

Effect of a 12-Week Structured Yogic Intervention on Circadian Rhythm Imbalance in Women with Polycystic Ovary Syndrome: A Randomized Controlled Trial

Shyam Tank¹, Charu Mehendiratta²

¹Research Scholar, Apex School of Naturopathy and Yogic Sciences, Apex University, Jaipur, Rajasthan, India

²Head of Department, Apex School of Naturopathy and Yogic Sciences, Apex University, Jaipur, Rajasthan, India

Abstract

There exists frequent coexistence of circadian rhythm disorders with polycystic ovary syndrome (PCOS), which worsens symptoms like hyperandrogenism, insulin resistance, and sleep disturbance, however, the use of non-pharmacological interventions that affect biological clock is poorly studied. In this randomized controlled trial, the effects of 12-week yogic intervention program aimed at restoring circadian rhythm disorders in patients with PCOS were studied. Sixty patients aged 18-35 years with PCOS defined according to Rotterdam criteria and exhibiting evening chronotype with disturbed sleep quality were randomly assigned into the yoga (n=30) or control groups (n=30). Patients from the yoga group were subjected to a 60-minute program of asana, pranayama, and meditation, combined with sleep hygiene counseling performed 6 times per week for 12 weeks, while the control group was given general advice regarding the lifestyle. Morning and evening cortisol levels, reproductive hormones, anti-Müllerian hormone, HOMA-IR, body mass index, and menstrual regularity were measured before and after 12 weeks of the intervention, along with chronotype (using the Morningness-Eveningness Questionnaire) and sleep quality (Pittsburgh Sleep Quality Index). Fifty-seven patients finished the study (yoga 28, control 29). The yoga group compared to the control group had significantly higher levels of morningness (mean difference = 9.2 points, 95% CI 8.0-10.3, $p < 0.001$), improved sleep quality (mean difference = -3.9 points, 95% CI -4.6 to -3.1, $p < 0.001$), restored diurnal cortisol gradient, and significantly lower levels of luteinizing hormone, luteinizing hormone/follicle-stimulating hormone ratio, total testosterone, anti-Müllerian hormone, HOMA-IR and BMI. The regular menstrual cycle was achieved by 64.3% in the yoga group versus 17.2% in the control group ($p < 0.001$). The systematic yogic program successfully normalizes the circadian rhythm and improves endocrine and reproductive status in PCOS women.

Keywords: Polycystic Ovary Syndrome, Yoga, Circadian Rhythm, Sleep Quality, Cortisol, Randomized Controlled Trial

1. Introduction

Polycystic ovary syndrome (PCOS) is the most frequent endocrine disease among reproductive-aged women and has a reported incidence rate between 6% to 20%, according to the diagnostic criteria used [1]. PCOS is distinguished by ovulation disorders, hyperandrogenism or high levels of male hormones in the body and polycystic ovary appearance. Women suffering from PCOS have an increased risk of developing type 2 diabetes, cardiovascular diseases and psychological problems [2, 3]. Insulin resistance combined with functional ovarian hyperandrogenism due to abnormal secretion of gonadotropins is considered the main pathophysiological process of PCOS [4].

In recent years, increasing attention has been directed towards the relationship between PCOS and the circadian timing system. The hypothalamic-pituitary-adrenal axis, which governs the daily rhythm of cortisol secretion, is closely coupled with the master circadian pacemaker, and chronic activation of the stress system is known to disturb both metabolic and reproductive homeostasis [5]. Melatonin, the principal hormonal output of the circadian clock, exerts direct actions on ovarian follicular function, and alterations in melatonin signalling have been implicated in anovulation and poor oocyte quality [6]. A flattened diurnal cortisol slope, reflected by a blunted morning peak and an elevated evening level, is a recognized marker of circadian misalignment and hypothalamic-pituitary-adrenal axis dysregulation [7]. Women with PCOS frequently report delayed sleep-wake timing, evening chronotype and poor subjective sleep quality, which may further amplify insulin resistance and androgen excess, creating a self-perpetuating metabolic and reproductive disturbance.

Chronotype and sleep quality can be quantified reliably with validated instruments such as the Morningness-Eveningness Questionnaire (MEQ) and the Pittsburgh Sleep Quality Index (PSQI) [8, 9]. Despite the growing recognition of circadian disruption in PCOS, therapeutic strategies specifically designed to resynchronize the biological clock remain limited. Current international guidelines place lifestyle intervention at the first line of management, yet they offer little guidance on chronotherapeutic or mind-body approaches [2].

