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SYSTEMATIC REVIEW

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The effects of different exercises on weight loss and hormonal changes in women with polycystic ovarian syndrome: a network meta-analysis study

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Abstract

Background Polycystic ovarian syndrome (PCOS) is one of the most common endocrine illnesses. There is evidence that exercise training positively affects on improvement of the pathogenic factors in women with PCOS. On the other hand, some studies reported similar effects of aerobic and resistance exercises or no effect of exercises on the improvement of the pathogenic factors. The aim of the current study was to perform a network meta-analysis of RCTs to evaluate the efficacy of exercises on body mass index (BMI), hormone concentrations, and regular menstruation in women with PCOS.

Methods The search was performed from databases of PubMed, Scopus, and Web of Science with the keywords of exercise, resistance exercise, aerobic exercise, endurance exercise, yoga, polycystic ovary syndrome, randomized controlled trial based on the CONSORT, BMI, sex hormone and regular menstruation from inception until April 15, 2022. Bayesian random-effects network meta-analyses were performed to calculate mean difference and 95% credible intervals.

Results Out of 1140 studies, 19 were eligible for inclusion. The results showed that moderate-intensity aerobic exercise effectively reduces BMI compared to no intervention and Yoga. No other forms of exercise led to weight loss. Additionally, exercise had no impact on sex hormones and regular menstruation. It was concluded that moderate-intensity aerobic exercise is the most effective for reducing BMI in women with PCOS.

Conclusions Due to the limitations regarding the small sample size and lack of subgroup and sensitivity analysis, the results of this study demonstrated that moderate-intensity, aerobic exercise is the most effective exercise for reducing BMI, while the other exercises were ineffective. Moderate-intensity aerobic exercise is suggested to decrease the BMI in women with PCOS.

Systematic review registration This systematic review and network meta-analysis study was registered in PROSPERO (CRD42022324839).

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Keywords Polycystic ovarian syndrome, Obesity, Hormone changes, Menstruation, Exercise

Introduction

Polycystic ovarian syndrome (PCOS) an anovulatory disease is one of the most common endocrine illnesses that affects 5–7% of women in reproductive aging [1, 2]. Obesity, insulin resistance (IR) compensatory hyperinsulinemia, sex, and follicle-stimulating hormone changes, as important pathogenic factors, are exhibited in 55% of women with PCOS [3]. Obesity is closely associated with insulin resistance, leading to hyperinsulinemia, which is a common feature in women with polycystic ovary syndrome (PCOS) [3]. Obesity, in addition to metabolic syndrome and dyslipidemia, leads to inducing cardiovascular disease in women with PCOS [3]. According to the guidelines, lifestyle modifications and obesity management by diet and exercise are considered the first-line treatment for PCOS [3]. Diet and exercise are strongly recommended to decrease weight, normalize anovulation, and reduce metabolic syndrome parameters in PCOS [4]. Some of the studies support the beneficial role of physical activity in managing insulin resistance in women with PCOS [3, 4]. There is evidence that exercise training positively affects maximal oxygen consumption (MaxVO2), weight, and waist circumferences in patients with PCOS [4–8]. Some studies have also shown that combined aerobic and resistance exercise is more effective than either aerobic or resistance exercise alone in improving insulin sensitivity, controlling glycemic and reducing abdominal fat in obese women with PCOS [4]. On the other hand, some studies reported similar effects of both aerobic and resistance exercises [9] or diet and aerobic exercise interventions [10] on cardiometabolic health markers in women with PCOS. In this regard, the meta-analyses of clinical trials and cohort studies demonstrated the effectiveness of exercise interventions in improving cardio-metabolic risk factors, ovulation, reduced insulin resistance, and weight loss in women with PCOS [9, 11, 12], while another meta-analysis of randomized controlled trials (RCT) indicated that the exercise interventions versus non-exercising control can just affect cardio-respiratory fitness, body mass index (BMI) and waist circumference in women with PCOS, not on cardio-metabolic risk factors (Systolic blood pressure, fasting blood glucose, insulin resistance, and lipid profiles) or reproductive hormones [13, 14]. However, previous meta-analyses mainly performed pairwise comparisons between intervention and control groups, while, conducting a comprehensive comparison of these interventions to identify more effective exercise among them is an important part of the analyses in medical research. In addition, determining the optimal exercise intensity for applying the most effective interventions in PCOS is very important [15, 16].

