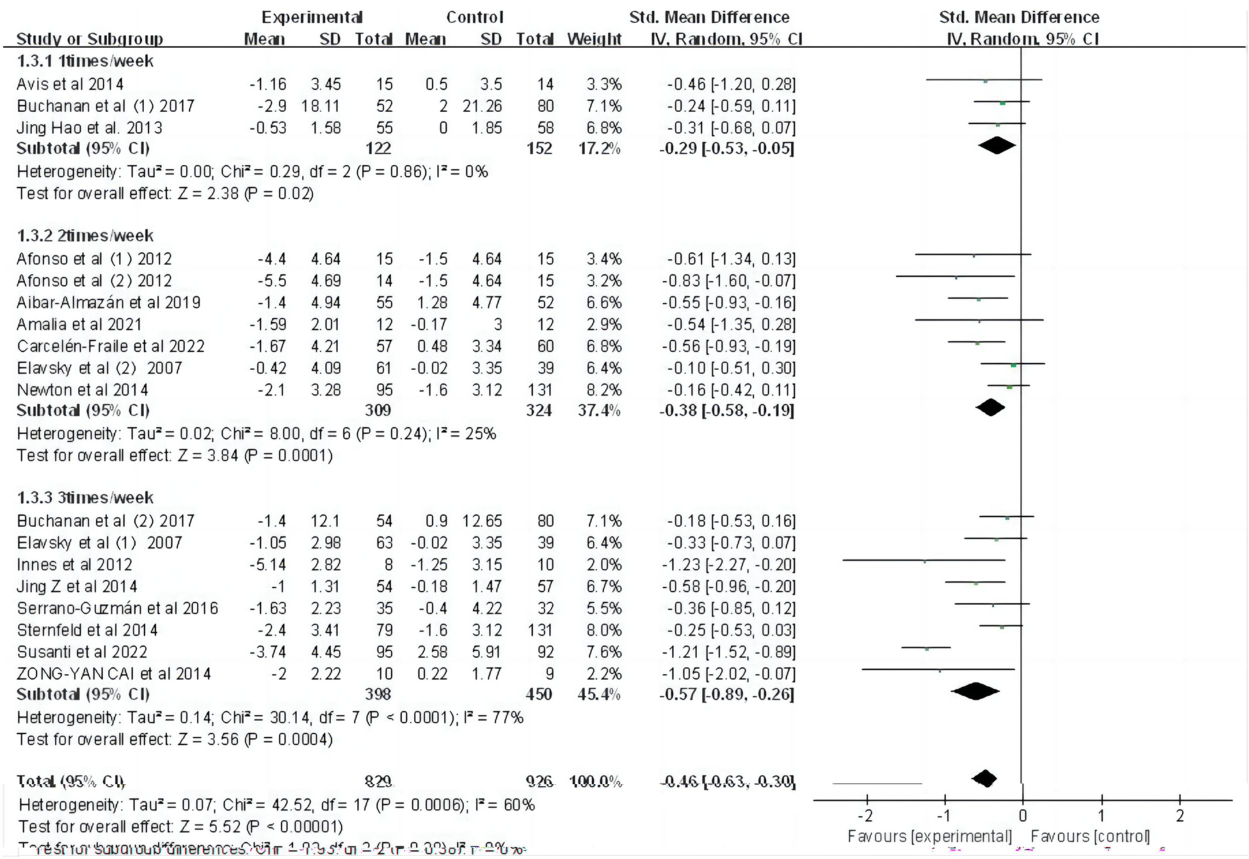

Fig. 4 Forest plot of intervention frequency subgroups

3-time/week subgroup ($I^2=77\%$, $P<0.001$). After excluding 1 study by Susanti et al. [38], the three times/week subgroup was significantly less heterogeneous ($I^2=21\%$, $P=0.27$). A closer analysis found that this study had significantly more intervention cycles (20 weeks) than the cohort study for the same number of weekly interventions. In particular, the supervision mechanism during the exercise process was different from that of the same group of studies, as shown in the following: after completing the centralized training, the subjects practiced alone at home with the help of instructional videos and manuals and the whole process was only encouraged and urged by the researcher, with no trainer to guide and correct the errors; although the inclusion criteria strictly limited the use of medication by the experimental subjects, the paper authors said that due to the influence of the supervision mechanism, it was not clear if the subjects used potentially sleep medication or not in the experimental process—likely sleep medications. After the exclusion of this study, the combined effect size decreased (SMD after exclusion = -0.36, 95% CI: -0.52, -0.20), but the result was still significant ($P<0.001$), so the study was retained for the analysis. According to the analysis of the study, the effect sizes among the three groups in the intervention frequency subgroup were moderately heterogeneous ($I^2=60\%$, $P<0.001$), suggesting that the frequency of intervention somewhat influences the effect of aerobic exercise intervention for sleep disorders in menopausal women. The three times/week group had the most significant effect size in intervening for sleep disorders in menopausal women (SMD = -0.57, 95% CI: -0.89, -0.26, $P<0.001$), followed by two times/week (SMD = -0.38, 95% CI: -0.58, -0.19, $P<0.001$), and lastly, one time/week (SMD = -0.29, 95% CI: -0.53, -0.05, $P=0.02$)(see Fig. 4).

Subgroups by time of intervention

Subgroup analysis by intervention time revealed no heterogeneity in the 30–50 min group ($I^2=0\%$, $P=0.58$) and 60 min group ($I^2=0\%$, $P=0.80$), and a high degree of heterogeneity in the 70–90 min group ($I^2=77\%$, $P<0.001$). When 1 study by Susanti et al. [38] (2022) was excluded, the heterogeneity of the 70–90 min group was significantly reduced ($I^2=27\%$, $P=0.23$). A closer analysis revealed that the study by Susanti et al. had the same single intervention timeframe as the cohort study but significantly more intervention cycles, the form of the exercise was individual practice, and the supervision mechanism in the exercise differed from the cohort study. After the exclusion of this study, the combined effect size of the 70–90 min group was reduced (SMD = -0.33 after the exclusion, 95% CI: -0.56, -0.11), but the result was still significant (P = 0.004), so the study was retained for the training science analysis. According to the analysis, the effect sizes among the three groups in the intervention time subgroup were moderately heterogeneous (I^2 = 60%, P < 0.001), suggesting that the duration of a single intervention somewhat influenced the effect of aerobic exercise intervention for sleep disorders in menopausal women. Among them, the 70–90 min group had the largest effect size in intervening sleep disorders in menopausal women (SMD = -0.64, 95% CI: -1.08, -0.21, P = 0.004), followed by the 60-min group (SMD = -0.52, 95% CI: -0.73, -0.32, P < 0.001), the 30–50 min group with the smallest amount of benefit (SMD = -0.27, 95% CI: -0.41, -0.14, P < 0.001)(see Fig. 5).

