ANALYTIC REVIEW

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Effect of Yoga Therapy on Health Outcomes in Women With Polycystic Ovary Syndrome: A Systematic Review and Meta-Analysis

Abstract: *The purpose of this study was to assess the effect of yoga therapy (YT) on health outcomes of women suffering from polycystic ovary syndrome (PCOS). Interventional studies, with postmenarchal and premenopausal females with PCOS who received YT, with any health outcome reported, were included. Scopus, Cochrane, PubMed, Embase, and Medline databases were electronically searched. Systematic review included 11 experimental studies, representing 515 participants with PCOS, out of which 2 randomized controlled trials (RCTs) were included for meta-analysis. Random effects model was applied using Review Manager Software version 5.4.1 and strength of evidence was assessed using GRADEpro Guideline Development Tool, 2020. Meta-analysis showed that YT may significantly decrease menstrual irregularity (MD −.41, 95% CI −.74 to −.08), clinical hyperandrogenism (MD −.70, 95% CI −1.15 to −.26), fasting blood glucose (MD −.22 mmol/L, 95% CI −.44 to −.01), fasting insulin (MD −28.21 pmol/L, 95% CI −43.79 to −12.63), and homeostatic model assessment-insulin resistance value (MD −.86, 95% CI −1.29 to −.43). Strength of evidence was "low." In conclusion, YT may have beneficial effects on health outcomes in women suffering from PCOS. However, low strength of evidence suggests need of conducting well-designed RCTs to assess the efficacy of YT for PCOS.*

Keywords: yoga therapy; holistic health; mind–body intervention; polycystic ovary syndrome; lifestyle disorder

> Yoga encompasses all the components of lifestyle modification, thereby promoting holistic health

Introduction

Lifestyle changes have caused immense impact on overall health and well-being of an individual giving rise to several health disorders like polycystic ovary syndrome

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(PCOS) among females. PCOS is emerging as one of the most common endocrine and metabolic disorder affecting 8–13% women[1] of reproductive age group worldwide causing significant health consequences for women impairing quality of life and increasing risk of comorbidity like glucose intolerance and diabetes mellitus, systemic inflammation, non-alcoholic fatty liver disease, hypertension, and cardiovascular disease.[2] PCOS is also one of the leading causes of infertility among women of reproductive age group[3] and also has an adverse impact on their psychological well-being.[4,5]

The complexity of the disorder and its impact on quality of life requires timely diagnosis, screening for complications and management strategies. The most common diagnostic criteria for PCOS is Rotterdam criterion[1] defined as at least two of the following three features: oligomenorrhea or amenorrhea (cycle length of ≥45 days and/or ≤8 cycles per year); hyperandrogenism (score of ≥6 on modified Ferriman–Gallwey scale or serum testosterone level >82 ng/dL); and polycystic ovaries (presence of more than 10 cysts in each ovary or an ovarian volume greater than 10 cm^3 on ultrasound) in the absence of other endocrine etiologies such as thyroid disease, non-classic congenital adrenal hyperplasia, and hyperprolactinemia.

Treatment goals in PCOS include improving hormonal imbalance, weight management, and improving quality of life. Lifestyle interventions (dietary, exercise, behavioral or combined) are recommended as first-line management according to latest evidence-based European Society of Human Reproduction and Embryology-2018 guidelines for PCOS.[1] Several pharmacological and surgical options target individual reproductive, androgenic, metabolic, weight-related, and psychological symptoms in women of different age groups suffering from PCOS. These conventional therapeutic options may have unwanted side effects, whereas lifestyle modifications offer a holistic treatment by improving underlying hormonal imbalance, optimizing weight, and improving quality of life of women suffering from PCOS.[1]

Yoga, a form of mind–body intervention, encompasses all the components of lifestyle modification (diet, exercise, and behavior), thereby promoting holistic health of an individual.[6] Several interventional trials have been conducted which assess the effectiveness of yoga therapy (YT) on neuroendocrine, anthropometric, metabolic, and quality of life factor in women with PCOS. However, to the best of author(s)' knowledge, currently there is no systematic review or meta-analysis assessing the evidence for effectiveness of specifically YT on health outcomes in women with PCOS. Thus, this review aims at specifically assessing the effect of YT on health outcomes in women with PCOS.

Materials and Methods

Protocol and Registration

This systematic review and meta-analysis was undertaken according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[7] (PRISMA Checklist provided as Supplementary Tables S1a and S1b) and registered with the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42021229619.

Eligibility Criteria

Criteria for Systematic Review. In this systematic review, all empirical research studies studying the effect of YT as an intervention for women diagnosed with PCOS were included. Theoretical research studies were excluded from this review in order to reduce heterogeneity. Studies were included if they measured the effect of any form of YT on PCOS-related reproductive, metabolic, anthropometric, or quality of life health outcomes either clinically or by using validated tools.

Criteria for Meta-Analysis. Studies were considered for meta-analysis if they met the following eligibility criteria:

1. Type of studies: randomized controlled trial (RCT).
2. Type of participants: postmenarchal and premenopausal females with PCOS diagnosed on the basis of Rotterdam criteria.
3. Type of interventions:
   a. Intervention group: YT (defined as structured yogic postures, breathing, meditation, and relaxation techniques) for duration of 12 weeks or more.
   b. Control group.
   c. *Minimal treatment (MT)* (defined as either no treatment or standard unstructured minimal dietary, exercise or behavioral advice).
4. Type of outcome measures (measured at end of intervention):
   a. Primary outcome:
      o. Reproductive:
         ➢ Menstrual cycle regularity (initiation of menses or significant shortening of cycle length or increase in cycle frequency per month).
   b. Secondary outcomes:
      o. Reproductive:
         ➢ Clinical hyperandrogenism (hirsutism assessed clinically by modified Ferriman–Gallwey (mFG) score).
      o. Metabolic:
         ➢ Fasting blood glucose (FBG) level,

- ➢ fasting insulin (FI) level, and
- ➢ homeostatic model assessment-insulin resistance (HOMA-IR).

o. Anthropometric:
- ➢ body mass index (BMI) and
- ➢ waist-to-hip ratio (WHR).

o. Quality of life (psychological):
- ➢ anxiety and depression (measured by validated scales).

Information Sources and Search Terms

Electronic databases Cochrane, PubMed, Embase, Medline, and Scopus were searched for identification of relevant studies published till July 2020. Also, controlled trials registries Cochrane Central Register of Controlled Trials (CENTRAL) and Clinical Trials Registry of India (CTRI), conference abstracts, relevant journals, reference lists of relevant papers, and reviews were electronically hand searched to identify further eligible studies. Searches were re-run prior to the final analysis and submission. Yoga, lifestyle management, complementary and alternative therapy, PCOS, and randomized controlled trials were used as keywords and MeSH terms. Results were refined by selecting only interventional trials which primarily assessed the effect of YT on any health outcomes of women of any age group suffering from PCOS. Summary of search methods is provided in Supplementary Tables S2a and S2b.

Study Selection and Data Extraction

Relevant studies, searched from abovementioned databases, were then exported to citation manager (Mendeley version 1.19.4) for filtering and elimination of duplicates. Titles and abstracts of articles thus retrieved were screened individually, and verified and full text versions of potentially eligible studies were obtained. The following information was then extracted from each study: location of study, study design, number of subjects with their mean age, PCOS diagnosis criteria, intervention, follow-up period, and information related to outcomes. Main trial report was used as reference for studies which had multiple publications, and additional details were provided from their secondary research articles. Unit conversion factors applied in this review are provided in Supplementary TableS3.

