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Impact of Physical Activity on Polycystic Ovary Syndrome in Women: Systematic Review and Meta-Analysis

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ABSTRACT

Aim: The aim of this study is to assess the impact of different types of exercise on important outcomes related to reproductive function as well as factors related to metabolic parameters in females with poly cystic ovary syndrome (POCS).

Methods: This systematic review and meta-analysis adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria. Included randomized trials' risk of bias was evaluated using the updated Cochrane Risk of Bias Tool (RoB 2). With discrepancies resolved by a third reviewer, two independent reviewers examined research papers, gathered data, and assessed methodological quality.

Results: Our systematic search identified 35 studies involving 7526 patients. The analysis revealed that exercise interventions significantly increased menstruation frequency/year (SMD: 0.51, 95% CI: 0.15–0.87). No significant effects were observed on FSH (SMD: −0.02, 95% CI: −0.19, 0.14), LH (SMD: −0.44, 95%CI: −1.06, 0.18), and testosterone (SMD: 0.13, 95% CI: −0.09, 0.35). For metabolic outcomes, exercise reduced BMI (SMD: −0.11 kg/m², 95% CI: −0.23, −0.01) and homeostatic model assessment for insulin resistance (HOMA-IR) (SMD: −0.43 kg/m², 95% CI: −0.73, −0.13).

Conclusion: The meta-analysis found that exercise therapies improved menstruation frequency and metabolic outcomes, particularly insulin resistance and waist circumference, in women with PCOS. However, exercise did not significantly differ from dietary interventions in terms of lowering BMI or enhancing insulin sensitivity. The study suggests the need for consistent, structured interventions to achieve significant clinical improvements, while supporting current guidelines primarily for metabolic benefits.

Keywords: *Polycystic ovary syndrome, Ovulation, Reproductive, Physical activity, Aerobic- Resistance.*

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1. INTRODUCTION

An endocrine disorder that is characterized by abnormalities in hormone levels is called polycystic ovarian syndrome (PCOS) [1]. Insulin resistance, obesity, hypertension, diabetes mellitus, anxiety, dyslipidemia, depression, and cardiovascular risk are among the major clinical disorders that are linked to an increased prevalence of PCOS [2]. Additionally, many women of reproductive age are at risk of reproductive complications [3, 4]. Anovulatory infertility, irregular menstruation, excessive male hormone production, and pregnancy complications are the most prevalent reproductive manifestations of PCOS [5].

Currently, PCOS is considered the most common endocrinopathy in women, accounting for 12% of cases worldwide [6]. The diagnosis of this syndrome necessitates either higher levels of anti-Mullerian hormone in adults or prolonged anovulation, hyperandrogenism, and polycystic ovary morphology [7]. The endocrine foundations of PCOS, such as insulin resistance, neuroendocrine alterations, and hyperandrogenism, are driven by genetic factors, lifestyle factors, and obesity [8].

The metabolic syndrome and its corresponding components—in particular, an increased waist circumference and raised fasting glucose—are more likely to develop in women with PCOS [9]. Although it is not one of the diagnostic criteria, obesity is a prevalent finding in women with PCOS. Research consistently demonstrates that obese and overweight women are more likely to develop PCOS, and up to 30% of women who fit the diagnostic criteria for PCOS had a body mass index (BMI) of greater than 30 kg/m2 [10]. Furthermore, insulin resistance affects approximately 70% of obese women with PCOS [11]. The etiology of PCOS is based on insulin resistance, which is not included in any diagnostic criteria due to diversity in evaluation methodology. Although there is no specific treatment for PCOS at this time, the disorder is managed with an emphasis on symptom relief, potential fertility, and cardiometabolic risk reduction [12].

The international evidence-based guidelines for PCOS include prescribed exercise recommendations for females with PCOS that are comparable to those for the general population [13]. Nevertheless, some evidence adopted to support the exercise components is of low quality and includes results of non-randomized controlled trials. Multiple meta-analyses and systematic reviews have demonstrated the positive impact of exercise on the management of PCOS symptoms [14-19]. However, inconsistent and sparse research on the qualities of exercise raises challenges for its recommendation for PCOS-affected women.

Furthermore, a previous study indicated that even though aerobic exercise variations like high-intensity interval training (HIIT) frequently require less time and energy to complete, they can occasionally improve cardiometabolic risk factors [20]. Therefore, more research is needed to determine the effectiveness of this therapy compared to other exercise therapies in the context of PCOS. The increasing number of published clinical trials concerning the impact of exercise on PCOS calls for periodic reviews and literature analysis to guarantee that clinical practice stays informed and relevant. It is critical to comprehend the long-term effects of physical activity on PCOS symptoms and associated health outcomes [21]. To ascertain the impact of different types of exercise on important outcomes related to reproductive function, such as hormones, menstrual cycle regularity, and ovulation rate, as well as factors related to metabolic parameters such as BMI, waist circumference, and waist-hip ratio, this systematic review and meta-analysis will use pooled data from randomized controlled trials (RCTs).

2. METHODS

Registration and Protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were followed in the conduct and reporting of this systematic review and meta-analysis [22], which was registered on the International Prospective Register for Systematic Reviews (PROSPERO) with the registration number CRD42024567628 [23].

Data extraction, study selection, and search strategy

During September 2024, we conducted a thorough literature search using the Google Scholar, Cochrane, and PubMed databases using the search terms “Polycystic ovary syndrome” OR “PCOS” AND “exercise” OR “Physical activity” OR “aerobic” OR “resistance” OR “fitness” AND “Reproductive function” OR “Menstrual cycle” OR “Ovulation” OR “Body composition” OR “BMI” OR “Weight” OR “Body mass index”. Only peer-reviewed, published, English-language articles were included in the search, with no restrictions on the publication date. For every database, the search terms were modified as needed. To find further possible relevant studies, the reference lists of previous review papers were examined. Grey literature was also searched through the ProQuest database (http://ProQuest.com). Two reviewers separately assessed papers by title and abstract after duplicates were removed. The same reviewers then carried out full-text screening independently. A third reviewer was consulted, or a consensus was reached to resolve any disagreements. Two reviewers separately extracted data from relevant articles using a pre-established extraction form following full-text screening.

Eligibility criteria

Table 1 lists the PICOS (Population, Intervention, Comparison, and Outcomes) framework that was applied for this systematic review.

Table 1: Eligibility criteria of the included studies

Criteria	Inclusion
Population	women between the ages of 18 and 40 who present menstrual disorders and infertility or who have been diagnosed with PCOS based on the Rotterdam criteria or the National Institutes of Health criteria.
Intervention	Any type of exercise program, whether supervised or unsupervised greater than eight weeks duration
Comparator	No exercise control group Diet only group Different types of exercise No control group
Outcome	Primary outcomes: Outcomes related to reproductive function, such as hormones, menstrual cycle regularity, and ovulation rate. Secondary outcomes: Those related to metabolic parameters (such as HOMA-IR) and body composition (weight, BMI, waist circumference, and waist-hip ratio).
Study design	RCTs and non-randomized controlled trials.

Quality and publication bias assessment

The updated tool for evaluating the risk of bias in randomized trials (RoB 2) was used to assess the risk of bias in the included studies [24]. The methodological quality was evaluated independently by two reviewers, and conflicts were resolved by consensus. Review Manager (Revman 5.3) software was used to prepare the risk of bias graph and summary. For ten or more included papers, publication bias was evaluated using a funnel plot and Egger's regression test; a P-value of less than .01 was considered significant.

Analysis of Data

R software was used to perform the meta-analyses. The common effects of exercise and its modifiers were estimated using the model's fixed effects. To account for variations in study estimate means that were not explained by the fixed effects, a random effect representing estimate identity was stated. Study-specific odds ratio (OR) or mean difference (MD) estimates were used for pooled effects using either a fixed-effects model or a random-effects model, in case significant heterogeneity exists. The median and interquartile range (IQR) were used to infer the mean and standard deviation for estimations in which these values could not be obtained from the data. Subgroup analysis was performed based on the duration of the exercise.

3. RESULTS

Studies selection

Our search identified 553 records in total. Duplicates identified were 177, 296 records were excluded by screening title and abstract. The remaining 80 records were retrieved in full text for eligibility assessment. After careful review, 35 [17, 25-

56] studies were found eligible for the review (**Figure 1**).