Intervention cycle subgroups

Subgroup analysis by intervention cycle revealed mild heterogeneity (I^2 = 8%, P = 0.35) in the 8- to 10-week group, moderate heterogeneity (I^2 = 73%, P < 0.001) in the 12-week group, and a high degree of heterogeneity (I^2 = 80%, P < 0.001) in the 16- to 20-week group. After excluding 1 study by Tadayon et al. [18], the heterogeneity of the 12-week group decreased significantly (I^2 = 8%, P = 0.37). Further analysis revealed that the study by Tadayon et al. was the same as its cohort in terms of intervention period and intervention mode, but instead of setting a fixed intervention time and intervention frequency, it provided subjects with a target number of steps per day, monitored the number of steps walked per day by using a pedometer, and had weekly reminders and recordings of the weekly number of steps by the researcher. In addition, after excluding 1 study by Susanti et al. [38], the heterogeneity of the 16- to 20-week group decreased significantly (I^2 = 0%, P = 0.49). Further analysis revealed that the study by Susanti et al. differed from its cohort in terms of the monitoring mechanism of the intervention. After excluding the two studies, the combined effect sizes of the 12-week group (SMD = -0.33, 95% CI: -0.45, -0.20, P < 0.001) and the 16-20 week group (SMD = -0.32, 95% CI: -0.53, -0.11, P = 0.002) were statistically significant