Network Meta-Analysis (NMA) is a valuable approach to study the impact of specific interventions on continuous outcomes [17]. By incorporating indirect comparisons, NMA provides a comprehensive assessment of the relative effectiveness or safety among various interventions, particularly in situations where direct comparisons are lacking [17]. Moreover, NMA facilitates the ranking of interventions based on their effectiveness or safety, thereby assisting decision-making and informing clinical practice. It also helps identify areas where direct comparisons are needed and guides future research endeavors by pinpointing crucial unanswered questions that require attention. Considering the evidence, we aimed to perform a systematic review and network meta-analysis of RCTs to evaluate the efficacy of exercise training on BMI, sex hormone concentrations (luteinizing hormone [LH] and follicle-stimulating hormone [FSH]), and regular menstruation in women with PCOS.

Materials and methods

We followed instructions outlined in the Cochrane Handbook for Systematic Reviews of Interventions [18] and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Handbook to conduct our systematic review [19, 20]. The systematic review study protocol was registered in PROSPERO (CRD42022324839).

Systematic search

PubMed, Scopus, and Web of Science were searched by us in a systematic manner from inception until April 15, 2022. All databases were searched in a systematic manner simultaneously. We developed and performed the literature search by AJ and AE. In addition, a team of two reviewers (FE and FM) independently screened duplicate titles abstracts, and full-text articles. When necessary, AJ, a third reviewer, was involved in the discussion to resolve any differences. We also screened the reference lists of all published meta-analyses of RCTs on the effect of foods or food groups on body weight. The complete search strategy used to find articles of original research for inclusion in the present systematic review is provided in Supplementary Table S1.

Eligibility criteria

Original controlled trials with the following criteria were considered eligible for inclusion: (1) randomized trials with either parallel or cross-over design conducted in women with PCOS aged ≥ 18 years; (2) trials with an intervention period of four weeks or longer; (3) trials evaluating two or more types of exercise (e.g., aerobic, resistance, etc.); or comparing one of these exercises against no intervention (control group); and (4) 4) trials which participants did not receive any medication therapy.

Outcomes

Our main outcome was a change in BMI (kg/m2), while our secondary outcomes included serum FSH and LH concentrations (mIU/mL), and menstruations (days).

Screening and data extraction

After the study selection process, two reviewers (FE and FM) independently and in duplicate extracted the following characteristics from each trial: the last name of the first author, year of publication, study design (parallel or cross-over), sample size, mean age, baseline weight (mean and SD), intervention duration, description of intervention/control arms, and mean and corresponding SD of change from baseline weight for each arm. Disagreements were resolved by consensus between the two authors. We classified the intensity of exercise training as the following criteria [21–23]: (1) light: 1.6 to <3 metabolic equivalents (METs), or 40 to <65% HRmax, or 20 to <40% maximal oxygen consumption (Volume Oxygen Maximum [Vo2max]), or <40% Vo2 reserve (Vo2R) or HR reserve; (2) moderate: 3 to <6 METs, or 65 to <75% HRmax, or 40 to <60% Vo2max, or 40–59% Vo2R or HR reserve; and (3) vigorous: 6 to <9 METs, or 77 to <93% HRmax, or 60 to <85% Vo2max, or 60–84% Vo2R or HR reserve.

Risk of bias (quality) assessment

Two authors (FE and FM) independently assessed the risk of bias in the trials using guidance outlined in the Cochrane tool for risk of bias assessment. The Cochrane tool for risk of bias assessment is a widely used tool in systematic reviews and meta-analyses to assess the risk of bias in the included randomized controlled trial studies. Bias was evaluated as a judgment (high, low, or unclear) for distinct components across five domains (selection, performance, attrition, reporting, and others). Overall risk-of-bias assessment and categorization were determined using one of three levels in each domain for each study: Low risk of bias; Some concerns; or High risk of bias [18].