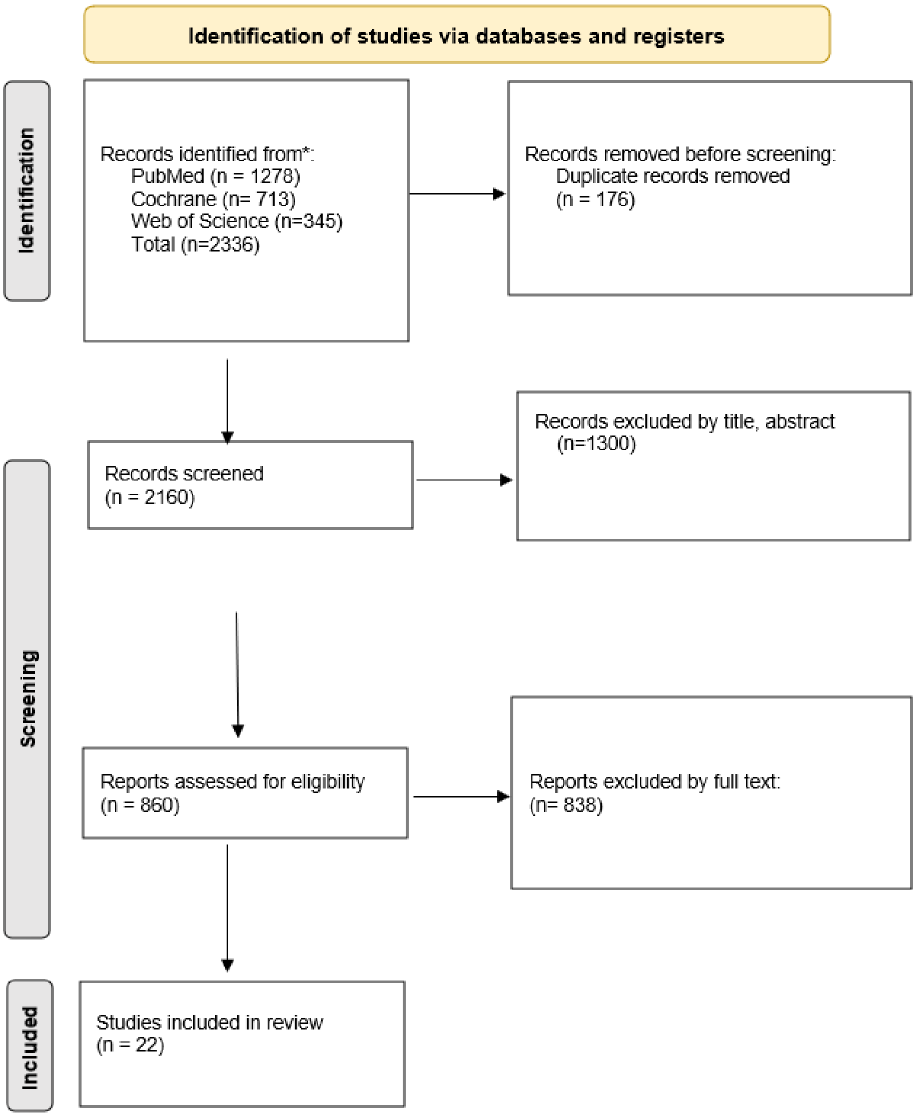

Figure 1. PRISMA 2020 flow diagram for systematic reviews

Characteristics of the included studies

Table 2 presents an overview of the study's general characteristics. The study includes 34 RCTs and one non-randomized trial [57]. Between 1999 and 2024, the studies were published in a variety of countries. The total number of participants in all investigations was 7526.

Table 2: Characteristics of the included studies

Study ID	Study design	Year of publication	Country of origin	Total number of patients	Number in Group 1	Number in Group 2
Dietz de Loos, 2022 [25]	RCT	2021	Netherlands	183	60	63
Benham, 2021 [17]	RCT	2021	Canada	47	16	14

Prakash, 2021 [26]	RCT	2021	India	20	10	10
Sá, 2015 [27]	RCT	2015	Brazil	30	15	15
Dietz de Loos, 2021a [28]	RCT	2021	Netherlands	183	63	60
Ribeiro, 2021 [69]	RCT	2021	Brazil	87	28	29
Victorin, 2009 [70]	RCT	2009	Swede	20	9	5
Roessler, 2012 [31]	RCT	2012	Denmark	17	8	9
Kazemi, 2019 [32]	RCT	2019	Canada	61	30	31
Tiwari, 2018 [33]	RCT	2018	India	66	33	33
Patten, 2022 [34]	RCT	2022	Australia	29	15	14
Nybacka, 2019 [35]	RTC	2019	Swede	57	19	19
Turan, 2015 [36]	RCT	2015	Turkey	30	16	14
Bruner, 2006 [37]	RCT	2006	Canada.	12	7	5
Kiel, 2021 [38]	RCT	2021	Norway;	64	21	20
Serrao, 2013 [39]	RCT	2013	Canda	40	16	24
Jedel, 2010 [40]	RCT	2010	Sweden	84	34	50
de Loos, 2021b [41]	RCT	2021	Netherlands	67	27	24
Ribeiro, 2020 [42]	RCT	2020	Brazil	57	28	29
Nybacka, 2011 [35]	RCT	2011	Sweden	57	19	19
Abazar, 2015 [43]	RCT	2015	Iran	24	12	12
Thomson, 2010 [44]	RCT	2010	Adelaide, South Australia	94		
Thomson, 2008 [45]	RCT	2008	Adelaide, South Australia	94		
Gaeini, 2014 [46]	RCT	2013	Iran	40		
Palomba,2008 [47]	RCT	2008		40	20	20
Aqdas,2022 [48]	RCT	2022	Pakistan	28	18	10
Nasiri, 2022 [49]	RCT	2022	Iran	45	30	15
Huber-Buchholz, 1999 [50]	RCT	1999	Australia	28	18	10
Rao, 2022 [51]	RCT	2024	Pakistan	50	25	25
Aryani, 2023 [57]	Non-randomized trial	2023	Indonesia	20		
Furtado, 2024 [53]	RCT	2024	Brazil	56	30	26
Ribeiro, 2019 [29]	RCT	2019	Brazil	57	29	28
Samadi, 2019 [54]	RCT	2019	Iran	30	15	15
Jafari, 2020 [55]	RCT	2020	Iran	24	12	12

Li, 2022 [56]	RCT	2022	China	42	24	18

Participants characteristics

Table 3 provides a summary of participant characteristics from several studies. Participants in the studies ranged in age from 18 to 47 years, with BMIs ranging from 18 to 45 kg/m2, and periods of follow-up ranging from 2 months to 12 months.

Table 3: Characteristics of the included studies' participants

Study ID	Age range	Mean Age in years, SD	BMI range	BMI mean, SD	Follow-up duration in months
Dietz de Loos, 2022	18–38	29 years (IQR 26–32)	≥25 kg/m²	I32.8 kg/m² (IQR 30.1–36.1)	12 months
Benham, 2021	18 - 40	29.2 years (±4.7)	stratified into BMI groups <28 and ≥28 kg/m²	31.4 (±8.4) kg/m²	6 months
Prakash, 2021	20 - 25	23.05 years (±1.2)	25-35 kg/m²	28.5 kg/m² (± 1.5)	3 months
Sá, 2015	18 - 34	25.8 years (± 4.8)	≥25 kg/m²	32.3 kg/m² (Control group), 32.1 kg/m² (Exercise group)	4 months
Dietz de Loos, 2021a	18 - 38	29 years (IQR 26–32)	>25 kg/m²	32.8 kg/m² (IQR: 30.1–36.1)	12 months
Ribeiro, 2021	18 - 39	G1 28.5(5.760 G2 28.97(4.32)	<30 and ≥30 kg/ m²	Group 1 29.33± 5.43 kg/m² / Group 2 28.17 ± 5.67 kg/m²	4 months
Victorin, 2009	18-35	29.9 ± 4.5, 30.4 ± 5.5, and 31± 3.2	>25 kg/m²	G1 27.5±8.6 G2 26.8±4.8	4 months
Roessler, 2012	19-47	31.6	25–40 kg/m2	36.3 kg/m2	4 months
Kazemi ,2019	18-35	G1 26.2 (4.8) G2 26.7 (5.2)	>25 kg m2	G1 32.0 (7.8) G2 34.7 (9.8)	4 months 3
Tiwari, 2018	-	G1 24.46±4.76 / G2 24.33±3.89		25.86±3.59	6 months
Patten, 2022	18-45	29.7±4.8	>25 kg m2	35.5±6.8	3 months

Nyback a,2019	18-40	G1 29.9 ± 5.5 G2 31.3 ± 4.8	> 30 kg/m2	G1 35.4 ± 4.9 G2 34.8 ± 5.2	4 mont hs
Turan, 2015	17–34	24.45 (± 2.8)	< 25 kg/m2	G1 21.8±1.0 G2 21.9±1.1	2 mont hs
Bruner, 2006	18-37	32.3±1.0	> 27 kg/m2	36.6 kg/m2	2 mont hs
Kiel, 2021	18 - 45	Group 1 30.4 ± 5.0y Group 2 30.1 ± 4.9y	<27 or ≥27 kg·m².	Group 1 29.5 ± 5.7 kg/m² Group 2 30.8 ± 7.2 kg/m²	12 mont hs
Serrao, 2013	19- 36	28.3 ± 3.44	24.2 - 40.3	33.7 ± 6.89	12 mont hs
Jedel,2 010	18 –37	30.2 (±4.7)	25-35 kg/m²	27.7(±6.44)	4 mont hs
de Loos,20 21b	18-38		>25 kg/m2,		12 mont hs
Ribeiro ,2020	18-39 years,	group1(29.1± 5.3) group2(29.0 ± 4.3)	18-39.9kg/m2	group1(28.4 (5.6)) group2(28.7 (4.8)	4 mont hs
Nyback a,2011	18–40 years;		>27 kg/m2		12 mont hs
Abazar ,2015	20-30	26.87 ± 4.43 years	29.86 ± 3.22 kg/m2		12 week s
Thoms on,2010		29.3 ± 0.7 years	36.1 ± 0.5 kg/m2		20 week s
Thoms on,2008		29.3 ±.7 yr;	36.1 ±.5 kg/m2		20 week s
Gaeini, 2014			lean (BMI<20) and obese (BMI>25)		12 week s
Palomb a,2008					24 week s
Aqdas, 2022					12 week s
Nasiri, 2022	18-40				8 week s
Huber-	22–39 yr		27–45 kg/m2		6