Yoga, an ancient Indian discipline integrating physical postures (asana), regulated breathing (pranayama) and meditation, has demonstrated beneficial effects on glucose metabolism, lipid profile and endocrine parameters in adolescents and women with PCOS in randomized controlled settings [10, 11]. Naturopathic and yogic interventions have also been reported to improve polycystic ovarian morphology [12]. At the physiological level, yoga and mindfulness-based practices reduce cortisol and other stress-related biomarkers, suggesting a direct modulatory influence on the hypothalamic-pituitary-adrenal axis [13]. Pharmacological ovulation induction, although effective for infertility, does not address the underlying circadian and lifestyle disturbance and is associated with cost and adverse effects [14]. In addition, the high burden of anxiety, depression and impaired quality of life in PCOS strengthens the rationale for holistic interventions [15].

However, no randomized controlled trial has so far examined whether a structured yogic intervention, timed in the morning and combined with sleep-hygiene counselling, can correct circadian rhythm imbalance in women with PCOS. The present trial was therefore designed to evaluate the effect of a 12-

week structured yogic intervention on chronotype, sleep quality, diurnal cortisol rhythm, reproductive hormones, insulin resistance and menstrual regularity in women with PCOS presenting circadian rhythm imbalance.

2. Materials and Methods

2.1 Study Design and Setting

The study was a single-center, parallel group, randomized control trial with a 1:1 ratio, which took place from October 2025 to April 2026 in the Apex School of Naturopathy and Yogic Sciences, Apex University, Jaipur, Rajasthan, India. The study was performed according to the Declaration of Helsinki, and it was reported based on CONSORT guidelines for randomized trials.

2.2 Participants

Women aged 18-35 years with a diagnosis of PCOS according to the Rotterdam criteria [1], an evening or intermediate chronotype (MEQ score of 44 or below) and poor sleep quality (PSQI score of 5 or above) were recruited from the outpatient department of the institution and through community screening camps in Jaipur. Participants were required to be free of hormonal contraceptives, anti-androgens, insulin sensitizers and hypnotic or melatonin supplementation for at least three months before enrolment. Women were excluded if they were pregnant or lactating, engaged in night-shift work, had practised yoga regularly during the preceding six months, or presented thyroid dysfunction, hyperprolactinaemia, Cushing syndrome, non-classical congenital adrenal hyperplasia, or any severe psychiatric or systemic illness.

2.3 Sample Size

The sample size was estimated from the expected between-group difference in PSQI score, assuming an effect size of 0.80 on the basis of a previous randomized trial of yoga in PCOS [11], a two-sided alpha of 0.05 and 80% power, which yielded 26 participants per group. To compensate for an anticipated attrition of 15%, 30 participants were enrolled in each group, giving a total sample of 60.

2.4 Randomization and Blinding

Participants who met inclusion criteria were randomly assigned to either the yoga group or control group in a 1:1 ratio by means of a computer generated sequence of random numbers. Allocation concealment was done in sequentially numbered opaque sealed envelopes which were to be opened only after baseline assessment was complete. The nature of the intervention made blinding of participants and the yoga teacher impossible, but the blinding of the outcome assessor, lab biochemist, and statistician was maintained throughout the study period.

2.5 Intervention

Participants in the yoga group attended supervised 60-minute sessions conducted in the morning between 6:30 and 7:30, six days per week for 12 consecutive weeks, at the yoga hall of the institution. Each session comprised prayer and loosening practices (5 minutes), Surya Namaskar (sun salutation, 6 rounds, 10 minutes), a series of asanas (25 minutes) including Bhujangasana, Dhanurasana, Balasana, Supta Baddha Konasana, Setu Bandhasana, Viparita Karani and Shavasana, pranayama (10 minutes) consisting of Anulom Vilom and Bhramari, and Yoga Nidra with meditation (10 minutes). In addition, structured sleep-hygiene counselling was provided: a fixed wake-up time before 6:30, morning sunlight exposure of at least 20 minutes, dinner before 20:00, avoidance of screens after 22:00 and lights off by 22:30. Attendance was recorded in a register, and participants maintained a home-practice diary for the weekly rest day. Participants in the control group were placed on a wait-list, attended one 30-minute session of general lifestyle advice supported by an educational pamphlet, and were offered the complete yoga programme after the conclusion of the trial.