Data synthesis and analysis

We carried out Bayesian random-effects pairwise meta-analyses for each comparison to inform direct estimates [24, 25]. We calculated mean differences (MDs) with corresponding 95% credible intervals (CrI) for primary and secondary outcomes. We calculated changes from baseline values following intervention with each exercise relative to the control group. If the mean values and SDs of changes were not available in text or in graphs, we calculated these values using data from measures before and after the intervention, based on the Cochrane Handbook guidance [18]. For trials that reported standard error instead of SD, the former was converted to SD [18]. If either SD or standard error were not reported in the trials, we used the average SDs obtained from other trials included in the corresponding analyses [24, 26]. For trials that reported median data instead of mean data, we converted the former to mean data using standard methods [26, 27].

We conducted a random-effects network meta-analysis also using a Bayesian framework [24, 25, 28]. After an initial burn-in of 10,000 and a thinning of 10, we proceeded to use three Markov chains with 100,000 iterations. To assess convergence, trace plots and the Brooks-Gelman-Rubin statistic were employed. Our method for evaluating incoherence and generating indirect estimates involved the use of node-splitting models. We calculated the probability of ranking and the surface of the cumulative ranking curves (SUCRA). Both pairwise and network meta-analysis were performed using the gemtc package of R version 3.4.3 (RStudio, Boston, MA).

Analyzing subgroups and sensitivity

We were unable to conduct sensitivity and subgroup analyses because there were too few trials in the analyses.

Grading of the evidence

Two independent reviewers (AJ and AE) rated the certainty of the evidence using the GRADE approach. We assigned a high, moderate, low, or very low rating to the certainty of the evidence for each outcome, based on the direct, indirect, and network evidence. To start, we rated the certainty of the evidence for each direct comparison according to standard GRADE guidance [19, 25]. We then rated the evidence for indirect estimates based on the dominant first-order loop and evidence of intransitivity [19]. Subsequently, we rated the certainty of network evidence based on the direct or indirect evidence that was the predominant comparison and then considered rating down the certainty in the network estimate imprecision and for incoherence between the indirect and direct estimates [19].

Results

The literature searches and study selection process are shown in Supplementary Fig. S1. During the initial systematic search, 1140 eligible studies were determined. Of these, 150 articles were duplicated, and another 912 were not qualified according to the title and abstract. Finally, 78 papers were reviewed, and 19 provided sufficient information for the systematic review. The reasons for excluding are mentioned in (Supplementary Fig. S1).

Characteristics of primary trials included in the network meta-analysis

19 trials included in present meta-analysis (*n*=709 women with Polycystic ovarian syndrome (PCOS)) [5–9, 30–43]. The included trials were published from 2007 to 2022. Of 19 trials, 13 trials were conducted exclusively in women with overweight and obesity (body mass index ≥ 25 kg/m2) [5–9, 30, 32, 35, 38, 40–43], 3 trials did not specify the BMI of participants [31, 33, 36], and 3 trial was conducted in women with BMI ≥ 20 kg/m2 [8, 34, 39]. In all of the trials, patients had aged ≥ 18. Most trials (*n*=10) were conducted in women with mean age ≥ 30 [6–8, 30, 31, 33, 35, 36, 40, 42].

Intervention duration ranged between 6 and 16 weeks. The intervention period of 14 trials lasted between 12 to ≤16 weeks [5–9, 30, 32, 33, 35, 38, 40–43], and 5 trials ≤ 8 weeks [31, 34, 36, 37, 39]. Exercise programs included aerobics, resistance, and yoga. Of 19 trials, the intervention program in 12 trials was conducted based on aerobic exercise [6–9, 30, 32, 33, 35, 38, 40–43], 3 trials were based on yoga [8, 31, 36], and 3 trials were resistance exercise [5, 34, 39].

The frequency of the aerobic exercise program was 2 to 5 weeks in all trials. That was 2/week in one trial (35), 5/week in one trial (6), 1 trial did not specify the frequency of aerobic exercise program [43], and 3/week in the other trials [6, 7, 9, 30, 32, 33, 35, 37, 38, 40–42]. In 13 trials, the intervention program was compared to a control group without any intervention [5–8, 30–32, 34, 35, 39–41, 43], in 4 trials control group received usual care [5, 36, 37, 40], and in 2 trials high and moderate-intensity aerobic exercise program was compared [9, 38].