Buchholz, 1999					months
Rao, 2022				36.6 kg/m2	12 weeks
Aryani, 2023	20-29				
Furtado, 2024	between 18 and 39 years		between 18 and 39.9 kg/m2		16 weeks
Ribeiro, 2019			18– 39.9 kg/m2		16 weeks
Samadi,2019	between 20 and 35		≥30 kg/m2		12 weeks
Jafari,2020	20-30 years	26.87±4.43		29.86±3.22 Kg/cm2	12 weeks
Li, 2022	between 18 and 35 years		equal to or greater than 23 kg/m2		3 months

Intervention details and outcome measures

Studies on different physical activity programs and their impact on the health outcomes of PCOS-affected females are included in Table 4. The table illustrates how well physical activity programs work to improve cardiovascular, metabolic, and reproductive health indicators. Although exact results varied, the majority of studies found positive changes in the primary and secondary health outcomes, indicating that regular physical activity—whether aerobic or in combination with resistance/HIIT—has a positive effect, especially for those with metabolic syndrome or PCOS.

Table 4: Intervention details and outcome measures

Study ID	**Type of physical activity**	**Frequency of treatment**	**Duration of treatment**	**Primary outcomes**	**Secondary outcomes:**	**Measurement tools**	**Time points of measurement**
Dietz de Loos, 20	Aerobic and resistance	20 meetings over 12 months	12 months	Prevalence of metabolic syndrome	Changes in waist circumference, blood pressure, glucose, insulin, cholesterol, HDL	Waist circumference, blood pressure monitor, fasting blood tests for glucose, insulin, lipids	baseline,3,6,9,12 months

22							
Benham, 2021	High-Intensity Interval Training (HIIT) and Continuous Aerobic Exercise Training (CAET	3 times per week	6 months	Ovulation rate, menstrual regularity	Body weight, BMI, waist circumference, LDL-C, HDL-C, VO_2 max	Ovulation prediction kits, anthropometric measurements, blood tests (lipid profiles), VO_2 max testing	Baseline,3 and 6 months
Prakash, 2021	Aerobic exercises and Swiss ball exercises	6 days per week	3 months	Reduction in body weight, abdominal fat, and improvement in menstrual irregularities	androgen levels	Girth measurement, Menstrual Irregularity Questionnaire (MIQ)	Baseline and after 3 months
Sá, 2015	Aerobic	3 times per week	4 months	improvement of cardiac autonomic modulation	changes in resting heart rate and blood pressure	Heart rate variability (HRV) analysis (linear and nonlinear methods), systolic and diastolic blood pressure measurements	Baseline and after 4 months
Dietz de Loos, 2021a	Aerobic	Not found	12 months	Improvements in PCOS characteristics such as ovulatory dysfunction, biochemical hyperandrogenism, and PCOM	Changes in phenotype distribution and weight loss	Antral follicle count, serum testosterone levels, waist circumference, BMI, menstrual cycle regularity, SHBG, anti-Müllerian hormone (AMH)	Baseline, 3, 6, 9, and 12 months
Rib	continuous (CAT) and intermitt	3 times per week	4 months	Changes in testosterone levels, telomere length, and obesity indexes (waist circumference,	Changes in lipid profile (total cholesterol,	Dual-energy X-ray absorptiometry (DXA), biochemical markers (blood	Baseline and after 4 months

eiro, 2021	ent (IAT) aerobic			body composition)	LDL), waist-to-hip ratio, free androgen index (FAI)	tests), real-time PCR for telomere length	
Victorin, 2009	aerobic exercise	2 times per week	16 weeks	In the physical exercise group, MSNA was decreased	-	height, body weight, BMI (ratio between weight in kilograms and the square of the height in meters)	baseline and after 16-wk treatment
Roessler, 2012	Aerobic	2 days per week	16 weeks	decrease in waist circumference, weight, and BMI, and a significant increase in VO2max	-	Waist circumference, body mass index and maximal aerobic capacity	Baseline ,2,4 months
Kazemi, 2019	health counseling (monthly) and aerobic exercise (5 days/week; 45 minutes/ day)	5 days per week	16 weeks	improved HRQoL scores in women with PCOS	decreased risk of cardiovascular disease and type 2 diabetes, decrease hypercholesterolemia	total testosterone (TT), follicle-stimulating hormone (FSH), and luteinizing hormone (LH)	baseline and post-intervention
Tiwari, 2018	exercise	3 days per week	3 months	improvement in the clinical symptoms of oligomenorrhoea, polymorph-ous	Improved BMI, reduced waist circumference	Body mass index	Baseline and after 3 months

Patten, 2022	high-intensity interval training (HIIT)	3 times per week	12 weeks	improvements in VO2 peak	Neither training intervention influenced fasting . insulin levels, HbA1c levels or lipid profiles	DXA test	Baseline and 3 months
Nybacka, 2019	either diet, exercise or the combination of both	2–3 times per week.	4 months	Waist circumference decreased significantly in all groups	Reduction in systolic BP, decreased in HOMA index, LDL was reduced in the diet group	DXA test	Baseline and after 4 months
Turan, 2015	Combined aerobic and resistance exercise	3 times per week	8 weeks	anthropometric and cardiovascular parameters improved significantly after the exercise program	improvements in waist and hip measurements but did not lead to significant weight loss.	Waist and hip measurements diastolic blood pressure; respiratory rate, levels of low-density lipoprotein cholesterol, total cholesterol, fasting glucose, and fasting insulin; and the homeostasis model assessment of insulin resistance index	Baseline and after 8 weeks
Bruner, 2006	Aerobic	3 days per week	12 weeks	body composition analyses; insulin sensitivity, androgen levels, fasting lipid levels, cardiorespiratory fitness, resting meta-bolic rate, ovarian follicle population;	-	BMI, WG, sum of 2 skinfolds, Blood samples, Transvaginal ultrasonography	baseline and after 2 months
KIEL, 2021	High-Intensity Interval Training	3 times per week for 16 weeks	16 weeks of semi-supervised HIT followed by 36 weeks of home-based	Menstrual frequency	Pregnancy rate, ovarian morphology, cardiometabolic markers	Menstrual diaries, ovarian ultrasound, fasting blood samples, 2-hour oral glucose tolerance test, DXA	Baseline, 16 weeks, and 12 months.

			HIT.				
Serrao, 2013	Aerobic	5 sessions per week;	16 weeks	ovulation rate	hormonal and metabolic profiles)	Diagnostic visit, diagnostic bloodwork, diagnostic ultrasound, OGTT, DEXA, and diet instruction	Baseline, 16 weeks, and 12 months.
Jedel, 2010	aerobic	3 days per week	16 weeks	changes in the concentration of total testosterone	changes in menstrual frequency; concen-trations of androgens, estrogens, androgen precursors, and glucu-ronidated androgen metabolites;	anthropometric measurements and cal-culation of BMI, Fasting blood samples,	baseline, after 16 weeks
de Loos, 2021b	continuous aerobic training		12 months	weight loss	hyperandrogenism (HA), polycystic ovarian morphology, menstrual cycle length	Body weight, height, Waist circumference, transvaginal ultrasound, serum testosterone,	bsline,3, 6, 9 and 12 months
Ribeiro, 2020	continuous (CA) and intermittent (IA) aerobic training	3 times per week,	16 weeks	hormonal and metabolic parameters and body composition		DXA scan, anthropometric, Blood sampling, testosterone level.	baseline, after 16 weeks
Nybacka	Aerobic	-	4 months	Ovarian function, endocrinologic, and metabolic status and body composition	-	Ovarian function, endocrinologic, and metabolic status and body composition.	at baseline ,4 month, 12month

, 2011						
Abazar, 2015	Aerobic exercises	3 exercise sessions per week	12 weeks	Reduction in body compositions: BMI. WHR percent body fat, body fat mass	Polar Pulse measuring device from England	baseline ,12 week
Thomson, 2010			20weeks	Depression and PCOS-specific HRQOL	Depression and PCOS-specific HRQOL	At baseline, the midpoint (week 10) and the end of the intervention (week 20)
Thomson, 2008	aerobic or combined aerobic-resistance exercise		20 weeks		BMI, Body fat, WC	At baseline, the midpoint (week 10) and the end of the intervention (week 20)
Gaeini, 2014	aerobic	3 days/week	12 weeks		Biochemical analysis, sonography, questionnaire	At baseline, week 12
Pal			24 weeks		Rotterdam ESHRE ASRM (2004) and the National Institutes of	baseline, and at 12- and 24-

omba, 2008						Health	week
Aqdas, 2022	Resistanc e Exercise	3 session s per week	12 weeks		Difference in lipid profile & BMI	Lipid profile, BMI	Baselin e, week 12
Nasiri, 2022	High Intensity Intermitt ent and Combine d (Resis tant and Enduranc e)		8 weeks	both HIIT and COM training could be beneficial in improving some Anthro-pometric indices			Baselin e at the eighth week.
Huber-Buchholz, 1999	Exercise		6-month			Clamp technique, hormone assays, menses monitoring	Baselin e, week 24
Rao, 202	Aerobic	three times per week	12 weeks			skinfold measurements for BF% using a body caliper,	Baselin e 12 weeks