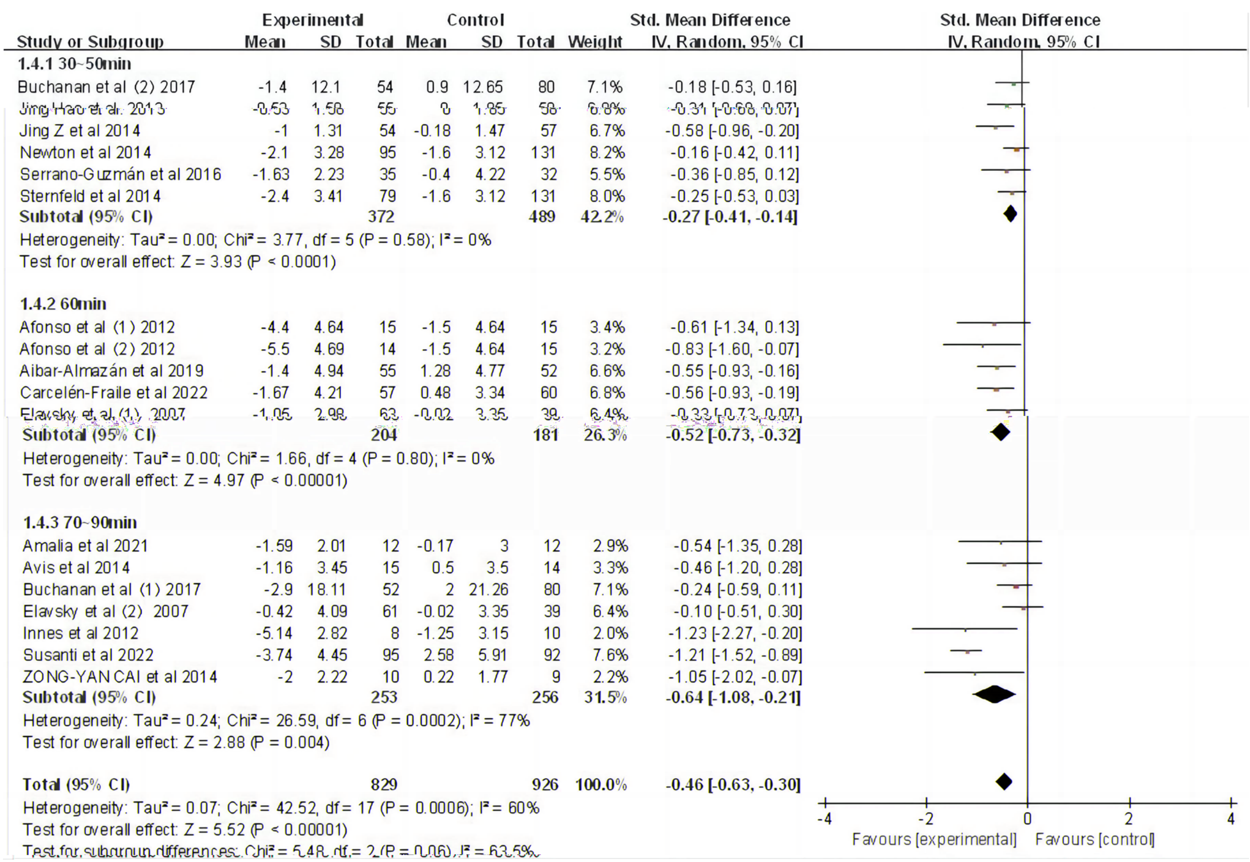

Fig. 5 Forest plot of intervention time subgroups

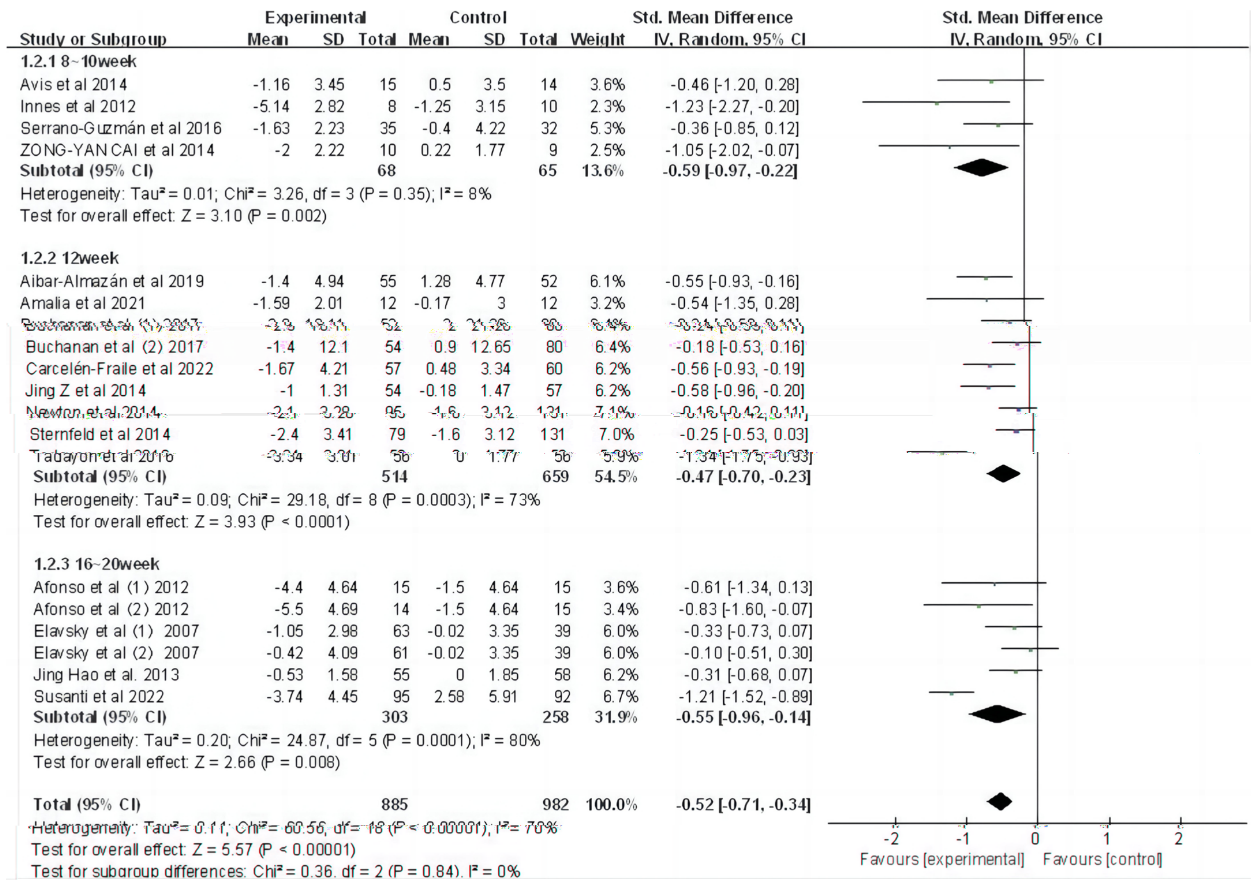

Fig. 6 Forest plot of Intervention cycle subgroups

although they decreased, and the two studies were therefore retained for training academic analysis. According to the analysis, the effect sizes among the three groups in the intervention cycle subgroup were moderately heterogeneous ($I^2=70\%$, $P<0.001$), suggesting that the effect of aerobic exercise intervention for sleep disorders in menopausal women is somewhat influenced by the intervention cycle. Among them, the 8–10 weeks group had the most significant effect size (SMD = -0.59, 95% CI: -0.97, -0.22, $P=0.35$), followed by the 16–20 weeks group (SMD = -0.55, 95% CI: -0.96, -0.14, $P<0.01$), and the smallest effect size was found in the 12 weeks group (SMD = -0.47, 95% CI: -0.70, -0.23, $P<0.001$)(see Fig. 6).

Exercise form subgroups

The study found high heterogeneity in the static exercise form group ($I^2=80\%$, $P<0.001$), moderate heterogeneity in the dynamic exercise form group ($I^2=68\%$, $P=0.002$), and no heterogeneity in the combined active and static form group ($I^2=0\%$, $P=0.33$). After excluding 1 study by Susanti et al. [38], the heterogeneity of the static exercise form group decreased significantly ($I^2=24\%$, $P=0.25$). Further analysis revealed that although the study by Susanti et al. was identical to the cohort study in terms of exercise form, its subjects practiced individual exercises, and the mechanism of supervision during exercise differed from the cohort study. In addition, heterogeneity in dynamic exercise forms group also decreased significantly after excluding 1 study by Tadayon et al. [18] ($I^2=0\%$, $P=0.55$). Further analysis revealed that the study by Tadayon et al. differed from its cohort in its aerobic exercise intervention design in that it did not set a fixed duration for a single intervention but instead provided subjects with a target number of steps per day and used a pedometer to monitor the number of steps walked per day. After the exclusion of the two studies, the combined effect sizes for the static (SMD = -0.27, 95% CI: -0.44, -0.10, $P=0.002$) and dynamic (SMD = -0.37, 95% CI: -0.52, -0.23, $P<0.001$) forms of exercise groups were statistically significant although they decreased, so the two studies were retained for the training science analysis. According to the analysis, the effect sizes among the groups in the aerobic exercise form subgroup were