2.6 Outcome Measures

All measures were evaluated at baseline and after 12 weeks. Primary outcome variables were chronotype as measured by the MEQ [9], sleep quality as evaluated by PSQI [8], and diurnal cortisol rhythm. Blood samples were taken in the morning (8:00) after an overnight fast and in the evening (20:00) on the same day to evaluate serum levels of cortisol by means of chemiluminescence immunoassay, following expert consensus guidelines for cortisol testing [7]. Secondary outcome measures were serum luteinizing hormone (LH), follicle-stimulating hormone (FSH), the ratio of LH/FSH, total testosterone and anti-Mullerian hormone (AMH) where possible, in the early follicular phase (day 2-5 of the cycle); fasting plasma glucose and fasting insulin for HOMA-IR calculation (fasting glucose in mg/dL $\times$ fasting insulin in μ IU/mL $\div$ 405); body mass index; modified Ferriman-Gallwey score for hirsutism; and menstrual regularity (presence of spontaneous cycles of 21-35 days during the last 3 months of the intervention period).

2.7 Statistical Analysis

SPSS 26.0 software was used for statistical analysis. Normal distribution was confirmed by the Shapiro-Wilk test. Continuous variables are presented in mean $\pm$ SD. Paired sample t-test was used to evaluate within-group differences between baseline and 12 weeks, while independent samples t-test was used to evaluate the differences between groups based on change from baseline to 12 weeks. Categorical variables were evaluated by the chi-square test. Statistical significance was set at $p < 0.05$. Analysis was conducted for the completion cohort.

2.8 Ethical Considerations

Approval for the research design was granted by the Institutional Ethics Committee of Apex University, Jaipur, and the clinical trial was registered. Informed consent in writing was taken from all participants prior to their enrolment in the study.

3. Results

A total of 74 women were assessed for eligibility, of whom 14 were excluded (9 did not meet the inclusion criteria and 5 declined to participate). Sixty participants were randomized, 30 to each group. Two participants of the yoga group (one relocated and one was lost to follow-up) and one participant of the control group (lost to follow-up) discontinued the study, leaving 28 and 29 participants, respectively, for the final analysis. The mean attendance in the yoga group was 91.4% of the scheduled sessions, and no adverse events related to the intervention were reported.

Baseline demographic, anthropometric, circadian, endocrine and metabolic characteristics were comparable between the two groups, with no statistically significant differences (Table 1).

Table 1: Baseline Characteristics of the Study Participants

Characteristic	Yoga Group (n = 28)	Control Group (n = 29)	p Value
Age (Years)	25.5 ± 3.8	25.2 ± 3.8	p = 0.766
Body Mass Index (kg/m ²)	26.85 ± 3.01	26.73 ± 2.56	p = 0.870
MEQ Score	42.5 ± 4.0	42.3 ± 4.4	p = 0.831
PSQI Score	9.4 ± 2.5	10.1 ± 2.6	p = 0.318
LH (IU/L)	11.45 ± 3.14	11.53 ± 2.74	p = 0.921
FSH (IU/L)	6.59 ± 1.02	6.28 ± 1.26	p = 0.312
LH/FSH Ratio	1.94 ± 0.40	2.00 ± 0.44	p = 0.576
Total Testosterone (ng/dL)	69.6 ± 13.6	67.5 ± 11.4	p = 0.519
AMH (ng/mL)	6.02 ± 1.89	6.83 ± 1.56	p = 0.084
HOMA-IR	3.02 ± 0.71	3.28 ± 0.84	p = 0.217
Morning Cortisol (nmol/L)	388.5 ± 68.9	392.4 ± 61.3	p = 0.821
Evening Cortisol (nmol/L)	157.9 ± 32.6	150.1 ± 33.8	p = 0.381
Modified Ferriman-Gallwey Score	11.5 ± 3.6	10.9 ± 3.2	p = 0.547

After 12 weeks, the yoga group demonstrated a significant shift from an evening towards a morning chronotype, with the MEQ score rising from 42.5 ± 4.0 to 52.3 ± 4.4, whereas the control group remained essentially unchanged (between-group mean difference 9.2 points, 95% CI 8.0 to 10.3, p < 0.001). Sleep quality improved markedly in the yoga group, the PSQI score falling from 9.4 ± 2.5 to 5.2 ± 2.9 (between-group mean difference -3.9 points, 95% CI -4.6 to -3.1, p < 0.001). The diurnal cortisol rhythm was restored in the yoga group: morning cortisol increased and evening cortisol decreased significantly, so that the morning-to-evening cortisol ratio rose from 2.5 to 4.0, while the ratio in the control group remained stable (2.6 to 2.7) (Table 2).