2							
Aryani, 2023				menstrual regularity, waist circumference, fertility, dominant follicle		a letter of informed consent, weight scale, height meter, tape measure, and ultrasonography machine.	
Furtado, 2024	Resistance and aerobic training	three times a week, in 50-minute to one-hour sessions for 16 weeks	16 weeks				Baseline 16 weeks
Ribeiro, 2019	aerobic exercise		16 weeks			anthropometric measurements, Waist circumference (WC), Hip circumference (HC), Waist-to-hip ratio (WHR), Testosterone, Prolactin, thyroid-stimulating hormone (TSH), and 17-hydroxyprogesterone (17-OHP)	16weeks of intervention
Samadi, 2019	AHIIT	three sessions of 20 minutes. Metformin (1500 mg) 3 days for 12 weeks.	for 12 weeks			--	for 12 weeks
Jafari, 2020	Aerobic	three 60-minute sessions a week.	12 weeks	improved ovulation, reduced IR and weight loss			12 weeks

Li, 2022	Aerobic	60 min exercise session three times per week for 12 weeks.	3 months	BMI significantly decreased in the Tai chi group compared with before treatment. Compared with the self-monitored exercise group, there was a significantly decreased BMI in the Tai chi group adjusted for baseline BMI	After treatment, the Tai chi group showed favorable changes in body weight, FINS, and HOMA-IR with no significant differences between the groups.		3 months

Physical Activity Types and Frequency

A variety of exercise forms are used in the interventions, such as resistance, high-intensity interval training (HIIT), aerobic, and continuous aerobic exercise training (CAET). While the frequency of physical activity varied from study to study, it generally ranged from two to six times per week.

The Duration of physical activity

The interventions' durations also differed; some (such as Tiwari, 2018) lasted only three months, while others (like Dietz de Loos, 2021 and Dietz de Loos, 2022) lasted up to twelve months.

Primary and Secondary Results

Primary results: usually centered on fundamental health indicators, such as:

Metabolic Health: Research such as that by Dietz de Loos (2021) sought to lower the prevalence of metabolic syndrome.

Symptoms of PCOS: In studies like Benham (2021) and Ribeiro (2021), improvements in ovulation rate, menstrual regularity, body weight, and PCOS-related features were the focus.

Weight management, especially the reduction of abdominal fat, was the emphasis of Prakash (2021) and Tiwari (2018).

Secondary Results: Mostly comprised indicators of metabolic and cardiovascular health, including blood lipid profiles (e.g., HDL, LDL, and cholesterol) and waist circumference, variations in VO_2 max, resting heart rate, testosterone levels and body composition.

Time Points and Measurement Tools

Tools for Measurement: Measurements of waist circumference, fasting blood tests, dual-energy X-ray absorptiometry (DXA) scans, VO_2 max testing, and biochemical markers were among the various tools used in the investigations.

Time Points: In order to monitor progress over time, a number of studies included extra points, such as at 3, 6, and 12 months, in addition to the standard baseline and post-intervention assessments.

4. META-ANALYSIS

Primary outcomes

Effect of exercise compared to care as usual on ovulatory dysfunction in females with PCOS: The forest plot indicates that there is no significant effect of the intervention compared to the control group in decreasing ovulatory dysfunction (OR: 1.07, 95% CI: 0.88–1.29). The consistency (low heterogeneity) within and across time points indicates that the intervention's effect is stable over time (I^2=0%, P=0.965) (Figure 2).

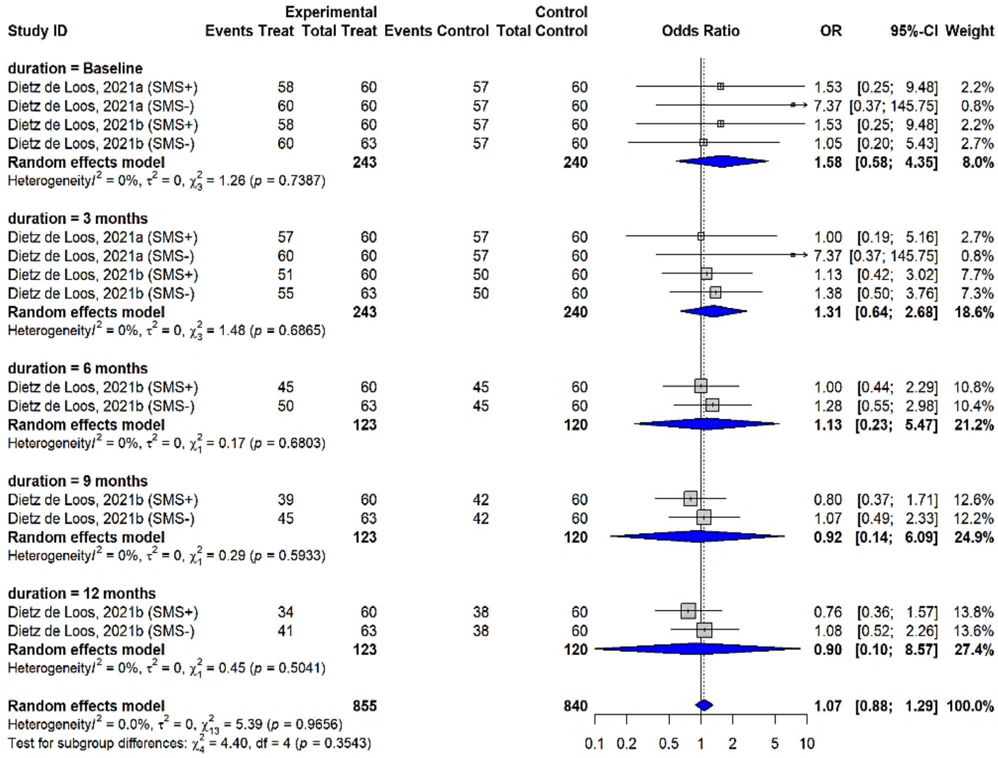

Figure 2: Effect of exercise compared to care as usual on ovulatory dysfunction in females with PCOS

Effect of exercise compared to care as usual on menstruation frequency in females with PCOS: A statistically significant and moderate overall positive effect is demonstrated by the interventions as compared to control in increasing menstruation frequency/year (SMD: 0.51, 95% CI: 0.15– 0.87). At 4 (SMD: 1.13, 95% CI: 0.16– 2.1) and 8 months (SMD: 0.83, 95% CI: 0.15– 1.52), the effect is more pronounced and statistically significant. The effect sizes appear to differ slightly between studies, particularly at the 4-month time point (I^2 = 61%), according to the moderate heterogeneity (Figure 3).

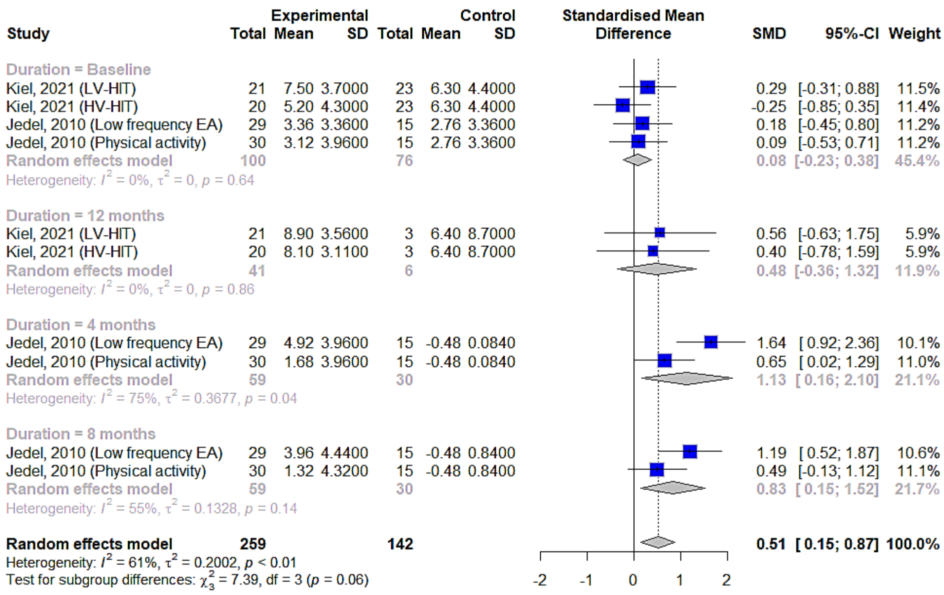

Figure 3: Effect of exercise compared to care as usual on menstruation frequency in females with PCOS

Effect of exercise compared to care as usual on FSH in females with PCOS: There is no significant difference between the intervention and control groups, according to the pooled estimate for the whole study with an SMD of -0.02 [-0.19, 0.14]. Considering there is little heterogeneity ($I^2 = 18\%$), it is more likely that variations in the actual effects of the various studies account for the majority of the variation than chance. Subgroup differences are significant ($p < 0.01$), suggesting that the duration of the follow-up may affect the intervention's effectiveness (Figure 4).