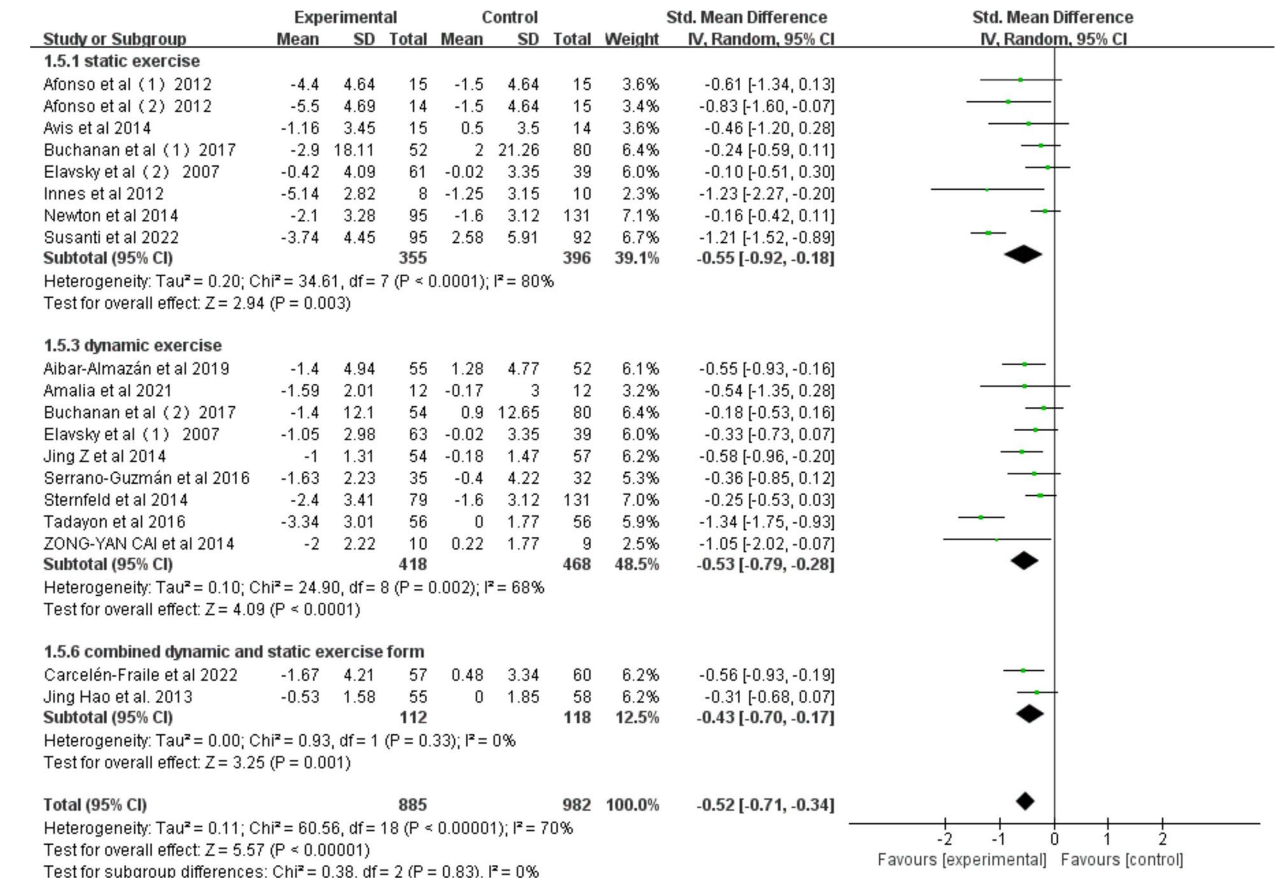

Fig. 7 Forest plot of exercise form subgroups

moderately heterogeneous ($I^2 = 70\%$, $P < 0.001$), indicating that the form of exercise somewhat influenced the effect of aerobic exercise intervention for sleep disorders in menopausal women. Among them, the static exercise form group had the most significant effect size (SMD = -0.55, 95% CI: -0.92, -0.18, $P = 0.003$), followed by dynamic exercise form (SMD = -0.53, 95% CI: -0.79, -0.28, $P < 0.001$) and combined dynamic and static form (SMD = -0.43, the 95% CI: -0.70, -0.17, $P = 0.001$)(see Fig. 7).

Subgroups of practice mode

The analysis revealed high heterogeneity in the individual exercise group ($I^2 = 90\%$, $P < 0.001$). In contrast, the degree of heterogeneity was none ($I^2 = 0\%$, $P = 0.56$) and mild ($I^2 = 40\%$, $P = 0.16$) in the group exercise group and the combined individual and group exercise group, respectively. The degree of heterogeneity in the individual practice group was significantly reduced ($I^2 = 0\%$, $P = 0.87$) after the same exclusion of 2 studies by Susanti et al. [38] and Tadayon et al. [18]. After excluding the two studies, the individual practice group effect size decreased (SMD = -0.25 after exclusion, 95% CI: -0.44, -0.05), but it was still statistically significant ($P = 0.01$), so the two studies were retained for the training science analysis. Based on the analysis, it was clear that there was moderate heterogeneity in the effect sizes among the three groups in the exercise form subgroup ($I^2 = 70\%$, $P < 0.001$), indicating that the effectiveness aspect of aerobic exercise intervention for sleep disorders in menopausal women is somewhat influenced by the exercise form. The most significant effect size was found in the individual exercise group (SMD = -0.66, 95% CI: -1.15, -0.17, $P < 0.01$), followed by the group exercise group (SMD = -0.44, 95% CI: -0.60, -0.28, $P < 0.001$), and the smallest effect size was found in the group combining individual and group exercise (SMD = -0.37, 95% CI: -0.62, -0.12, $P < 0.001$) (see Fig. 8).

Reporting biases publication bias test

Funnel plots and Egger regression analysis were used to test for publication bias in the RCT studies included in this systematic review. The funnel plot results (Fig. 9) showed that the left and right sides were symmetrical. The $t = 1.28$, $p = 0.216$, and 95% CI of bias in Egger's was