Risk of Bias in Individual Studies

Quality of included studies were assessed using the Revised Cochrane Risk-of-Bias Tool for Randomized Trial (RoB2)[8] and Risk-of-Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool.[9] Rating of studies were categorized as per abovementioned scales.

Synthesis of Results

Extraction and summarization of data for health outcome was done by meta-analysis for homogenous studies. Random effects model was used combining data from included studies. For continuous data, mean difference (MD) and related 95% confidence intervals (CIs) between treatment groups were calculated for measurement of treatment effect. Heterogeneity was estimated by I-squared statistics. Data management and analysis was performed using Review Manager (RevMan) version 5.4.1 (RevMan 2020, The Cochrane Collaboration, Oxford, UK).

Overall Quality of Evidence

Strength of evidence for significant outcomes was assessed using GRADEpro and Cochrane methods.[10] The quality of evidence was assessed on the basis of following GRADE criteria: *risk of bias* (lack of allocation concealment, lack of blinding, incomplete accounting of patients and outcome events, selective outcome reporting, other limitations); *inconsistency* (unexplained heterogeneity or variability in results across studies); *imprecision* (uncertainty in results due to few patients and events and wide CI around the estimate of the effect); *indirectness* (evidence does not directly answer the health care question asked); and *other considerations like publication bias* (selective publication of studies). Based on these criteria, the quality of evidence was assessed into one of the four categories: high, moderate, low, or very low.

Results

Search Results

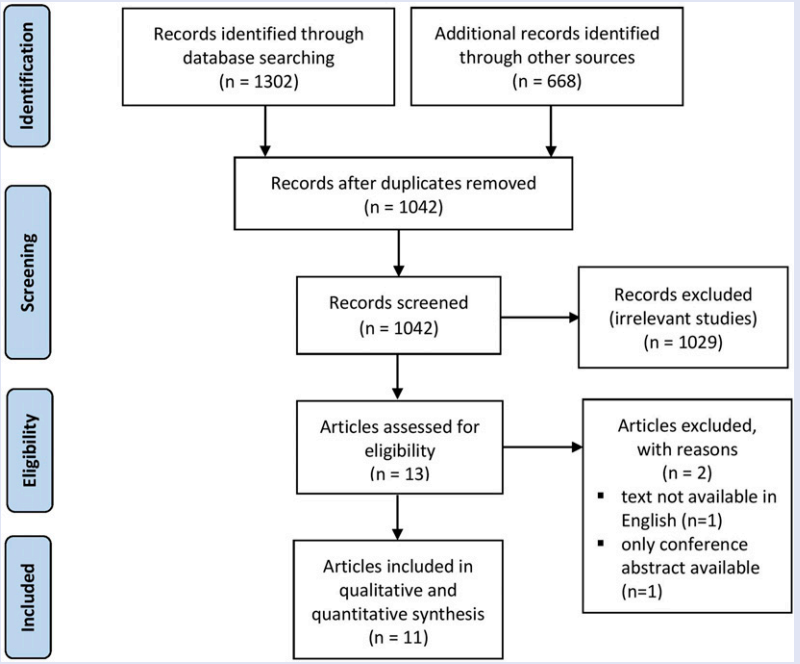
Process of study selection is detailed in PRISMA flow diagram (Figure 1). Initial search retrieved 1302 articles from electronic databases [Scopus (n = 546), Cochrane CENTRAL (n = 249), PubMed (n = 135), and Embase (n = 372)] and 668 trials from CTRI database. Duplicate records were removed to yield 1042 articles which were then screened for irrelevant studies (n = 1029) based on title and abstract. As a result, 13 full text articles were then assessed for eligibility, from which 2 articles were excluded as text of one research article was not available in English and only conference abstract was available for another article. The remaining 11 articles were included for systematic review. Out of these, 3 RCTs belonged to the same study (study by Nidhi et al had 3 publications). Hence, a total of 9 studies were available for this review. Further, 2 RCTs (Nidhi et al, 2012, 2013a, 2013b; Patel et al, 2020) were included for meta-analysis due to homogeneity.

Characteristics of Eligible Studies

Characteristics of eligible studies are provided in Table 1. A total of 11 studies were found eligible for this review which were conducted in

Figure 1.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for study selection.



India, Iran, and the United States. Out of these studies, 9 were included for this review among which 3 studies were RCTs, 5 were pre-post clinical trials, and 1 was case series. A total number of subjects were 515 which were diagnosed with PCOS on the basis of Rotterdam and other assessment criteria. Intervention provided in these studies primarily consisted of YT. Follow-up duration of these studies ranged from 6 weeks to 4 months. Effect of YT on health outcomes including reproductive, metabolic, anthropometric, and quality of life was assessed in these studies.

Risk of Bias in Individual Studies

Among RCT studies, 1 study was assessed with low overall risk of bias and the other 2 studies with moderate overall risk of bias. Among non-randomized studies, 3 studies were assessed with moderate overall risk of bias and 3 studies with serious overall risk of bias. Thus, among all 9 studies included for this review, 1 study was assessed to be of high quality, 5 were of moderate quality, and remaining 3 studies were of low quality. Risk of bias graph and summary for RCT and non-randomized studies is shown in Figures 2A-2D.

Overall Quality of Evidence

Summary of findings presented in Table 2 evaluates the overall quality of body of evidence for review outcomes including menstrual regularity, clinical hyperandrogenism, glucose tolerance, BMI, WHR, and anxiety level. Outcome data were extracted from included studies and comparisons were formatted in data tables for preparation of "Summary of Findings" table. Evidence quality was then classified into high, moderate, low, or very low according to GRADE criteria and incorporated into reporting of the results for each outcome.

Systematic Review

Summary of effect of YT on health outcomes as mentioned in included studies among women suffering from PCOS is presented in Tables 3–6.

Reproductive Outcomes. Menstrual cycle regularity significantly increased ($P < .001$) in the study by Shalini et al, 2019; right ovarian volume significantly decreased ($P = .001$) in the study by Vibhuti et al, 2018; mFG score significantly decreased ($P = .002$) in the study by Nidhi et al, 2012; testosterone levels significantly decreased ($P = .002$ and $P = .041$) in the study by Nidhi et al, 2012 and Patel et al, 2020, respectively; anti-Müllerian hormone (AMH) levels significantly decreased ($P = .006$ and $P = .004$) in the study by Nidhi et al, 2012 and Vibhuti et al, 2018, respectively; and luteinizing hormone (LH) levels significantly decreased ($P = .005$ and $P = .006$) in the study by Nidhi et al, 2012 and Vibhuti et al., 2018, respectively.

Metabolic Outcomes. FI level significantly decreased ($P < .001$) in the study by Nidhi et al, 2012; FBG level significantly decreased ($P = .001$) in the study by Vanitha et al, 2018; lipid profile significantly improved ($P = .001$) in the study by Nidhi et al, 2012 and Vanitha et al, 2018; and hemoglobin A1C (HbA1C) level significantly decreased ($P = .0001$ and $P = .01$) in the study by Vanitha et al, 2018 and Vibhuti et al, 2018, respectively.

Anthropometric Outcomes. Weight of the study participants significantly decreased ($P < .001$)

Table 1.

Demographic Details of Eligible Studies.