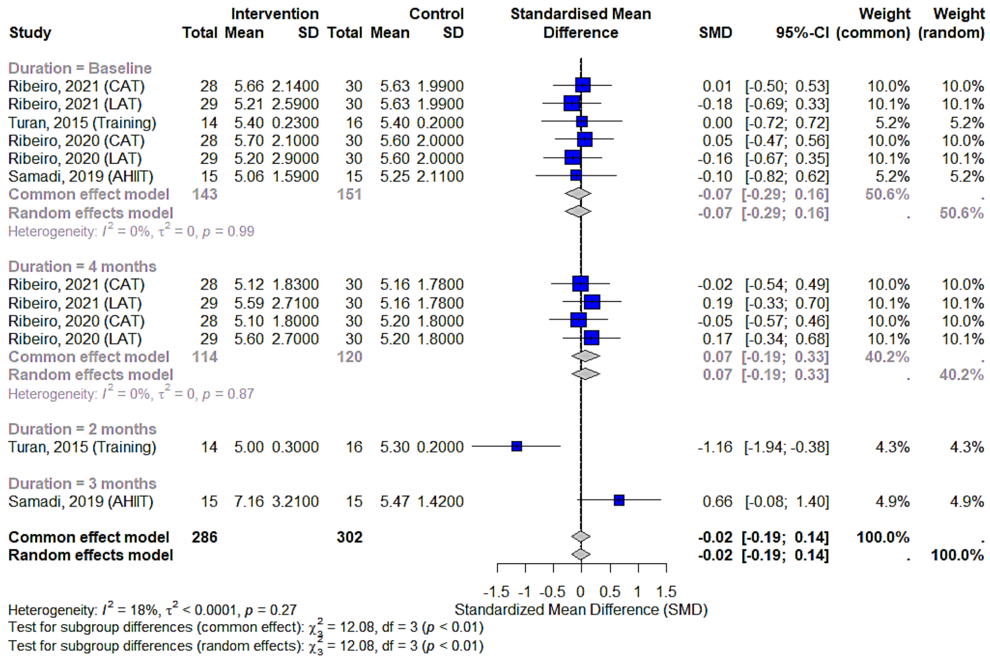

Figure 4: Effect of exercise compared to care as usual on FSH levels in females with PCOS

Effect of exercise compared to care as usual on LH in females with PCOS: There is no statistically significant difference between different types of exercises and control groups at baseline or after 4 months. There is a tendency to favor the intervention group in decreasing LH levels in the pooled analysis across durations, but this effect is not statistically significant (SMD: -0.44, 95% CI: -1.06– 0.18). The significant variations in the included studies results indicated by the high heterogeneity ($I^2 = 83\%$) indicate that the effects of the interventions vary widely among studies. (Figure 5).

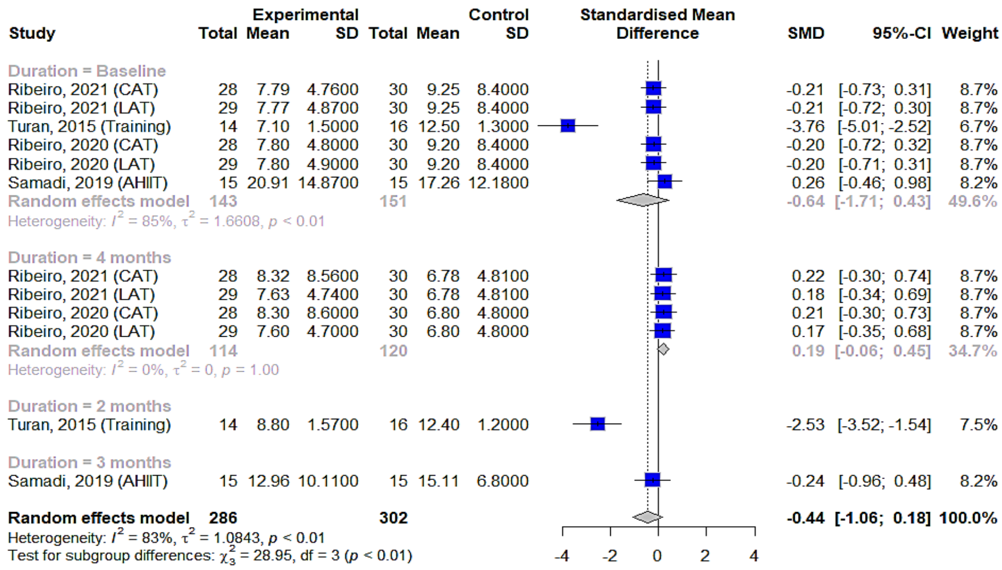

Figure 5: Effect of exercise compared to care as usual on LH levels in females with PCOS

Effect of exercise compared to care as usual on testosterone in females with PCOS: A small, non-significant overall effect favoring the control in lowering testosterone levels is shown by the pooled estimate for the whole analysis, which has an SMD of 0.13 [-0.09, 0.35]. The effects reported by different studies exhibit some variation, as indicated by the moderate heterogeneity (I^2 = 56%). The results of the subgroup analysis show that the impact of the intervention on testosterone levels varies depending on the time point, showing a significant rise at baseline (SMD = 0.52) and a decline after 4 months (SMD = -0.25) (Figure 6).

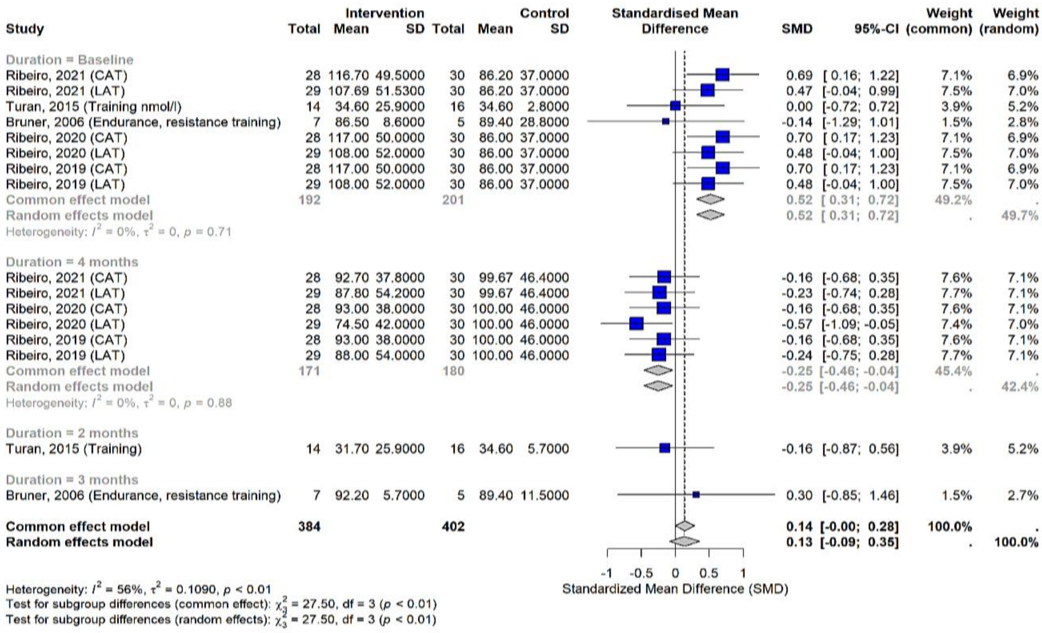

Figure 6: Effect of exercise compared to care as usual on testosterone levels in females with PCOS

Effect of exercise compared to care as usual on Ferriman-Gallwey score in females with PCOS: The pooled effect size for all studies and time periods is -0.11 [-0.38, 0.16], which suggests that the intervention group's Ferriman-Gallwey scores decreased slightly relative to the control group, but not significantly. Since there is no significant heterogeneity (I^2 = 0%), the findings are consistent between studies. The findings imply that the intervention does not have a statistically significant impact on the decrease of hirsutism at any of the time points examined, as there are no significant differences between the baseline, 4 months, and 12 months (Figure 7).

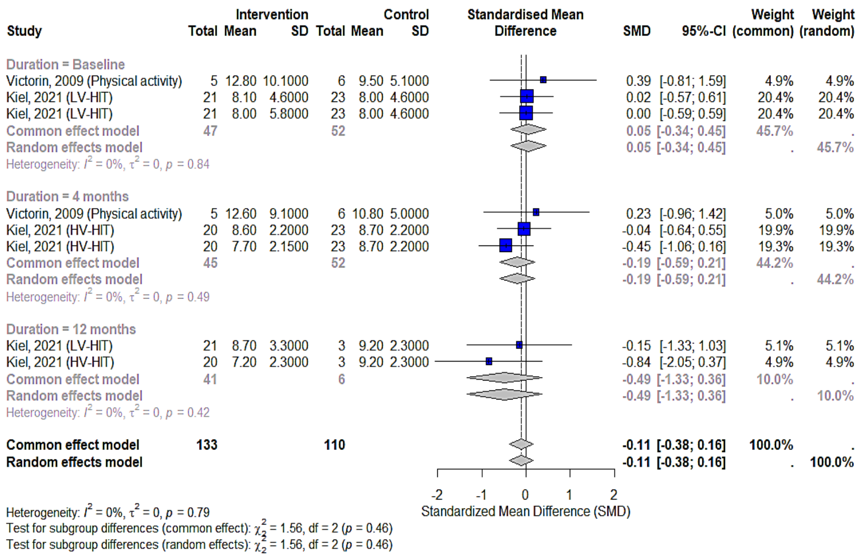

Figure 7: Effect of exercise compared to care as usual on Ferriman-Gallwey score in females with PCOS

Secondary outcomes

Effect of exercise compared to care as usual on body mass index in females with PCOS: According to the forest plot, different exercise interventions lower BMI slightly when compared to controls; however, this effect is usually small and not always statistically significant (SMD: -0.11, 95% CI: -0.23– 0.01). While data at 4 months provides the most consistent evidence of a positive effect (Figure 8). The funnel plot indicates that the meta-analysis may have some publication bias or small-study effects, wherein smaller studies that demonstrate statistically significant reductions in body mass index are more likely to be published (Figure S.1).