Only 4 trials implemented calorie restriction co-interventions [6, 35, 37, 43]. Supplementary Table S2 shows the characteristics of the trials included in this network meta-analysis.

4 trials were rated to have a low risk of bias (good quality) [8, 9, 37, 41], 7 trials were rated to have fair quality (some concerns) [7, 32–34, 39, 40, 43], and the other 8 trials as high risk of bias (poor quality) [5, 6, 30, 31, 35, 36, 38, 42] (Supplementary Table S3).

Effect of exercise on BMI

Comparative effects of different exercise modalities on BMI in women with PCOS are indicated in Fig. 1; Table 1. Moderate-intensity aerobic exercise was effective for weight loss when compared with no intervention (MD: -1.12 kg/m2, 95%CrI: -1.82, -0.42; very low-certainty evidence) and Yoga (MD: -1.61 kg/m2, 95%CrI: -3.1, -0.12; very low-certainty evidence). Other types of exercises led to no weight loss when compared with either no intervention or other types of exercises.

Effect of exercise on serum FSH and LH concentrations

Comparative effects of different types of exercise on serum FSH and LH concentrations are indicated in Fig. 2; Tables 2 and 3. Different exercise modalities led to no effect on levels of serum FSH and LH when compared with either no intervention or other exercise types.

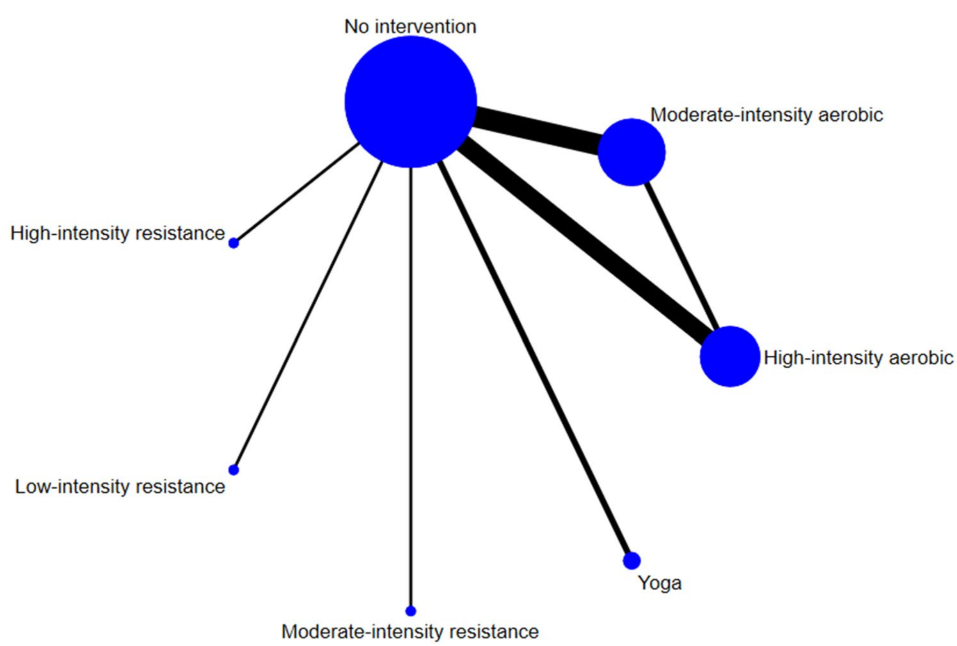

Fig. 1 The effects of different exercise modalities on BMI in women with PCOS

Table 1 Comparative effect of different types of exercise on body mass index (kg/m^2) in women with polycystic ovary syndrome (mean difference and 95% credible interval)