#	Study, year	Country	Study design	Number of subjects (females)		Mean age ± SD		PCOS diagnosis criteria	Intervention		Follow-up duration	Outcomes measured	Included in systematic review or meta-analysis or both
				Yoga group	Control group	Yoga group	Control group		Yoga group	Control group			
1	Bahrami et al,[16] 2019	Iran	RCT	31	30	30.77 ± 6.01	30.35 ± 5.53	Cannot be specified	Yoga practices consisting of asanas, pranayama, and relaxation techniques	No intervention	6 weeks	*Primary:* Quality of life, hirsutism, no. of follicles/ovary, no. of embryos, and βHCG *Secondary:* Weight, acne, infertility, and menstrual disorder	No; article text not available in English
2	Nidhi et al,[11-13] 2012	India	RCT	42	43	16.22 ± 1.13	16.22 ± .93	Rotterdam criteria	Yoga practices consisting of asanas, pranayama, relaxation techniques, meditation, and counseling	Similar set of conventional physical exercises along with counseling session	3 months	*Primary*: Serum FI, FBG, AMH, serum lipids,[a] state anxiety, and trait anxiety *Secondary:* BMI, WHR, LH, FSH, TT, prolactin, mFG score, and menstrual cycle length	Yes (included in systematic review and meta-analysis)
3	Patel et al,[14] 2020	United States	RCT	13	9	30.9 ± 1.2	31.2 ± 2.3	Rotterdam criteria	Yoga practices consisting of mental body scan, pranayama, asanas (vinyasa and restorative), and meditation	Wait list, no intervention was given	3 months	*Primary*: Serum testosterone level *Secondary*: Menstrual cycle length, mFG score, DHEA, DHEAS, A4, FBG, FI, HOMA-IR, adiponectin, WHR, BMI, BAI score, and BDI-II score	Yes (included in systematic review and meta-analysis)

(continued)

Table 1. (continued)

4	Rao et al,[19] 2018	India	RCT	32	32	29.23 ± 5.34	29.27 ± 5.06	Rotterdam criteria	Ayurvedic treatment consisting of Panchakarma practices and Ayurvedic medicines along with yoga practices consisting of asanas, pranayama, relaxation techniques, and meditation	Ayurvedic treatment consisting of Panchakarma practices and Ayurvedic medicines	3 months	AMH, prolactin, testosterone, FSH, LH, T3, T4, TSH, ovarian mass, HbA1C, weight, anxiety, and depression	Included in systematic review
5	Ratnakumari et al,[23] 2018	India	Pre-post clinical trial	25	25	23.77 ± 5.33	25.05 ± 4.83	Rotterdam criteria	Yoga intervention consisting of asanas, pranayama, relaxation techniques and kriyas and naturopathic intervention consisting of hydrotherapy, mud therapy, manipulative therapy, fasting, and diet	Wait list, no intervention given	12 weeks	*Primary*: Ovarian morphology *Secondary*: Body weight, BMI, chest circumference, waist circumference, hip circumference, and WHR	Included in systematic review
6	Shalini et al,[17] 2019	India	Case series	10	—	Not provided	—	Cannot be specified	Asanas along with varma stimulations and internal medication	—	3 months	Irregular menstrual cycle, duration of bleeding, and BMI	Included in systematic review
7	Shanthi et al,[18] 2014	India	Pre-post clinical trial	10	—	25 ± 5.23	—	Cannot be specified	Kayakalp yogic exercises	—	3 months	FSH, LH, Hb, PP blood glucose, and cholesterol	Included in systematic review

(continued)

Table 1. (continued)

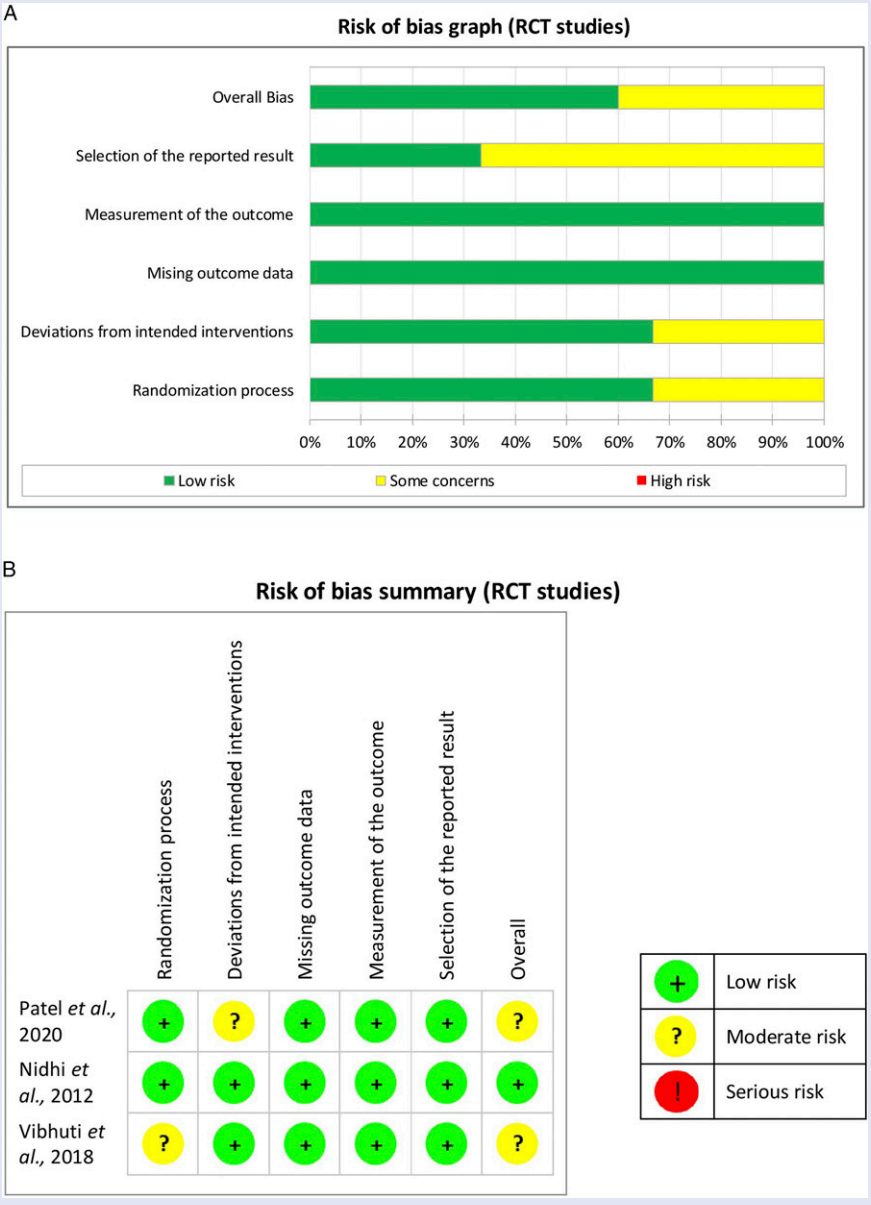
8	Selvaraj et al,[15] 2020	India	Pre-post clinical trial	102	102	33.42 ± 7.33	22.87 ± 12.15	PCOS risk assessment questionnaire	Yoga practices consisting of asanas, pranayama, relaxation techniques, meditation, counseling, and brisk walking	No intervention	4 months	PCOS risk minimization	Included in systematic review
9	Sode et al,[24] 2017	India	Pre-post clinical trial	30	—	Cannot be specified	—	Rotterdam criteria	Yoga module comprising of asanas, pranayama, and meditation	—	1 month	Level of depression	Included in systematic review
10	Vanitha et al,[22] 2018	India	Pre-post clinical trial	40	—	26.13 ± 5.30	—	Rotterdam criteria	Yoga nidra	—	3 months	*Primary*: Blood glucose levels, lipid profile, and HbA1C *Secondary*: BMI, WHR, SBP, and DBP	Included in systematic review
11	Verma et al,[21] 2017	India	Pre-post clinical trial	30	—	Cannot be specified	—	Cannot be specified	Yoga	—	3 months	FBG, FI, and HOMA-IR	No; only conference abstract available for this study

Abbreviations: PCOS, polycystic ovarian syndrome; RCT, randomized controlled trial; βHCG, positive beta human chorionic gonadotropin; FI, fasting insulin; FBG, fasting blood glucose; AMH, anti-Müllerian hormone; BMI, body mass index; WHR, waist-to-hip ratio; LH, luteinizing hormone; FSH, follicle-stimulating hormone; TT, total testosterone; mFG, modified Ferriman–Gallwey; DHEAS, dehydroepiandrosterone sulfate; A4, androstenedione; HOMA-IR, homeostatic model assessment-insulin resistance; BAI, Beck Anxiety Inventory; BDI-II, Beck Depression Inventory-II; Hb, hemoglobin; PP, post-prandial; SBP, systolic blood pressure; DBP, diastolic blood pressure; T3, triiodothyronine; T4, thyroxine; TSH, thyroid-stimulating hormone; HbA1C, glycated hemoglobin.