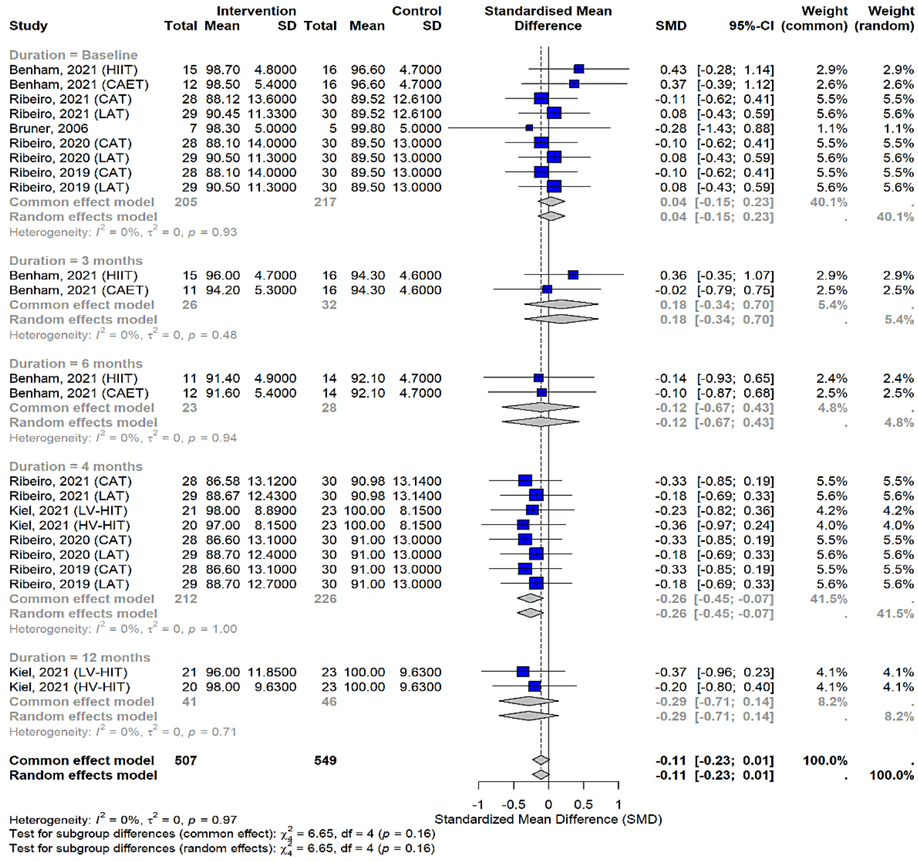

Figure 8: Effect of exercise compared to care as usual on body mass index in females with PCOS

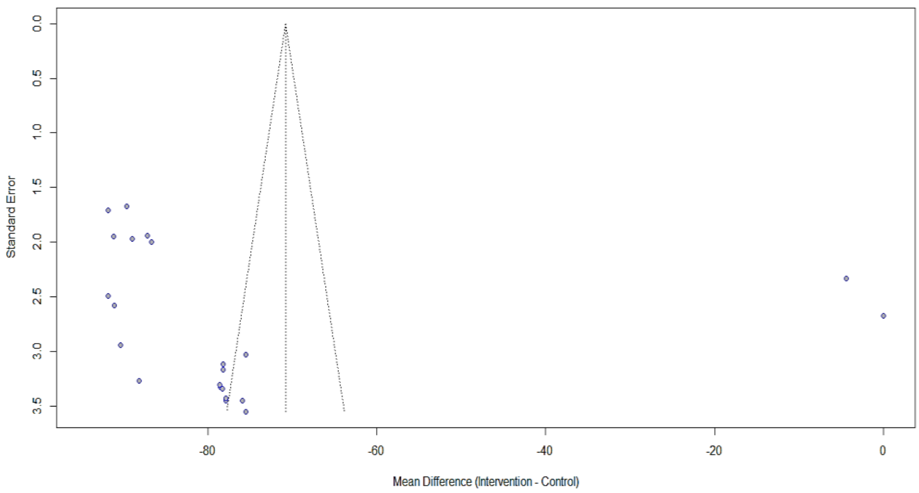

Figure S.1: Publication bias in the included studies of the body mass index outcome

Effect of exercise compared to care as usual on waist circumference in females with PCOS: In comparison to the control groups, the meta-analysis revealed a slight decrease in waist circumference for the intervention groups (SMD: -0.11, 95% CI: -0.23– 0.01), especially at the 4-month point when the effects are statistically significant (SMD: -0.26, 95% CI: -0.45– -0.07). Since there is no significant heterogeneity ($I^2 = 0\%$), the findings are consistent between studies (Figure 9). The funnel plot indicates that the meta-analysis may have some publication bias or small-study effects, wherein smaller studies that demonstrate statistically significant reductions in body mass index are more likely to be published (Figure S.2).

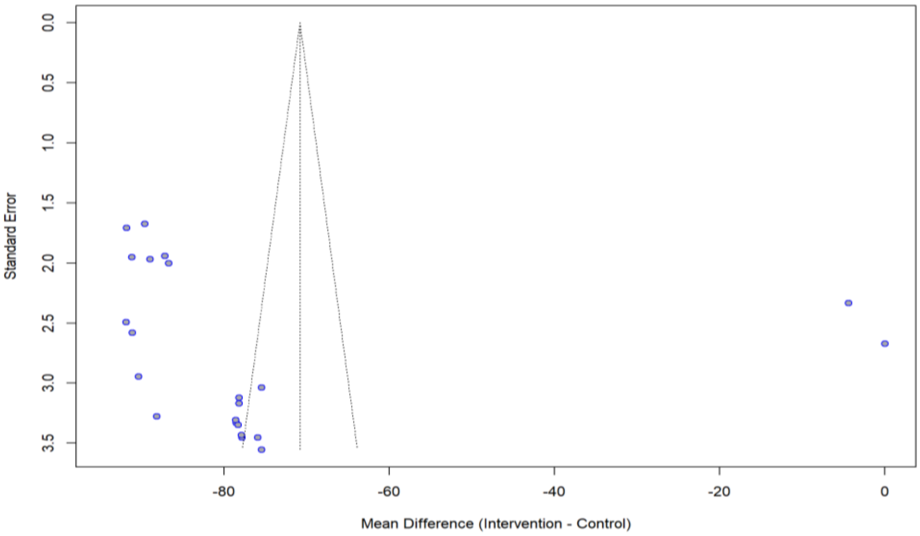

Figure S.2: Publication bias in the included studies in waist circumference outcome

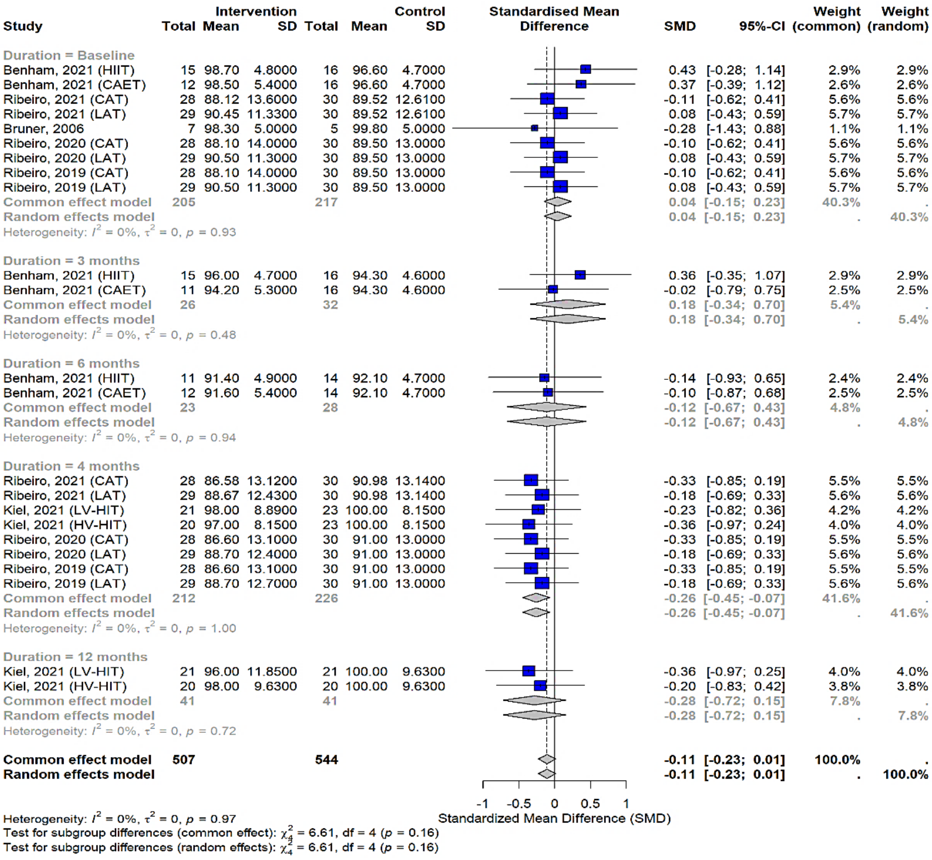

Figure 9: Effect of exercise compared to care as usual on waist circumference in females with PCOS

Effect of exercise compared to care as usual on HOMA-IR in females with PCOS: Several time periods indicate that the intervention is more effective than the Control, particularly at the 2- (SMD: -0.97, 95% CI: -1.74– -0.21) and 6-month (SMD: -1.26, 95% CI: -1.85– -0.65) follow-ups (Figure 10). The funnel plot's asymmetry raises the possibility that the meta-analysis contains publication bias or other types of bias (Figure S.3).