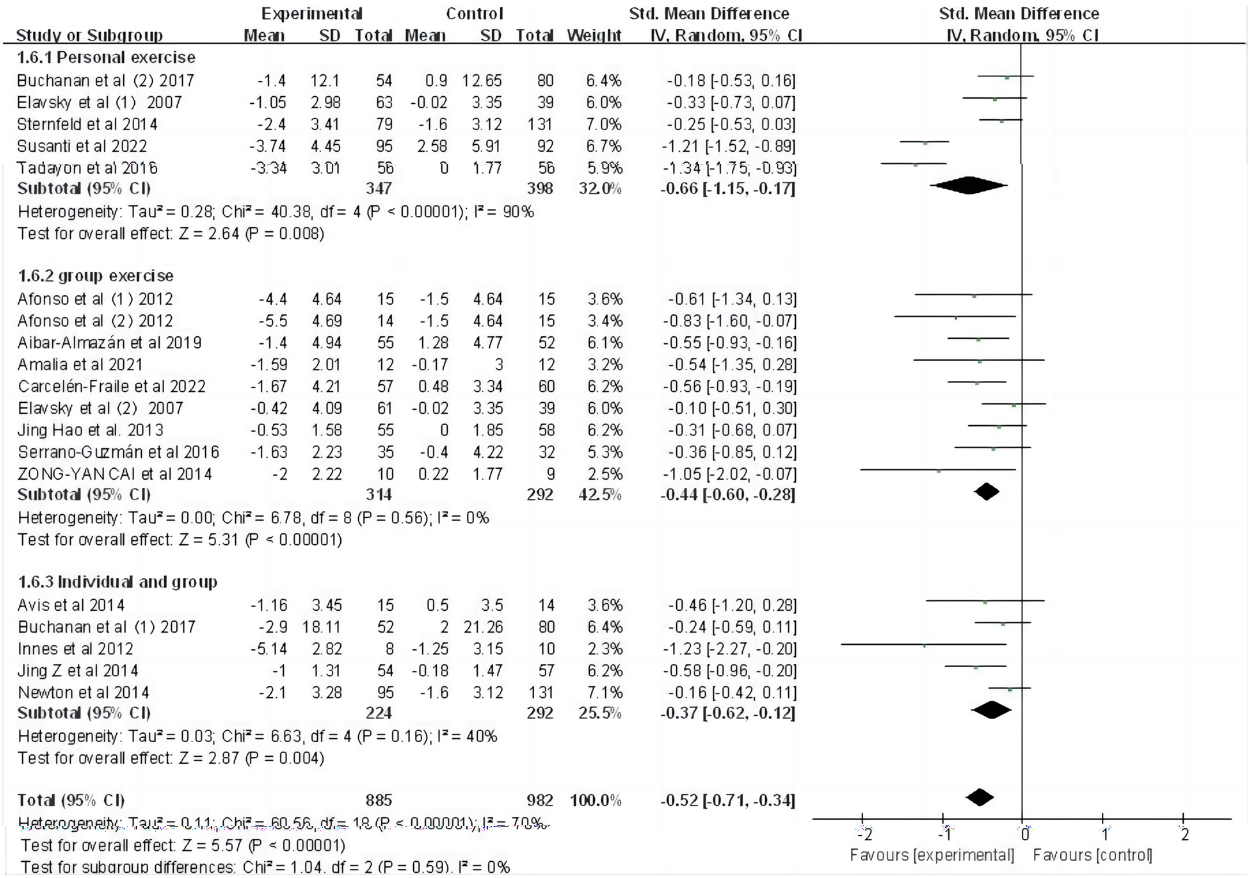

Fig. 8 Forest plot of Practice mode subgroups

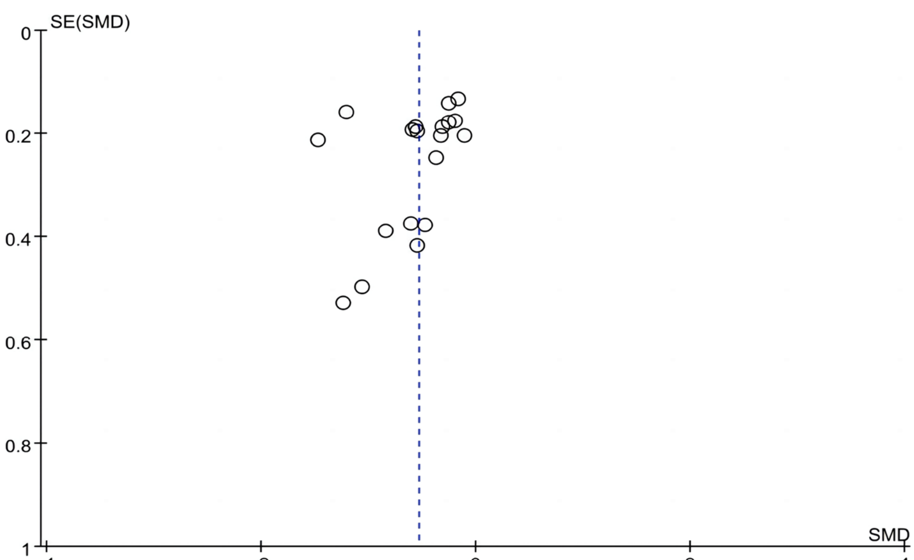

Fig. 9 The funnel plot of publishing bias

(-1.045035, 4.297902), so there was no significant publication bias among the studies.

Sensitivity analyses

To further examine the stability of the systematic review results, sensitivity analyses of the included studies were performed using State16.0 software (see Fig. 10). The results showed that all the included studies had good stability, which was manifested in the fact that there was no significant change in the overall combined results when any of the literature was excluded, indicating that the evaluation results of the effects of aerobic exercise intervention on sleep disorders in menopausal women were relatively stable.

Discussion

Summary of findings

A good night's sleep is essential for the body to eliminate fatigue, improve immunity, and enhance disease resistance. In this study, a systematic review of aerobic exercise interventions for sleep disorders in menopausal women found that aerobic exercise had a significant effect in intervening for sleep disorders in menopausal women compared with the control group (SMD = -0.52, $p < 0.001$). The reason for this is that aerobic exercise can improve sleep disorders in menopausal women by balancing the estrogen secretion mechanism, relieving somatic symptoms, and regulating adverse emotions. Specifically, on the one hand, the decrease of estrogen secretion induced by the decline of ovarian function can directly affect the neurotransmitters related to sleep regulation, as well as body temperature changes, physiological rhythms, and other biological effects of the human body [41], resulting in sleep disorders such as difficulty in falling asleep, easy to wake up, and short sleep in menopausal women. Regular aerobic exercise (e.g., aerobics, jogging, etc.) can significantly increase the level of serum estradiol, which is positively correlated with sleep quality [42, 43].