[a]Serum lipids: total cholesterol (TC), triglycerides (TRIG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL), TC/HDL.

Figure 2.

(A) Risk of bias graph (randomized controlled trial (RCT) studies). (B) Risk of bias summary (RCT studies). (C) Risk of bias graph (non-randomized studies). (D) Risk of bias summary (non-randomized studies).



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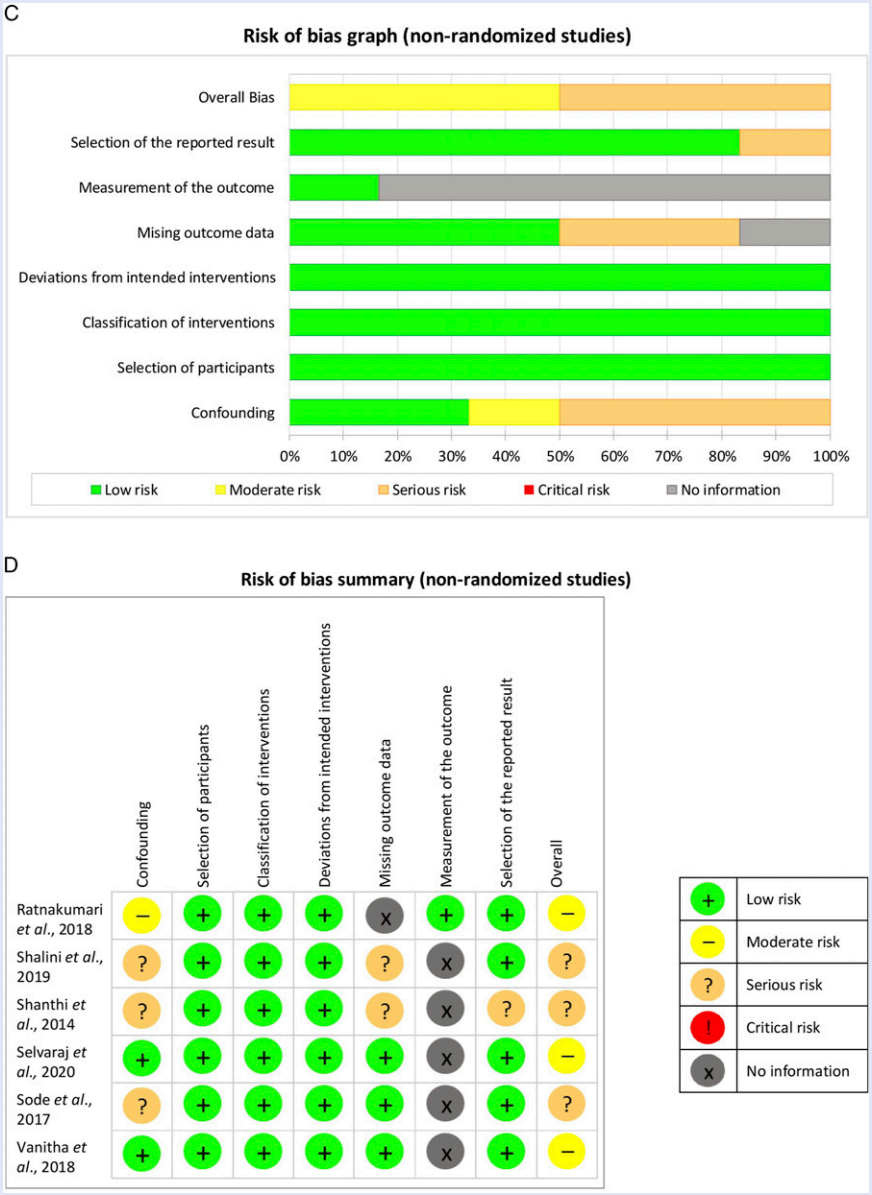
in the study by Ratnakumari et al, 2018 and Vanitha et al, 2018; BMI significantly decreased ($P < .001$) in the study by Ratnakumari et al, 2018, Shalini et al, 2019, and Vanitha et al, 2018; and WHR significantly decreased ($P < .02$) in the study by Vanitha et al, 2018.

Quality of Life Outcomes. Anxiety level significantly decreased ($P = .002$, $P < .001$) in the study by Nidhi et al, 2012 and Vibhuti et al, 2018, respectively and depression level significantly decreased ($P < .0001$, $P < .0001$, $P < .001$) in the study by Patel et al, 2020, Sode et al, 2017, and Vibhuti et al, 2018, respectively.

Meta-Analysis

Meta-analysis was conducted for two of the included studies for primary and secondary health outcomes as defined in

Figure 2. Continued.



this review and is presented as forest plots in Figure 3. Comparison of health outcomes of included studies is represented in Table 7.

Primary Outcome

Reproductive. Menstrual cycle regularity (defined as initiation of menses or significant shortening of cycle length or increase in cycle frequency per month): Only one study[11-13] reported on this outcome. This study reported the data as mean ± SD menstrual cycle frequency per month for YT vs MT [2.38 ± .64 vs 1.97 ± .79, MD .41, 95% CI −.74 to −.08, P = .02] suggestive of YT resulting in a greater increase in menstrual cycle frequency per month as compared to MT (exercise).

Secondary Outcomes

Reproductive. Clinical Hyperandrogenism (hirsutism assessed clinically by mFG *score)* was assessed in both included studies by reporting changes in mFG scores. Pooled analysis of results show that YT may result in a greater decrease in hirsutism (mFG score) (MD −.70, 95% CI −1.15 to −.26, I^2 = 0%) compared to MT, with very low heterogeneity.

Table 2.

Summary of Findings.