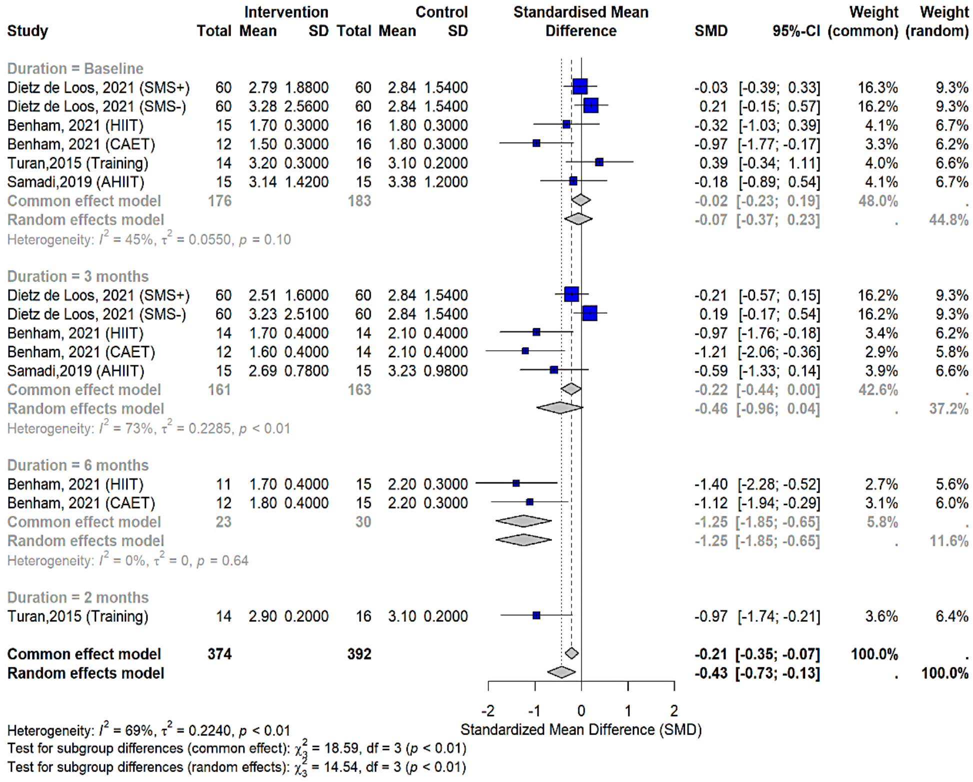

Figure 10: Effect of exercise compared to care as usual on HOMA-IR in females with PCOS

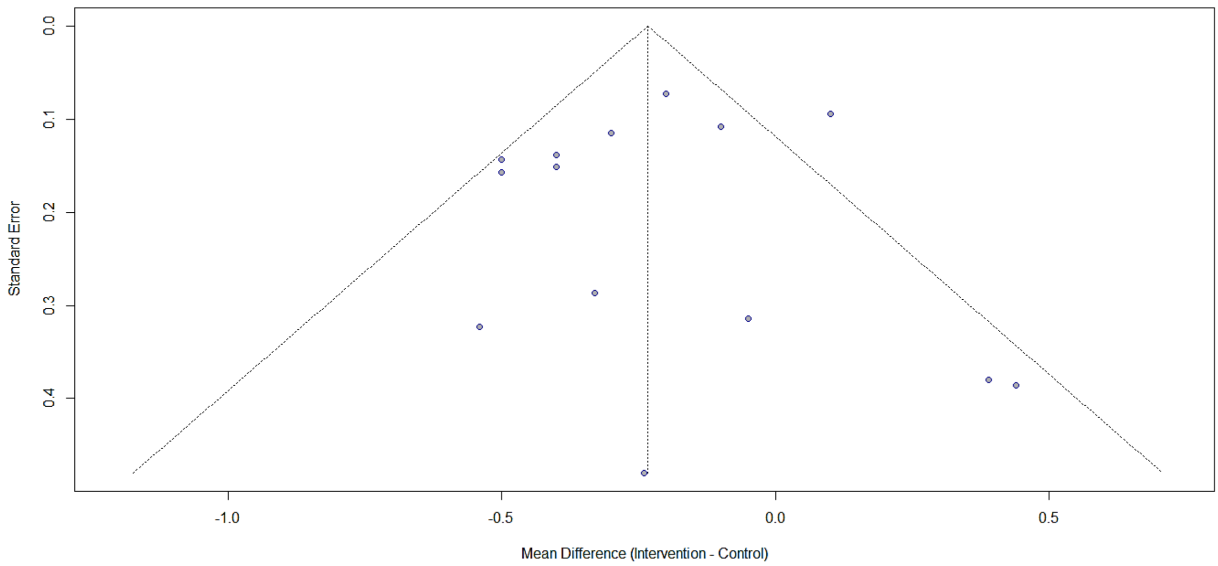

Figure S.3: Publication bias in the included studies in HOMA-IR outcome

Comparison between diet and exercise regarding the effect on PCOS

Effect on body mass index: The overall findings suggest that diet interventions tend to be more effective in lowering BMI than exercise interventions but the effect was not statistically significant (SMD: -0.67, 95% CI: -1.39– 0.05). There is a significant heterogeneity between the studies as indicated by I^2 of 85% (Figure 11).

Effect on HOMA-IR: The meta-analysis, which has a total pooled effect size (SMD: 0.01, 95% CI: -0.29– 0.31) provides no convincing evidence that either diet or exercise is substantially superior at improving HOMA-IR (Figure 12).

Effect on HOMA-IR (subgroup analysis): There is no significant difference between diet and exercise (SMD: 0.01, 95% CI: -0.29– 0.31) and at any time point according to the meta-analysis that is stratified by duration. The 4-month period, however, exhibits low heterogeneity (I2=22%, p=0.27) (Figure 13).

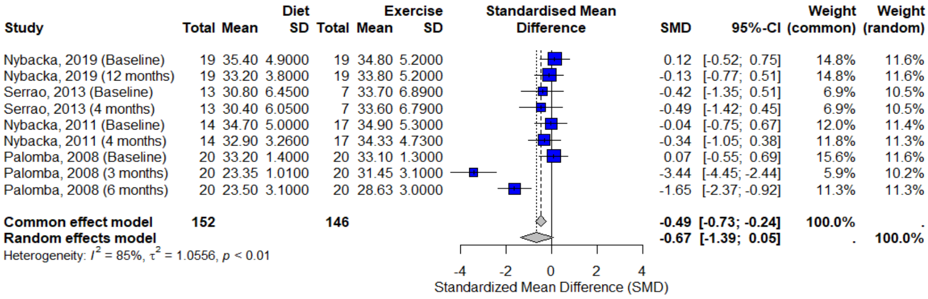

Figure 11: Effect of exercise compared to diet on body mass index in females with PCOS