Meanwhile, Zong-Yan CAI et al. [17] showed that ten weeks of aerobic treadmill exercise could improve sleep problems by increasing melatonin levels in menopausal women. On the other hand, aerobic exercise may also enhance the quality of sleep in menopausal women by way of alleviating vasodilatory symptoms, hot flashes, headaches, palpitations, anxiety, depression, and other bodily or psychological conditions [31, 35, 44]. However, inconsistent with the present results is the study of Elavsky et al. [22], which concluded that moderate-intensity walking and low-intensity yoga exercises did not significantly intervene in sleep disorders in menopausal women. The intervention dose possibly influenced the reason for this. Further, although the study by Elavsky et al. [22]. stipulated that the intervention time was 60 min/session, in practice, it used an incremental increase in the intervention time, specifying that the first intervention time was 15 min/session, and then increased to 40–45 min/session at the fourth month, and did not

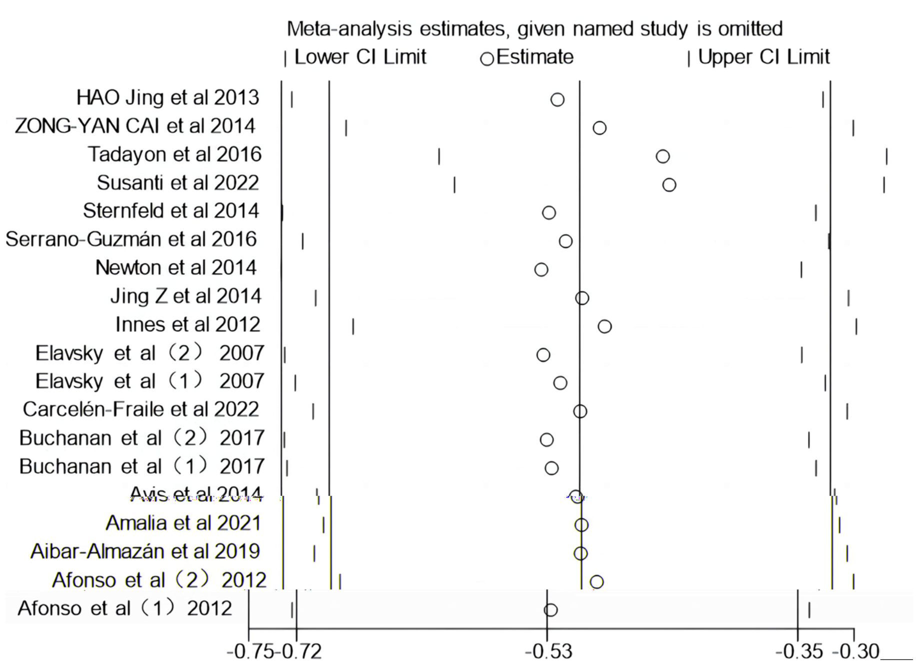

Fig. 10 Sensitivity Analysis plot

specify the magnitude of each increase during the period, which may lead to the inconsistency of the intervention time for each subject or even the overall intervention time not meeting the standard. In addition, the study adopted a low intensity in terms of yoga intervention, which may ultimately lead to a decrease in the effect of the intervention. In conclusion, aerobic exercise has a significant impact on improving sleep disorders in menopausal women. However, the specific effect is affected by training factors such as the intervention dose, aerobic exercise form, and practice mode.

Interpretation

Intervention effects of different frequencies, times, and cycles

Regarding intervention frequency, aerobic exercise intervention three times per week could produce the most excellent effect in improving sleep disorders in menopausal women. The effect gradually decreased with the decrease in the number of weekly interventions. In terms of intervention time, aerobic exercise with a duration of 70–90 min per session was the most effective in improving sleep disorders in menopausal women, followed by 60 min per session, with a minimum effect size of 30–50 min per session, and the overall effect size decreased with decreasing intervention time. This suggests that there is a significant dose relationship for aerobic exercise in intervening for sleep disorders in menopausal women, influenced by the number of interventions and the duration of a single intervention. To find the reasons for this, it was found that the interventions in the RCTs included in this systematic review were low- and moderate-intensity aerobic exercise, except for the study by Zong-Yan CAI et al. [17]. (75%-85% HRR high-intensity aerobic exercise). It is worth noting that participating in high-intensity workouts poses a significant challenge for individuals, especially menopausal women in poor physical condition, when it comes to substantially boosting both the duration of individual exercise sessions and the weekly frequency of these workouts. Consequently, in contrast to engaging in high-intensity exercise, menopausal women are more capable of extending their individual session durations and increasing their weekly exercise frequency during low- to moderate-intensity aerobic activities. By adopting a strategy that involves increasing both session durations and weekly exercise frequencies, they can significantly enhance their daily and cumulative weekly exercise volumes. This optimization leads to refined hormone secretion mechanisms, mitigation of menopause syndrome symptoms, and improved sleep quality. This is consistent with the findings of Tworoger et al. [45], who showed that moderate-intensity aerobic exercise significantly improved subjective sleep quality in menopausal women and that menopausal women who exercised for at least 225 min per week were more likely to fall asleep compared with menopausal women who exercised for less than 180 min/week. Similar results were also seen in a study by Kline CE et al. [46], which elucidated that caloric expenditure of 12 kcal/kg per week (equivalent to performing 190 min/week of moderate-intensity aerobic exercise) was more effective in improving sleep in menopausal women, compared to caloric expenditure of 4 kcal/kg or 8 kcal/kg per week. To further explore whether there is an interactive effect between intervention duration and intervention frequency on the effectiveness of low- to moderate-intensity aerobic exercise in improving sleep disorders among female menopausal individuals, a 3D side-by-side bar chart was plotted based on the analysis results, revealing that the time–frequency combination of 3 sessions/week and 70–90 min/session was the most effective (Fig. 11-a). In addition, in terms of the intervention period, the intervention effect of aerobic exercise was best in the 8–10 weeks group, followed by the 16–20 weeks group, and the smallest was the 12 weeks group, but the overall effect did not increase with the prolongation of the intervention period, so it was not possible to predict the trend of the intervention effect of low- and moderate-intensity aerobic exercise after 20 weeks. Admittedly, previous studies have analyzed the impact of 24-week as well as 1-year aerobic exercise interventions on sleep disorders in menopausal women [45, 46]. Some have elucidated that the improvement of sleep quality in menopausal women increased with the prolongation of the intervention cycle of aerobic exercise [47]. However, the above studies were not included due to a mismatch of data or non-RCT studies, which did not allow for a combined analysis of effects. Considering that the intervention effect may be affected by the interaction between the intervention period and weekly exercise volume, the intervention time and intervention frequency were now converted to weekly exercise volume, and 3D side-by-side bar chart of the effect values of weekly exercise volume as well as the effect values of each group in the subgroups of the intervention period were plotted to find out that, regardless of whether the weekly exercise volume meets the recommended adult activity threshold of 150 min per week, the intervention effect is consistently optimal in the 8–10 week group. Notably, when the weekly exercise volume reaches or exceeds this recommendation, the magnitude of the intervention effect is the highest during the 8–10 week period. (Fig. 11-b). In summary, low to moderate-intensity aerobic exercise taken three times/week, 70–90 min/session, for 8–10 weeks in menopausal women can significantly improve sleep disorders.