Yoga therapy compared to minimal treatment for women with polycystic ovary syndrome				
Patient or population: Women with polycystic ovary syndrome Setting: Residential college, wellness center Intervention: Yoga therapy Comparison: Minimal treatment (exercise or no intervention)				
Outcomes	Anticipated effects	Effect estimate[a] (95% CI)	No. of participants (studies)	Certainty of the evidence (GRADE)
Reproductive outcome: Menstrual regularity (frequency in months)	YT may reduce menstrual irregularity (frequency in months) by .41 (improvement of .74 to .08)	MD −.41 [−.74, −.08]	72 (1 RCT)	⊕⊕◯◯LOW[b,c]
Reproductive outcome: Clinical hyperandrogenism (hirsutism) (mFG score)	YT may reduce clinical hyperandrogenism (hirsutism) (mFG score) by .70 (reduction of 1.15 to .26)	MD −.70 [−1.15, −.26]	94 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Metabolic outcome: FBG (mmol/L)	YT may reduce FBG by .22 mmol/L (reduction of .44 mmol/L to .01 mmol/L)	MD −.22 [−.44, −.01] mmol/L	93 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Metabolic outcome: FI (pmol/L)	YT may reduce FI by 28.21 pmol/L (reduction of 43.79 pmol/L to 12.63 pmol/L)	MD −28.21 [−43.79, −12.63] pmol/L	93 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Metabolic outcome: HOMA-IR value	YT may reduce HOMA-IR value by .86 (reduction of 1.29 to .43)	MD −.86 [−1.29, −.43]	93 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Anthropometric outcome: BMI (kg/m^2)	YT may reduce BMI by 1.38 kg/m^2 (reduction of 2.37 kg/m^2 to .40 kg/m^2)	MD −1.38 [−2.37, −.40] kg/m^2	93 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Anthropometric outcome: WHR	YT may slightly reduce WHR by .02 (reduction of .03 to .01)	MD −.02 [−.03, −.01]	93 (2 RCTs)	⊕⊕◯◯ LOW[c,d]
Quality of life: Anxiety level score	Uncertain of effect of YT on anxiety level score	SMD −.13 [−.54, .28]	94 (2 RCTs)	⊕⊕◯◯ LOW[c,d]

Abbreviations: CI, confidence interval; MD, mean difference; SMD, standardized mean difference; YT, yoga therapy; FBG, fasting blood glucose; FI, fasting insulin; HOMA-IR, homeostatic model assessment-insulin resistance; BMI, body mass index; WHR, waist-to-hip ratio.
GRADE working group grades of evidence: ⊕⊕⊕⊕: True effect lies close to that of the estimate of the effect. ⊕⊕⊕◯: True effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. ⊕⊕◯◯: True effect may be substantially different from the estimate of the effect. ⊕◯◯◯: True effect is likely to be substantially different from the estimate of effect.
[a]Risk in intervention group (and its 95% confidence interval) is based on assumed risk in comparison group and relative effect of intervention (and its 95% CI).
[b]Downgraded one level for inconsistency: only one study reported this outcome.
[c]Downgraded one level for imprecision: few number of participants.
[d]Downgraded one level for serious risk of bias: high attrition rate of participants.

Metabolic

1. *FBG level* was measured in both included studies. Pooled analysis of results show that YT may result in slight decrease in hirsutism (mFG score) (MD −.22 mmol/L, 95% CI −44 to −.01, $I^2 = 85\%$) compared to MT, with high heterogeneity.
2. *FI level* was measured in both included studies. Pooled analysis of results show that YT may result in slight decrease in FI level (MD

Table 3.

Systematic Review: Change in Reproductive Outcomes After Intervention Among Women with PCOS.

#	Study, year	Group	Reproductive outcomes																			
			Menstrual cycle regularity			Ovarian volume			mFG score			Testosterone			AMH			FSH			LH		
			N	Mean change ±SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*
1	Nidhi et al,[12] 2012	YT	37	↑.89 ± .66	.049[a]	NS	NS	NS	37	↓1.14 ± 1.44	.002[b]	NS	NS	NS	37	↓2.51 ± 2.92	.006[b]	37	↓.40 ± 2.27	.474	37	↓4.09 ± 9.99	.005[b]
		C	35	↑.49 ± .98		NS	NS	NS	35	↑.06 ± 1.51		NS	NS	NS	35	↓.49 ± 2.20		35	↓.31 ± 2.70		35	↑3.00 ± 7.48	
2	Patel et al,[14] 2020	YT	NS	NS	NS	NS	NS	NS	13	0 ± 0.6	.95	13	↓1.72 ± .95	.041[a]	NS	NS	NS	NS	NS	NS	NS	NS	NS
		C	NS	NS	NS	NS	NS	NS	9	0 ± 0.6	.99	9	↓.03 ± 1.46	.967	NS	NS	NS	NS	NS	NS	NS	NS	NS
3	Ratnakumari et al,[23] 2018[c]	YT + N	22	29 days	.124	22	Right ↓1.67 (−3.8, 7.04) Left ↓3.68 (1.1, 8.44)	.307	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		C	22	33 days		22	Right ↑1.02 (−4.06, 3.7) Left ↑.79 (−4.5, 4.33)	.032[a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4	Shalini et al,[17] 2019	YT + S	10	↓1.80 ± .60	<.001[b]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	Shanthi et al, 2014	YT	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	10	↓.17 ± 1.18	NS	10	↓11.97 ± 6.67	NS
6	Vibhuti et al, 2018	YT + A	NS	NS	NS	30	Right ↓1.70 ± 4.38 Left ↓2.76 ± 3.86	.003[b] 089	NS	NS	NS	30	↓2.94 ± 6.86	.003[b]	30	↓2.86 ± 2.43	.004[b]	30	↓.35 ± 16.06	.728	30	↓2.77 ± 6.25	.006[b]
		A	NS	NS	NS	30	Right ↓1.99 ± 4.58 Left ↓1.25 ± 5.59	.376 .167	NS	NS	NS	30	↓1.11 ± 6.32	.266	30	↓2.76 ± 3.71	.006[b]	30	↓1.23 ± 3.36	.218	30	↓1.27 ± 5.06	.204

Abbreviations: SD, standard deviation; mFG, modified Ferriman–Gallwey; AMH, anti-Müllerian hormone; FSH, follicle-stimulating hormone; LH, luteinizing hormone; YT, yoga therapy; C, control; N, naturopathy; S, Siddha; A, Ayurveda; NS, not specified.

[a]Significant at $P < .05$.

[b]Significant at $P < .01$.

[c]Values provided in median (quartile 1, quartile 3).

Table 4.

Systematic Review: Change in Metabolic Outcomes After Intervention Among Women with PCOS.

#	Study, year	Group	Metabolic outcomes														
			FI			FBG			HOMA-IR			Lipid profile			HbA1C		
			n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*
1	Nidhi et al,[12] 2012	YT	35	↓9.04 ± 32.31	< .001[b]	35	↓.24 ± .39	< .001[b]	35	↓.38 ± .92	<.05[a]	35	TRIG ↓.15 ± .12 TCHL ↓.24 ± .29 HDL ↑.03 ± .04 LDL ↓.21 ± .25 VLDL ↓.06 ± .05	<.001[b] <.001[b]<.001[b] <.001[b] <.001[b]	NS	NS	NS
		C	36	↑11.09 ± 56.85	<.001[b]	36	↑.04 ± .44	.47	36	↑.29 ± 1.56	.19	36	TRIG ↓.07 ± .12 TCHL ↓.07 ± .46 HDL ↑.03 ± .58 LDL ↓.07 ± .39 VLDL ↓.03 ± .06	<.001[b] .15 <.01[b] .13 <.001[b]	NS	NS	NS
2	Patel et al,[14] 2020	YT	13	↓6 ± 69.55	.824	13	↓.09 ± .11	.387	13	↓.3 ± 2.31	.693	NS	NS	NS	NS	NS	NS
		C	9	↓12.6 ± 20.12	.328	9	↑.16 ± .21	.403	9	↓.48 ± .86	.382	NS	NS	NS	NS	NS	NS
3	Shanthi et al, 2014	YT	NS	NS	NS	10	↓1.2 ± .40	NS	NS	NS	NS	10	TCHL ↓1.01 ± .37	NS	NS	NS	NS
4	Vanitha et al,[22] 2018	YT	NS	NS	NS	40	↓.42 ± .68	.001[b]	NS	NS	NS	40	TRIG ↓.38 ± .69 TCHL ↓.31 ± .84 HDL ↑.11 ± .18 LDL ↓.46 ± .77 VLDL ↓.05 ± .15	.001[b] .001[b] .0001[b] .0001[b] .0001[b]	40	↓.62 ± .57	.0001[a]
5	Vibhuti et al, 2018	YT + A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	30	↓1.13 ± .54	.017[a]
		A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	30	↑2.11 ± .51	.035[a]

Abbreviations: SD, standard deviation; FI, fasting insulin; FBG, fasting blood glucose; HOMA-IR, homeostatic model assessment-insulin resistance; HbA1C, hemoglobin A1C; YT, yoga therapy; C, control; A, Ayurveda; NS, not specified.