Treatments	Moderate-intensity aerobic					
High-intensity aerobic	-0.85 (-2.29, 0.60)	High-intensity aerobic				
Low-intensity resistance	-0.18 (-2.45, 2.1)	0.85 (-1.43, 3.14)	Low-intensity resistance			
Moderate-intensity resistance	-1.35 (-3.33, 0.63)	-0.33 (-2.31, 1.68)	-1.17 (-4.03, 1.66)	Moderate-intensity resistance		
High-intensity resistance	-1.51 (-3.52, 0.5)	-0.49 (-2.49, 1.55)	-1.33 (-4.20, 1.54)	-0.16 (-2.80, 2.48)	High-intensity resistance	
Yoga	-1.61 (-3.1, -0.12)	-0.59 (-2.08, 0.94)	-1.43 (-3.96, 1.1)	-0.26 (-2.53, 2.01)	0.39 (-1.49, 2.27)	Yoga
No intervention	-1.12 (-1.82, -0.42)	-0.43 (-0.90, 0.85)	-0.94 (-3.11, 1.22)	0.23 (-1.62, 2.08)	-0.10 (-2.4, 2.19)	0.49 (-0.82, 1.81)

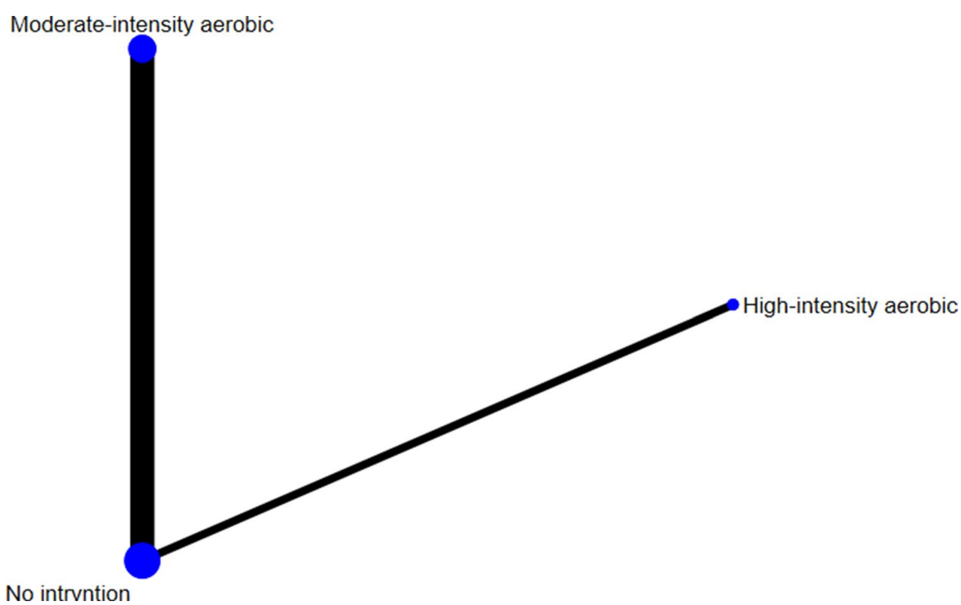

Fig. 2 The effects of different types of exercise on serum FSH and LH concentrations

Table 2 Comparative effect of different types of exercise on follicle stimulating hormone (mIU/mL) in patients with polycystic ovary syndrome (mean difference and 95% credible interval)

Treatments	Moderate-intensity aerobic	
High-intensity aerobic	-0.59 (-1.87, 0.72)	High-intensity aerobic
No intervention	-0.02 (-0.44, 0.45)	0.57 (-0.66, 1.79)

Table 3 Comparative effect of different types of exercise on follicle luteinizing hormone (mIU/mL) in patients with polycystic ovary syndrome (mean difference and 95% credible interval)

Treatments	Moderate-intensity aerobic	
High-intensity aerobic	-2.08 (-9.17, 4.95)	High-intensity aerobic
No intervention	-0.91 (-3.78, 1.94)	1.16 (-5.29, 7.65)

Effect of exercise on menstruations

Comparative effects of different types of exercise on menstruation are indicated in Fig. 3 and Supplementary Table S4. Different exercises had no effect on levels of menstruation when compared with either no intervention or other exercise types.

SUCRA values

Table 4 shows SUCRA values for the effects of different types of exercise on primary and secondary outcomes. Moderate-intensity aerobic exercise was the most effective exercise intervention for reducing BMI in women with PCOS, followed by low-intensity resistance and high-intensity aerobic.