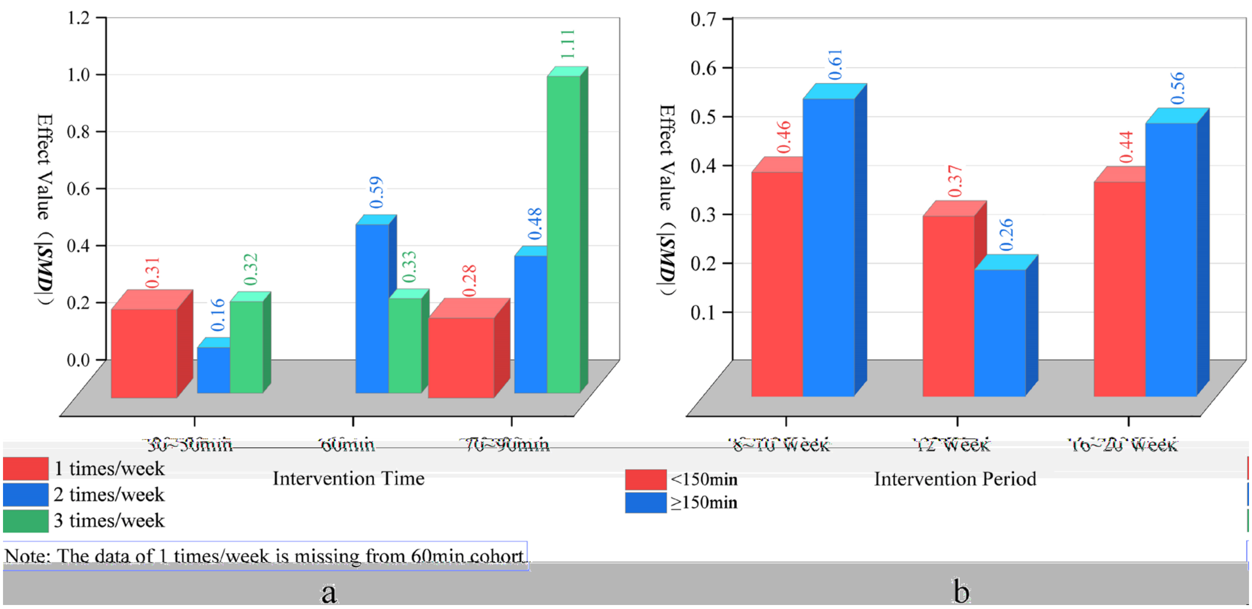

Fig. 11 Intervention effect plot of different intervention frequency, time, and period. Note: Missing 1 time/week in the 60 min/times group

Intervention effects of different exercise form

The systematic review results showed that aerobic exercise in the form of static, dynamic, and combined dynamic and static exercises were all influential in intervening sleep disorders in menopausal women. However, the effects of different forms of aerobic exercise varied, with static exercise being the most effective, followed by dynamic and combined dynamic and static forms, respectively. Further analysis revealed that this may be related to the specificity of the induction mechanism of the psychological and physiological effects of different forms of aerobic exercise in menopausal women. Firstly, static exercise (see Sect. 2.2 for specific definitions) can reduce muscle tension by stretching muscle ligaments and regulating respiration, reducing symptoms such as anxiety and depression [48] and improving sleep in menopausal women. Tworoger et al. [45]suggested that static stretching and stretching exercises of muscles work on a similar mechanism to progressive muscle relaxation training, which has been shown to improve sleep in patients regarding subjective or objective sleep quality [49]. In addition, some studies have shown that aerobic exercise in the form of static stretching, such as yoga, can also increase the concentration of γ-aminobutyric acid (inhibitory neurotransmitter) in the brain [50], decrease sympathetic tone and excite the parasympathetic nerves [51, 52] which are beneficial in alleviating the symptoms of vasodilatation as well as improving the quality of sleep in menopausal women. Secondly, dynamic exercise (see Sect. 2.2 for specific definition) has greater intensity than static exercise due to more significant muscle mobilization, larger movement amplitude, more complex movement structure, etc., which can better promote the body's respiratory and heart rate, increase blood flow rate, and increase perspiration.

Moreover, a large amount of sweating can make the concentration of appetite peptide, which maintains arousal and participates in the immune response, downregulate to promote sleep and anti-insomnia effect [53, 54]. Finally, the combination of dynamic and static exercise can effectively improve estrogen levels, relieve anxiety and depression, and improve sleep quality in menopausal women because it possesses the functional characteristics of both dynamic and static exercise forms [20, 55]. the conclusion that "The effect of static exercise is better than that of dynamic exercise and the combination of dynamic and static exercise" can be explained as follows. Although dynamic aerobic exercise has a higher intensity, which can help increase serum estradiol levels and relieve menopausal syndrome [56, 57], studies have shown that higher exercise intensity may trigger or even exacerbate hot flashes and other symptoms that affect sleep [58]. Furthermore, static aerobic exercise not only possesses certain functional effects akin to dynamic aerobic exercise, but also exhibits excellent results in regulating negative moods. And, there are fewer reports of adverse reactions associated with static exercise. Based on the evidence, it is likely that static aerobic exercise is more conducive to improving the mood disorders affecting sleep, such as anxiety, depression, agitation, etc., in menopausal women, and thus more beneficial for enhancing sleep quality. It is worth noting that the results of this systematic review showed that the intervention effect of the combined dynamic and static exercise forms was smaller than the other two groups. However, a non-RCT study reported that (Ba Duan Jin) was more effective than the dynamic exercise form (walking) in improving insomnia in menopausal women [59], which suggests that more RCTs are needed to validate its effect in the future. In summary, aerobic exercise in the form of static exercise, dynamic exercise, and the combination of dynamic and static exercise have sound effects in intervening sleep disorders in menopausal women, with the static aerobic exercise form being the best.