[a]Significant at $P < .05$.

[b]Significant at $P < .01$.

Table 5.

Systematic Review: Change in Anthropometric Outcomes After Intervention Among Women with PCOS.

#	Study, year	Group	Anthropometric outcomes								
			Weight			BMI			WHR		
			N	Mean change ± SD	*P*	n	Mean change ± SD	*P*	n	Mean change ± SD	*P*
1	Nidhi et al,[12] 2012	YT	37	↓.04 ± 1.34	.882	35	↓.11 ± .51	.32	35	↓.01 ± .05	.53
		C	35	↑.79 ± 4.13		36	↑.31 ± 1.63	.66	36	0 ± .05	.42
2	Patel et al,[14] 2020	YT	NS	NS	NS	13	↓.3 ± 1.95	.38	13	↓.013 ± .016	.32
		C	NS	NS	NS	9	↑.2 ± 3.3	0.4	9	↑.011 ± .02	.34
3	Ratnakumari et al,[23] 2018[c]	YT + N	22	↓6 (4, 8)	<.001[a]	22	↓2.36 (1.6, 3.28)	<.001[a]	22	↑.01 (−.03, .02)	.777
		C	22	0 (−1.5, 2)		22	0 (−.49, 0.84)		22	↑.01 (−.04, .01)	
4	Shalini et al,[17] 2019	YT + S	NS	NS	NS	10	↓.6 ± .81	<.001[a]	NS	NS	NS
5	Vanitha et al,[22] 2018	YT	40	↓4.34 ± 12.56	.001[a]	40	↓1.83 ± 4.59	.001[a]	40	↓.04 ± .03	.02[a]
6	Vibhuti et al, 2018	YT + A	30	↓.51 ± 16.55	.607	NS	NS	NS	NS	NS	NS
		A	30	↓.85 ± 9.58	.396	NS	NS	NS	NS	NS	NS

Abbreviations: SD, standard deviation; BMI, body mass index; WHR, waist-to-hip ratio; YT, yoga therapy; C, control; N, naturopathy; S, Siddha; A, Ayurveda; NS, not specified.
[a]Significant at $P < .05$.
[b]Significant at $P < .01$.
[c]Values provided in median (quartile 1, quartile 3).

Table 6.

Systematic Review: Change in Quality of Life Outcomes After Intervention Among Women with PCOS.

#	Study, year	Group	Quality of life outcomes					
			Anxiety			Depression		
			n	Mean change ± SD	*P*	N	Mean change ± SD	*P*
1	Nidhi et al,[12] 2012	YT	35	↓14.97 ± 9.87	.002[a]	NS	NS	NS
		C	36	↓7.42 ± 7.57		NS	NS	NS
2	Patel et al,[14] 2020	YT	13	↓3.1 ± 2.59	.037	13	↓8.75 ± 2.47	<.0001[a]
		C	9	↓1.1 ± 2.57	.633	9	↓6 ±1.91	.06[a]
3	Sode et al,[24] 2017	YT	NS	NS	NS	30	↓13.51 ± 7.37	<.0001[a]
4	Vibhuti et al, 2018	YT + A	30	↓6.30 ± 3.54	<.001[a]	30	↓6.08 ± 3.85	<.001[a]
		A	30	↓4.64 ± 3.12	<.001[a]	30	↓3.79 ± 3.48	<.001[a]

Abbreviations: SD, standard deviation; YT, yoga therapy; C, control; A, Ayurveda; NS, not specified.
[a]Significant at $P < .05$.
[b]Significant at $P < .01$.

−28.21 pmol/L, 95% CI −43.79 to −12.63, $I^2 = 0\%$) compared to MT.

3. *HOMA-IR* was measured in both included studies. Pooled analysis of results show that YT may result in slight decrease in HOMA-IR value (MD −.86, 95% CI −1.29 to −.43, $I^2 = 0\%$) compared to MT.

Anthropometric

1. *BMI* was measured in both included studies. Both included studies observed no significant change in BMI in both groups. Pooled analysis of results show that YT may result in slight decrease in BMI (MD − 1.38 kg/m^2, 95% CI − 2.37 to − .40, $I^2 = 0\%$) compared to MT.
2. *WHR* was measured in both included studies. Both included studies observed no significant change in WHR in both groups. Pooled analysis of results show that YT may result in slight decrease in WHR (MD − .02, 95% CI − .03 to − .10, $I^2 = 0\%$) compared to MT.

Quality of Life (Psychological). *Anxiety level* was measured in both included studies. Both included studies observed significant change in experimental group. One study[11-13] showed significant changes in trait anxiety scores in experimental group. Other study[14] showed significant change in Beck Anxiety Inventory scores in the experimental group. However, pooled analysis of results shows uncertainty about the effect of YT on anxiety levels (SMD − .13, 95% CI − .54 to .28, $I^2 = 0\%$) as compared to MT.

Discussion

Summary of Evidence

The current systematic review and meta-analysis was aimed at investigating the effect of YT on health outcomes in women with PCOS. Data from these studies showed evidence of beneficial effect of YT on reproductive (menstrual irregularity and clinical hyperandrogenism), metabolic (FBG, FI, and HOMA-IR values) and anthropometric outcomes (BMI and WHR) as compared to MT. However, pooled results show uncertainty about the effect of YT on quality of life outcome (anxiety level) as compared to MT.