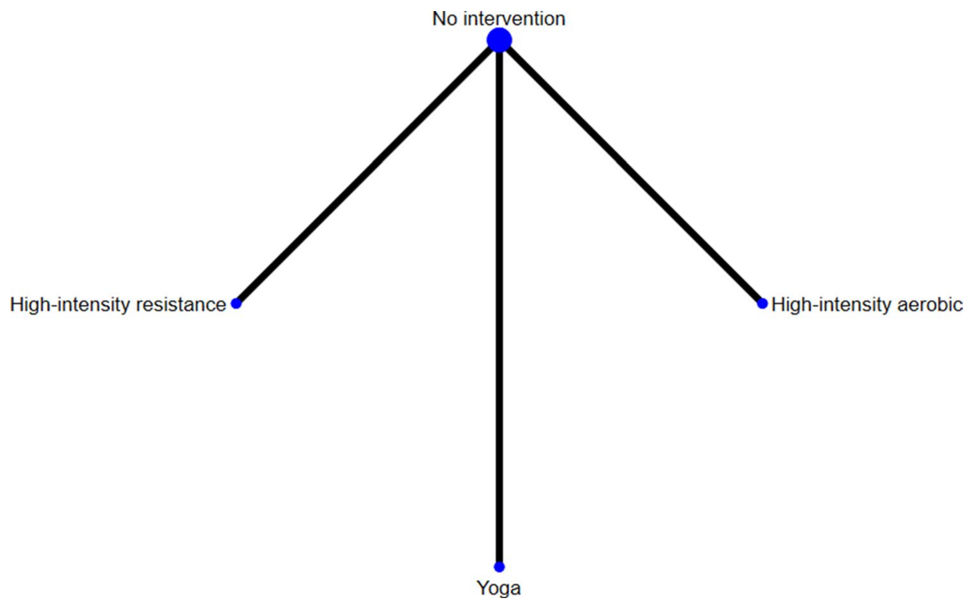

Fig. 3 The effects of different types of exercise on menstruations

Table 4 SUCRA values for the effects of different types of exercise on primary and secondary outcomes

Outcome	BMI	FSH	LH	Menstruation
Moderate-intensity aerobic	0.90	0.68	0.74	---
High-intensity aerobic	0.50	0.18	0.32	0.36
Low-intensity resistance	0.76	---	---	---
Moderate-intensity resistance	0.36	---	---	---
High-intensity resistance	0.31	---	---	0.38
Yoga	0.24	---	---	0.92
No intervention	0.44	0.64	0.44	0.34

Grading the evidence

Direct, indirect, and network estimates of the effects of different types of exercise on primary and secondary outcomes are indicated in Supplementary Tables S5–S8. Also, evidence ratings for the direct, indirect, and network estimates of the effects of different types of exercise are presented in Supplementary Tables S9–S20.

Discussion

How do the findings regarding exercise interventions align or conflict with current guidelines on PCOS management?

The present study was a network meta-analysis of randomized trials aimed at reviewing the effect of exercise training on pathogenic factors in women with PCOS based on the available evidence. Our findings indicated that moderate-intensity aerobic exercise was the most effective exercise intervention for reducing BMI in women with PCOS, but had no effects on the levels of serum FSH and LH. In this regard, Santos et al. (2020) in a systematic review and meta-analysis study concluded that aerobic exercise alone affects reducing BMI in women with PCOS [14]. In the Santos et al. study, the more efficacy of AE as compared to RE and non-exercise control conditions was found [14], while the current systematic review and network meta-analysis study compared different exercises with different intensities and also with non-exercise control conditions and was shown the most efficacy of moderate-intensity AE as compared to the high-intensity AE, low or high-intensity RE and yoga exercises. Smith et al. (2022) also conducted a systematic review and meta-analysis study to assess the effects of AE and RE exercises on cardio-metabolic factors in women with PCOS [13]. This study also compared the AE and RE with no-exercise control and reported the significant efficacy of AE and RE as compared to the control group on cardio-respiratory fitness and waist circumference. The other factors such as systolic blood pressure, fasting blood glucose, insulin resistance, and lipid profiles were no significant changes. The current study also indicated the efficacy of AE, RE, and Yoga exercises as compared to the control group on weight and BMI, while the LH, FSH, regular menstruation and ovulation were not changed after exercises. However, the efficacy of moderate-intensity AE was more than that of high-high-intensity AE, low or high-intensity RE, and yoga exercise.