Intervention effects of different practice modes

The systematic review showed that aerobic exercise in individual practice was the most effective in intervening sleep disorders, followed by group practice, and finally, the combination of group and individual. A closer look at the reasons for this suggests that it may be related to the psychological characteristics of menopausal women and the characteristics of the exercise modality. On the one hand, due to the decline of ovarian function and blood estrogen level, menopausal women may have different degrees of anxiety, depression, pessimism, irritability, sensitivity, fear, and other emotional disorders. They are prone to avoiding places and activities where there are many people and noise or things beyond their control. In group exercise, the whole process of exercise intervention is led by the exercise coach, resulting in menopausal women having less control over their personal exercise status, making it challenging to make adaptive adjustments according to their own physical or psychological real-time status, and being easily interfered by their exercise partners.

On the contrary, adopting the individual exercise method can enable menopausal women to increase their control over their internal state and external behavior during exercise. It will not cause anxiety, fear, and avoidance due to the noisy crowd around them. Studies have demonstrated that a stronger sense of control can increase life satisfaction, relieve stress, enhance psychological resilience, and promote subjective well-being [60–62]. On the other hand, due to the large number of exercise partners and the dominance of coaches, group exercise is prone to cause menopausal women to suffer from stimuli from peers, coaches, and other external environments, leading to distraction during exercise. As a matter of fact, during aerobic exercises such as tai chi, yoga, and Pilates, it is necessary to focus one's attention on the breathing rhythm, muscle force pattern, and joint movement amplitude to achieve physical and mental coordination and unity, to prevent sports injuries and to improve the effect of the exercises. Admittedly, the results of this systematic review indicate that individual exercise is superior to group exercise. However, previous studies have shown that the social environment presented by group exercise allows menopausal women to communicate and interact with other participants physically, verbally, and emotionally, thus obtaining multidimensional social support. Social support can enhance women's identity and understanding of sports participation [63], which is critical in increasing exercise continuity among menopausal women. Social support can enhance women's identity and awareness of sports participation [63], vital for improving the continuity of exercise in menopausal women. In conclusion, individual or group exercise is effective in intervening in sleep disorders in menopausal women, and personal exercise is the best; at the same time, menopausal women should choose appropriate exercise methods according to their characteristics in social support, family-work relationships, and symptoms.

Limitations

This systematic review reveals the actual effects of aerobic exercise in intervening sleep disorders in menopausal women and the relationship between training. However, due to the inclusion of the literature and the research methodology, the following limitations are unavoidable: (1) The included literature and the subjects are mainly concentrated in the countries or regions where the research of aerobic exercise in intervening sleep disorders in menopausal women was carried out, such as the United States, China, Spain, Indonesia, etc.Therefore, the results of the study are limited; (2)due to the amount of literature and other reasons, this study only used the overall score of the Sleep Disorders Scale for the combined analysis and did not analyze the sleep duration, sleep latency, daytime dysfunction, and other sub-items of the scale together;(3)in the training analysis, only individual studies reported the quantitative intensity of exercise, which led to the later analysis of the intensity of aerobic exercise, and could not quantify the intensity of exercise to measure the effect of the intervention in a more objective way. Consider the influence of exercise intensity on the intervention effect; (4) some subgroups (e.g., dynamic and static combined form) included a few literature, which may lead to the deviation of the combined effect value from the actual situation; (5) the frequency of intervention in the included literature was mainly concentrated in 1 ~ 3 times/week. Only one study was performed seven times/week, so it was only possible to evaluate the effect three times systematically.However, we believe this may be related to the characteristics of the menopausal female population and that the frequency of 1–3 times of exercise is more in line with the characteristics of this population's time, energy, and disease;(6)Some of the experimental interventions could not participate in the intervention centrally due to the constraints of the experimental conditions which may increase the error of experimental results.

Conclusion

(1)Low- and medium-intensity aerobic exercise has sound effects in intervening sleep disorders in menopausal women, but it is affected by training indicators such as intervention time, intervention frequency, intervention period, exercise form, and practice mode; (2) Low- and medium-intensity aerobic exercise interventions that are conducted three times/week, 70–90 min/time, and last for 8–10 weeks have the best effects in improving sleep disorders; (3)Aerobic exercise in static or dynamic exercise is more effective in improving sleep disorders in menopausal women, of which static aerobic exercise is the most effective. In the actual intervention process, suitable forms of aerobic exercise should be selected by the characteristics of the psychological or physiological conditions of menopausal women; (4)The individual exercise method is the most effective. However, the group exercise method can make menopausal women improve the continuity of exercise by obtaining social support during the exercise process.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12905-024-03477-2.

Supplementary Material 1.

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The registration information for the review is as follows:(1)the register name is "The effect of aerobic exercise on sleep disorder in menopausal women: A systematic review and metaAnalyses",(2) the registration number is CRD42024553454.

Authors' contributions

Yan Jing designed the project and wrote the manuscript.Mingyi Liu developed research ideas.Honglin Tang and Jingjie Cai searched the literature on the impact of sleep disorder in menopausal women and lockdown in aerobic exercise. Zikang Ying and Nianxin Kong extracted and analyzed the data. All authors contributed to the article and approved the submitted version.

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Data availability

Data is provided within the supplementary information files.

Declarations

Ethics approval and consent to participate

This study does not involve any human participants or animals, and therefore, does not require ethical approval.

Competing interests

The authors declare no competing interests.

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