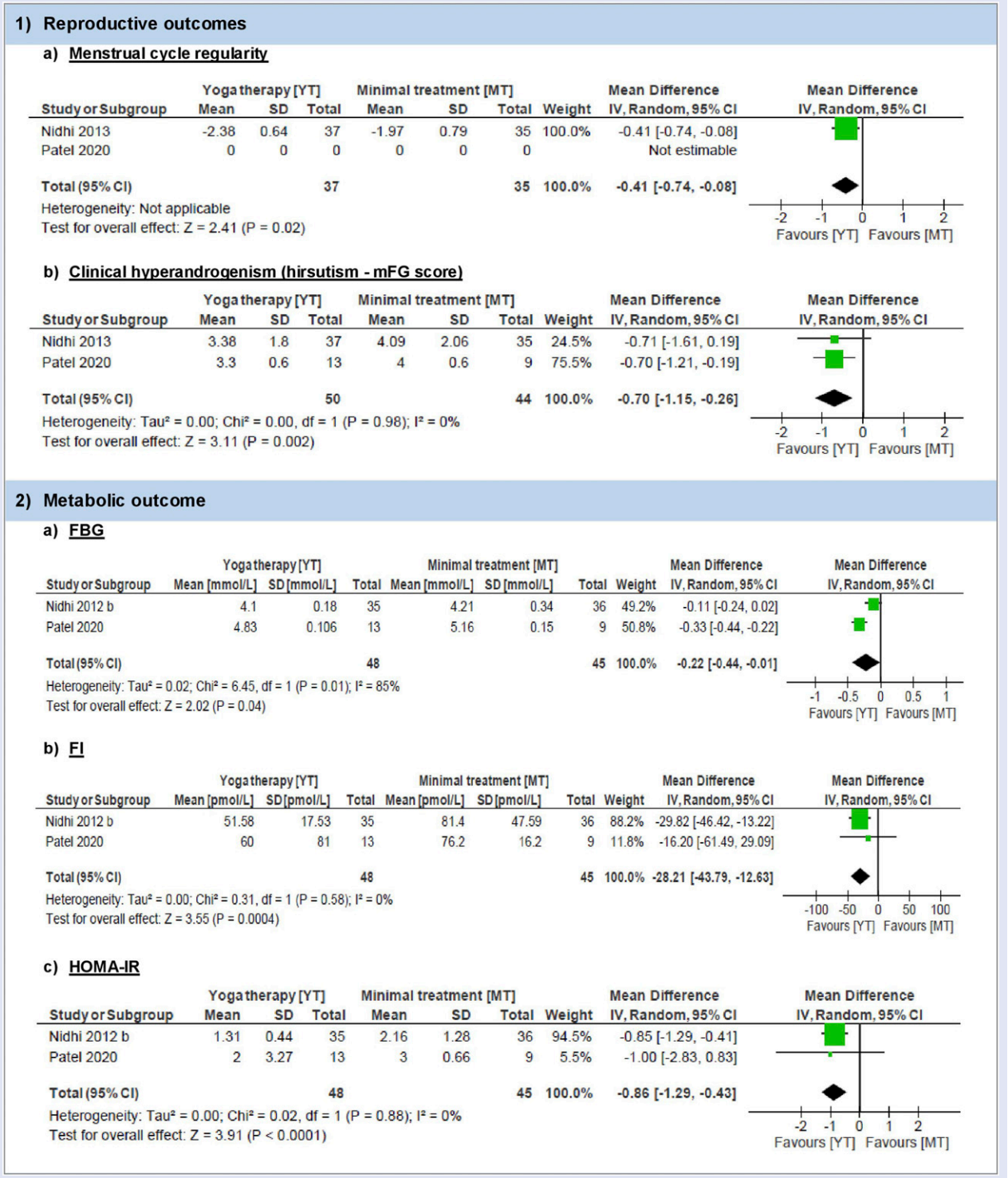
Findings

Reproductive Outcomes. The RCTs included in meta-analysis are suggestive of beneficial effects of YT on reproductive health outcomes such as menstrual regularity and clinical hyperandrogenism.

Menstrual regularity was however reported as an outcome measure in only one[13] of the studies included in meta-analysis. A recent study involving adolescent girls conducted in India[15] reported slight improvement on menstrual conditions after 2 months of YT intervention along with 2 months of brisk walking. Another study involving females suffering from infertility in Iran[16] reported a significant reduction in menstrual disorders ($P < .001$) after 6 weeks of YT intervention. Also, a case series study conducted in India[17] reported

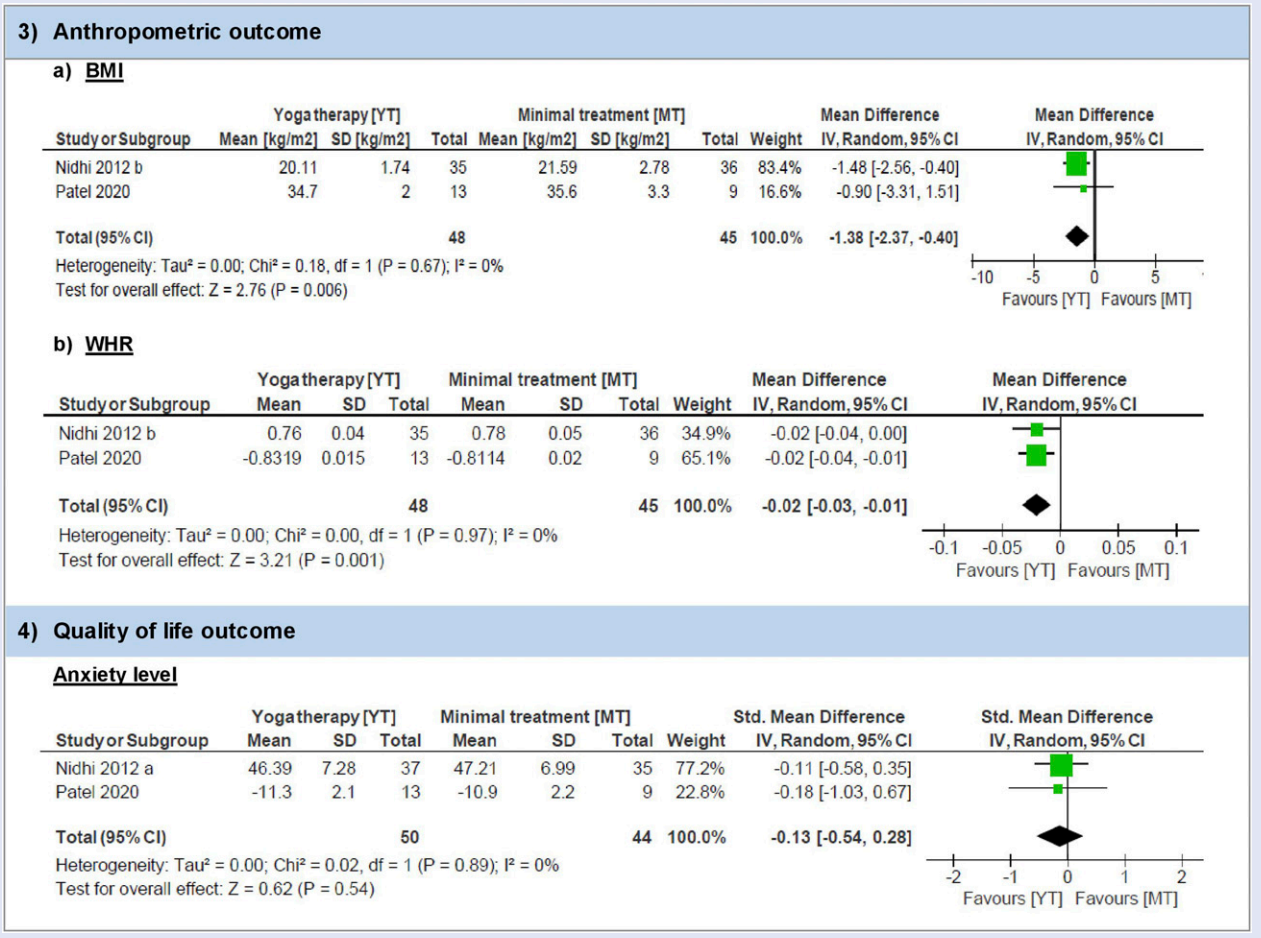
Figure 3.

Meta-analysis of health outcomes.



Continued

Figure 3. Continued.



significant improvement in menstrual cycle regularity ($P < .001$) after 3 months of YT intervention along with Siddha medication among females suffering from PCOS.