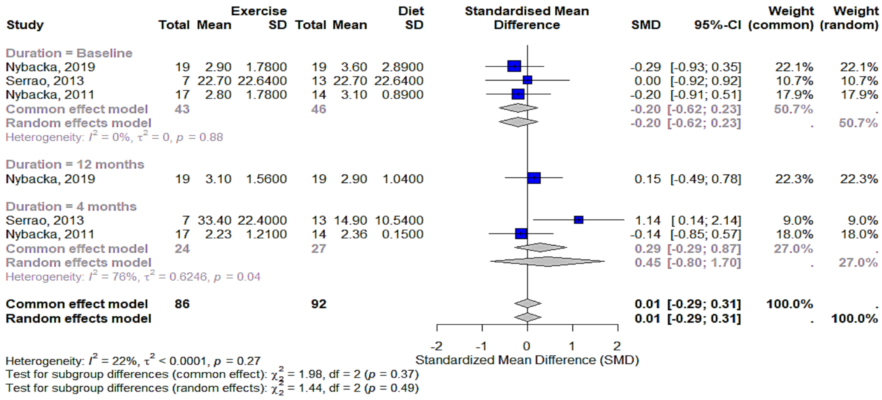

Figure 12: Effect of exercise compared to diet on HOMA-IR in females with PCOS

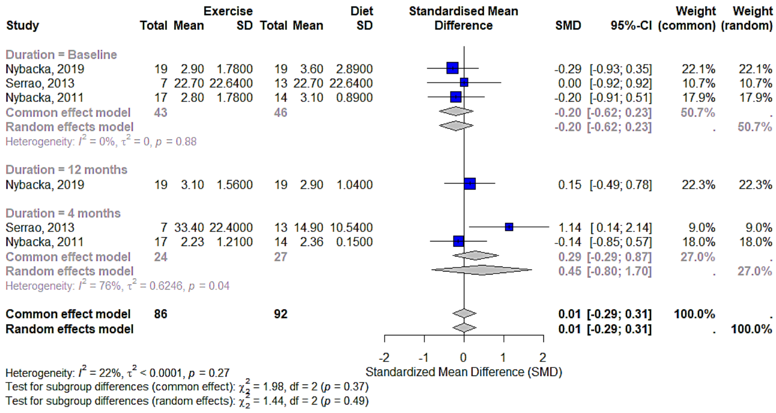

Figure 13: Effect of exercise compared to diet on HOMA-IR in females with PCOS

Quality assessment of the included studies

Most studies have a low risk of bias across all categories, indicating robust methodological rigor. A few studies have an unclear risk, particularly for blinding and randomization criteria, due to limited information. Only a few studies (Huber-Buchholz 1999 and Palomba 2008) reveal a substantial risk of bias in specific areas, which might compromise the credibility of their conclusions. Studies that have a significant risk of bias in certain areas (such as random sequence generation and blinding) may provide less precise information for a meta-analysis or systematic review. The general low bias in the majority of research suggests that the evidence synthesized from these studies is likely to be powerful (Figures 14 and 15).

Figure 14. Risk of bias graph

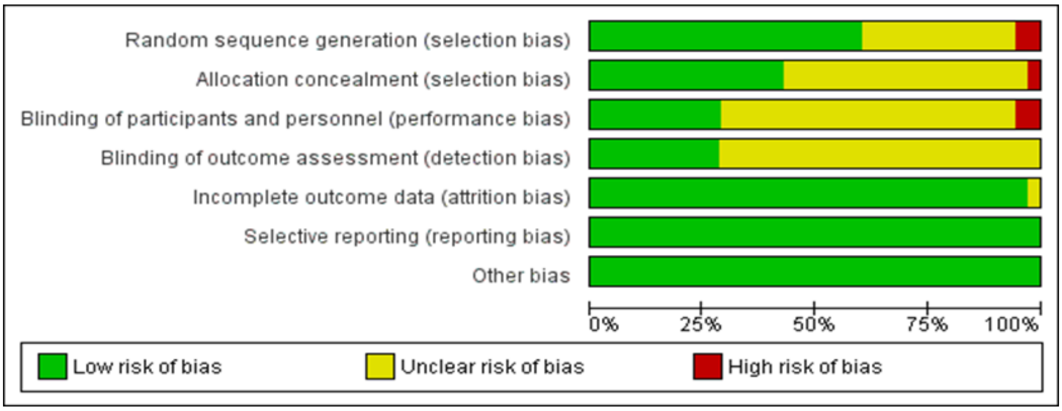

Figure 15: Risk of bias summary

5. DISCUSSION

The effects of exercise on reproductive and metabolic outcomes are thoroughly assessed in this meta-analysis of 35 studies involving 7,526 women with PCOS. It found that although exercise significantly increased menstrual frequency, especially after 4–8 months, it had no significant effect on ovulatory dysfunction, hormone levels, or hyperandrogenism markers. Although there were no significant differences between diet and exercise in terms of benefits in BMI or HOMA-IR, exercise resulted in small decreases in BMI and waist circumference and significant improvements in insulin resistance, particularly after six months of intervention.

The meta-analysis demonstrated that exercise has no significant effect on ovulatory dysfunction. Previous research has found that intense exercise (30-60 minutes per day) lowers the chance of anovulatory infertility, however, highly intensive exercise (>60 minutes per day) increases the risk [58]. Moderate physical activity greatly lowers the risk of infertility as compared to low activity levels; however high activity marginally raises the risk [59]. A prospective study indicated that high physical activity had no significant effect on ovarian reserve in normo-ovulatory, reproductive-age women, but that excessive exercise may disturb the hypothalamic-pituitary-ovarian axis [60]. The lack of a dose-response association in our study, which comprised studies with varying intensities, may have been caused by variations in exercise regimens across trials. Additionally, women with higher baseline BMIs were included in our group, and insulin resistance in obese PCOS patients could inhibit the benefits of exercise-induced ovulation. While more prolonged treatments tended to promote ovulation, short-term trials (less than 4 months) did not demonstrate any advantage.

The meta-analysis showed a moderate positive effect of interventions on increasing menstruation frequency per year compared to the control group. The most pronounced effect occurs at 4 and 8 months, suggesting that these interventions are particularly effective over these periods. The moderate heterogeneity at the 4-month time point suggests some variability in effect sizes across studies, possibly due to differences in study design, participant characteristics, or the specific interventions used. The meta-analysis results align with a prior review, which found exercise to be an effective strategy for primary dysmenorrhea [61]. This result contradicted the findings of a prior meta-analysis, which showed that no differences were identified in the outcomes such as menstrual regulatory, ovulation rates, and conception rates, between the physical activity intervention and comparator groups [62].

The study revealed no significant difference in follicle-stimulating hormone (FSH) levels between the intervention and control groups in females with polycystic ovarian syndrome (PCOS). The considerable subgroup differences imply that the duration of the follow-up may alter the intervention's efficacy. The significant subgroup differences indicate that the duration of the follow-up time may influence the intervention's effectiveness, implying that longer follow-up periods may be required to detect meaningful changes in FSH levels. A systematic review showed that moderate-intensity aerobic exercise lowered BMI in women with PCOS but had no significant effect on sex hormones, including FSH [63]. A prior review found that hard aerobic exercise improved insulin levels in PCOS women, however, the effects on FSH levels varied among research [64]. Longer follow-up durations were related with stronger effects of lifestyle interventions on hormone levels in women with PCOS, implying that longer follow-up periods may be required to detect substantial changes in FSH levels [65].

The study found a small, non-significant effect of an exercise intervention on testosterone levels compared to the control group. The study also showed moderate heterogeneity, suggesting differences in interventions, populations, or methodologies. The intervention initially increased testosterone levels at baseline, possibly due to exercise or other factors. However, after four months, testosterone levels declined, indicating a long-term effect of the intervention on lowering testosterone levels, likely due to the body's adaptation to sustained exercise. Mention a study with similar findings.

According to the findings of a previous systematic review, vigorous aerobic exercise improves insulin measurements in women with PCOS, whereas resistance or strength training may enhance androgen levels [64].

The study demonstrated that exercise interventions reduce BMI slightly in females with PCOS, but the effect is often small and not always statistically significant, particularly over short periods of time. However, data collected at four months revealed the most consistent evidence of a favorable effect on BMI decrease. This shows that longer periods of exercise may be required to achieve large BMI decreases. Kite et al. found that exercise had a statistically significant effect on BMI reduction when compared to usual care, with overweight/obese patients showing the largest improvement [66]. Longer follow-up periods and specific sorts of exercise could be more effective. The findings are consistent with prior studies, stressing the necessity of moderate-intensity aerobic exercise and extended follow-up periods for obtaining significant BMI reductions in women with PCOS [63].

At 2- and 6-month follow-ups, the study found that an exercise intervention improved the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) in females with PCOS more than the control group. Significant heterogeneity was observed at shorter durations, indicating that variables including the kind of exercise, its intensity, length, and adherence to the intervention may have an impact on the outcomes. Higher-intensity exercise may be more beneficial in reducing insulin resistance, according to earlier research, and certain exercise regimens, including high-intensity interval training (HIIT), may have a greater effect on insulin resistance than others [67, 68].

The study has limitations. It was challenging to make firm conclusions because the studies analyzed varied greatly in terms of the types, intensities, and lengths of exercise regimens. It's possible that variations in the populations under investigation (e.g., age, BMI, and baseline insulin resistance) led to the inconsistent outcomes. The absence of uniform exercise regimens in research makes it difficult to evaluate findings and reach definitive conclusions.

6. CONCLUSION

According to this meta-analysis, exercise therapies had no significant benefits on hirsutism, testosterone levels, or ovulatory dysfunction, but they significantly improved menstruation frequency and metabolic outcomes, especially insulin resistance (HOMA-IR) and waist circumference. After 4–8 months of exercise, the effects on menstrual regularity were most noticeable, and at 6 months, the metabolic gains peaked. However, in terms of lowering BMI or enhancing insulin sensitivity, exercise by itself did not vary substantially from dietary interventions, indicating that integrated lifestyle approaches would be more successful for comprehensive PCOS care. The results underline the need for consistent, structured interventions to produce significant clinical improvements while supporting current guidelines that recommend exercise primarily for metabolic benefits in PCOS, despite limitations like variability in exercise protocols and a lack of long-term data. Future studies should concentrate on evaluating the long-term durability of these benefits, improving exercise modalities, and accounting for dietary factors.

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