Our study, for the first, was an attempt to compare the effects of three exercise training interventions (AE, RE, and Yoga) in women with PCOS by the method of network meta-analysis. Some previous studies have investigated and compared different exercises in this way in other populations. For example, Wang et al. (2022) in a network meta-analysis study assessed the effectiveness of aerobic exercise (AE), resistance training (RT), combined aerobic and resistance training (CT), and high-intensity interval training (HIIT) on BMI and inflammatory factors in overweight and obese individuals [3]. They concluded that CT is the most effective modality to improve BMI and inflammatory status in overweight and obese individuals [3]. Also, Batrakoulis et al. (2022) following a network meta-analysis study on a total of 4331 participants from 81 studies indicated the most effective modality of combined aerobic and resistance training as compared to single-component modalities on improving cardio-metabolic health-related outcomes and BMI in overweight adults [44]. Although, in these network meta-analysis studies, the intensity of AE and RT was not considered, the AE and RT alone cannot affect significantly BMI. The current study also indicated that high intensity of AE and RT alone did not affect BMI in women with PCOS.

However, the findings regarding exercise interventions for the management of Polycystic Ovary Syndrome (PCOS) generally align with the current guidelines, although there may be some areas of potential conflict or additional considerations. Current guidelines for PCOS management, such as those from the Endocrine Society and the American College of Obstetricians and Gynecologists (ACOG), emphasize the importance of lifestyle modifications, including regular exercise, as a key component of PCOS management [45, 46]. Regular exercise can benefit individuals with PCOS by improving insulin sensitivity and glucose metabolism, managing weight, improving reproductive outcomes, reducing androgen levels, and enhancing psychological well-being [46, 47]. The current recommendations generally suggest a combination of aerobic exercise and resistance training for PCOS management, with a focus on achieving and maintaining a healthy body weight.

There were limitations in the present study that need to be acknowledged. A major limitation of the current network meta-analysis study is the small sample size of included studies, especially for hormone concentrations and menstruation outcomes. This can have hindered subgrouping and sensitivity analysis. Moreover, in the present study, there was a lower number of studies evaluating RE and Yoga interventions compared to AE intervention, which could have impacted the combined results. The second limitation was the high risk of bias and poor quality of the most included studies in the quality assessment. It is suggested to conduct high-quality further studies to assess the effect of different intensities of exercises on pathogenic factors in women with PCOS. The other limitation of the current study is the lack of a clear definition for the different intensities of the three exercise programs (AE, RE, Yoga). A comparison of the exercises with specific intensities in future studies is suggested to control the intensity bias in the subgroup analyses. Finally, conducting more high-quality RCTs to declare the optimal exercise intensity and duration is needed for future studies in women with PCOS.

Conclusion

The network meta-analysis studies provide an extensive assessment of the comparative effectiveness or safety of various interventions, particularly in situations where direct comparisons are not feasible. This is particularly valuable when multiple treatments are considered viable for a specific condition, as it assists researchers and decision-makers in making informed choices. According to this the current network meta-analysis study indicated that moderate-intensity AE was the most effective exercise intervention for weight loss and reducing BMI in women with PCOS, while it had no effects on the serum FSH and LH concentrations and also menstruation. The findings of the current network meta-analysis study also showed that other types of exercises were not effective for weight loss neither when compared with no intervention or with other types of exercises. The results of the current study suggested conducting moderate-intensity AE in women with PCOS to control weight and BMI. It is worth mentioning that, these results were obtained based on the limitations regarding the small sample size and lack of subgroup and sensitivity analysis.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

Fatemeh Motaharinezhad: Protocol/project development, Data collection, Manuscript writing. Alireza Emadi: Data collection, Data analysis, Manuscript writing. Motahareh Hosnian: Data collection, Manuscript writing. Alireza Kheirkhahan: Data collection, Data analysis, Manuscript writing. Ahmad Jayedi: Management Data analysis, Manuscript editing. Fatemeh Ehsani: Protocol/project development, Management Data analysis, Manuscript writing.

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Data availability

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics approval and consent to participate

Not applicable. However, this study was approved by Semnan University of Medical Sciences (IR.SEMUMS.REC.1401.283).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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