The effect of YT intervention on biochemical hyperandrogenism (in the form of androgen excess) was reported for different endocrine hormones and showed reduction in serum and total testosterone, dehydroepiandrosterone sulfate, LH, and AMH levels of participants in the intervention group. A clinical trial conducted on females with PCOS reported significant decrease in LH level ($P < .001$) after 3 months of YT intervention.[18] Also, a RCT reported significant decrease in levels of LH ($P = .006$), testosterone ($P = .003$), and AMH ($P = .004$) in females with PCOS after 3 months of YT along with Ayurveda treatment.[19]

This meta-analysis assessed the effect of YT intervention on clinical features of hyperandrogenism, mainly hirsutism, in the form of reduction in mFG scores. Findings of meta-analysis are suggestive of beneficial effect of YT in reducing hirsutism. This is consistent with the results of latest Cochrane review[20] on lifestyle changes in women with PCOS which suggests that lifestyle treatment may improve biochemical and clinical hyperandrogenism which is in agreement with recommendations of international ESHRE-2018 guidelines for PCOS.[1]

Metabolic Outcomes. In terms of metabolic outcomes, the included trials showed positive effects of YT in reduction of levels of FBG, FI, and HOMA-IR. The results are similar to the findings of another study conducted in India which reported significant reduction in these metabolic outcomes ($P < .01$) after 12 weeks of YT intervention.[21] A clinical trial conducted on females with PCOS reported significant decrease in post-prandial blood sugar (PPBS) level ($P < .001$) after 3 months of YT

Table 7.

Comparison of Health Outcomes.

#	Study, year	Outcomes																							
			Menstrual cycle regularity			mFG score			FBG			FI			HOMA-IR value			BMI			WHR			Anxiety level		
		Group	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*	n	Mean change	*P*
1	Patel et al,[14] 2020	Yoga therapy	—	—	—	13	0 ± .6	.95	13	↓.09 ± .11	.387	13	↓6 ± 69.55	.824	13	↓.3 ± 2.31	.693	13	↓.3 ± 1.95	.38	13	↓.013 ± .016	.32	13	↓3.1 ± 2.59	.037
		No intervention	—	—	—	9	0 ± .6	.99	9	↑.16 ± .21	.403	9	↓12.6 ± 20.12	.328	9	↓.48 ± .86	.382	9	↑.2 ± 3.3	.40	9	↑.011 ± .02	.34	9	↓1.1 ± 2.57	.633
2	Nidhi et al,[12] 2012	Yoga therapy	37	↑.89 ± .66	.049	37	↓1.14 ± 1.44	.002		↓.24 ± .39	<.001	35	↓9.04 ± 32.21	<.001	35	↓.38 ± .92	<.05	35	↓.11 ± .51	.32	35	↓.01 ± .05	.53	35	↓14.97 ± 9.87	.002
		Exercise	35	.49 ± ↑.98		35	↑.06 ± 1.15			↑.04 ± .44	.47	36	↑11.09 ± 56.85	<.001	36	↑.29 ± 1.56	.19	36	↑.31 ± 1.63	.66	36	0 ± .05	.42	36	↓7.42 ± 7.57	

Abbreviations: mFG, modified Ferriman–Gallwey; FBG, fasting blood glucose; FI, fasting insulin; HOMA-IR, homeostatic model assessment-insulin resistance; BMI, body mass index; WHR, waist-to-hip ratio.

intervention.[18] An RCT reported significant decrease in HbA1C level ($P = .017$) in females with PCOS after 3 months of YT along with Ayurveda treatment.[19] Also, another study similarly reported significant improvement in metabolic outcomes (FBG, PPBS, and HbA1C) ($P < .001$) of study participants after 3 months of YT intervention.[22] This is consistent with the evidence-based recommendation of ESHRE-2018 guidelines[1] that multicomponent lifestyle intervention should be recommended in all those with PCOS and excess weight, for reductions in weight, central obesity, and insulin resistance.

Similarly, changes in lipid profile after YT intervention was reported in only one[13] of the studies included in meta-analysis which reported significant improvement in lipid profile of participants in the intervention group. A clinical trial conducted on females with PCOS reported significant decrease in cholesterol level ($P < .001$) after 3 months of YT intervention.[18] A similar trial reported significant improvement in lipid profile ($P < .001$) of study participants after 3 months of YT intervention.[22]

Anthropometric Outcomes. Anthropometric outcomes including BMI and WHR were found to be modestly affected by YT intervention provided in the studies included in meta-analysis. This is consistent with the findings of other studies[15,17,19,23] which assessed the effect of YT intervention and reported slight reduction in BMI and WHR of participants. This may be due to presence of heterogeneity in baseline anthropometric parameters of included participants across studies. Only one clinical trial reported significant reduction in BMI ($p < .001$) of study participants after 3 months of YT intervention.[22]

Quality of Life Outcomes. Both studies included in meta-analysis \reported significant improvement in quality of life as measured by level of anxiety or depression. A study which evaluated the effect of 4 months of YT intervention along with brisk walking on PCOS risk reduction also reported similar finding.[15] Similarly, a clinical trial reported significant change in level of depression ($p < .01$) among study participants after 1 month of YT intervention.[24] Also, a RCT reported significant decrease in level of anxiety and depression ($p < .001$) in females with PCOS after 3 months of YT along with Ayurveda treatment.[19] Similar findings were reported in latest Cochrane review[20] which suggests that lifestyle intervention may improve quality of life scores in the domains of emotions and infertility in women with PCOS. This is consistent with the clinical consensus recommendations ESHRE-2018 guidelines[1] that lifestyle interventions could include behavioral strategies to optimize weight management, healthy lifestyle, and emotional well-being in women with PCOS.

Strengths and Limitations

This systematic review and meta-analysis add to the knowledge about effects of YT on health outcomes of women with PCOS. YT encompasses all domains of lifestyle modification, that is, diet, exercise, and behavioral modifications. Published reviews on the effect of lifestyle modification on PCOS also include studies with YT as an intervention, but the need for this systematic review is supported by the fact that sufficient number of research studies have been published which exclusively assess the effect of YT on PCOS. Hence, to the best of author(s)' knowledge, this study is the first and most updated and comprehensive data analysis on this topic.

This review is, however, limited by the fact that only two RCTs could be included in meta-analysis as inclusion of other non-RCT studies could result in high heterogeneity in results due to varying study designs. The sample size of both included studies was not large enough and the participants could not be blinded due to intervention characteristics. However, the objective outcomes including menstrual cycles, clinical hyperandrogenism, FBG, FI, HOMA-IR, BMI, and WHR were unaffected by the lack of blinding of participants.

Research Recommendations

More well-designed randomized clinical trials for participants of varied age groups with diverse control group interventions, sufficient sample size, and longer follow-up duration need to be conducted to assess the efficacy of YT as a form of complementary and alternative medicine (CAM) treatment for PCOS. As hormonal profile varies considerably among women of different age groups, efficacy of YT intervention should be assessed likewise. For development of standard YT intervention pertaining to a specific health problem, studies of differing duration with variety of YT interventions comprising a combination of asana (physical posture), pranayama (breathing exercise) and dhyana (meditation technique) will apprise the development of clinical guidelines relating to the use of YT as treatment for a range of reproductive health problems.

Conclusion

Based on the findings of this systematic review and meta-analysis, YT may have beneficial effects on

some reproductive (menstrual cycle regularity and clinical hyperandrogenism), metabolic (FBG, FI, and HOMA-IR), and anthropometric (BMI and WHR) health outcomes in women suffering from PCOS. Effect of YT on other health outcomes of women with PCOS could not be assessed due to insufficient number of studies. Based on these preliminary results, YT may be suggested as a safer and affordable form of CAM treatment for PCOS. Further, more clinical trials are warranted in order to strengthen the therapeutic role of YT for PCOS.

Author Contributions

AV and VS were involved in defining research question and the study design of the review. AV and VU were involved in conducting search strategy and assessing eligibility of studies for inclusion. AV, VU, and VS were involved in extracting and analyzing data, assessing quality of studies, drafting manuscript, and critical discussion. All authors read and approved the final version of manuscript.

Declaration of Conflicting Interests

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Supplementary Material

Supplementary material for this article is available online. AJLM

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