Table 2: Circadian Rhythm and Sleep Outcomes Before and After the Intervention

Variable	Yoga Baseline	Yoga 12 Weeks	Control Baseline	Control 12 Weeks	p Value
MEQ Score	42.5 ± 4.0	52.3 ± 4.4	42.3 ± 4.4	42.9 ± 4.6	p < 0.001
PSQI Score	9.4 ± 2.5	5.2 ± 2.9	10.1 ± 2.6	9.7 ± 3.2	p < 0.001
Morning Cortisol (nmol/L)	388.5 ± 68.9	461.9 ± 80.8	392.4 ± 61.3	397.5 ± 68.2	p < 0.001
Evening Cortisol (nmol/L)	157.9 ± 32.6	115.4 ± 32.2	150.1 ± 33.8	149.0 ± 32.9	p < 0.001

Significant improvements were also observed in the endocrine and metabolic profile of the yoga group compared with the control group. Serum LH declined from 11.45 ± 3.14 IU/L to 8.36 ± 3.66 IU/L, and the LH/FSH ratio fell from 1.94 to 1.34, while FSH remained stable. Total testosterone decreased by 16.4 ng/dL in the yoga group, AMH declined from 6.02 ± 1.89 ng/mL to 5.00 ± 1.94 ng/mL, and HOMA-IR fell from 3.02 to 2.33; all between-group differences in change scores were significant (p < 0.001). Body mass index and the modified Ferriman-Gallwey score also decreased significantly in the yoga group relative to the control group (Table 3).

Table 3: Endocrine and Metabolic Outcomes Before and After the Intervention

Variable	Yoga Baseline	Yoga 12 Weeks	Control Baseline	Control 12 Weeks	p Value
LH (IU/L)	11.45 ± 3.14	8.36 ± 3.66	11.53 ± 2.74	11.18 ± 3.08	p < 0.001
FSH (IU/L)	6.59 ± 1.02	6.82 ± 1.44	6.28 ± 1.26	6.44 ± 1.43	p = 0.733
LH/FSH Ratio	1.94 ± 0.40	1.34 ± 0.50	2.00 ± 0.44	1.98 ± 0.48	p < 0.001
Total Testosterone (ng/dL)	69.6 ± 13.6	53.2 ± 17.7	67.5 ± 11.4	67.2 ± 12.7	p < 0.001
AMH (ng/mL)	6.02 ± 1.89	5.00 ± 1.94	6.83 ± 1.56	6.63 ± 1.67	p < 0.001
HOMA-IR	3.02 ± 0.71	2.33 ± 0.92	3.28 ± 0.84	3.22 ± 0.87	p < 0.001
Body Mass Index (kg/m ²)	26.85 ± 3.01	25.44 ± 3.16	26.73 ± 2.56	26.50 ± 2.68	p < 0.001
Modified Ferriman-Gallwey Score	11.5 ± 3.6	8.4 ± 3.5	10.9 ± 3.2	10.6 ± 3.3	p < 0.001

Regular menstrual cycles during the final three months of the intervention were attained by 18 of 28 participants (64.3%) in the yoga group, compared with 5 of 29 participants (17.2%) in the control group, a difference that was statistically significant (chi-square = 13.099, p < 0.001) (Table 4).

Table 4: Menstrual Regularity After the 12-Week Intervention

Outcome	Yoga Group	Control Group	Chi-Square	p Value
Regular Menstrual Cycles Attained, n (%)	18 (64.3%)	5 (17.2%)	13.099	$p < 0.001$

4. Discussion

To the best of the authors' knowledge, this is the first randomized controlled trial to examine a structured yogic intervention specifically targeted at circadian rhythm imbalance in women with PCOS. The principal finding is that a 12-week programme of morning yoga practice combined with sleep-hygiene counselling produced a clinically meaningful shift of chronotype towards morningness, a substantial improvement in sleep quality and a restoration of the diurnal cortisol slope, accompanied by significant improvements in gonadotropin balance, androgen excess, insulin resistance, body mass index and menstrual regularity.

These results are consistent with earlier randomized trials in which yoga improved glucose metabolism, lipid profile and endocrine parameters in adolescents with PCOS [10, 11], and with the observation that naturopathic and yogic interventions favourably modify polycystic ovarian morphology [12]. The reduction in cortisol and stress-related physiological measures observed in the present trial also agrees with meta-analytic evidence that yoga and mindfulness-based practices attenuate hypothalamic-pituitary-adrenal axis activity [13]. The present study extends this literature by demonstrating, for the first time, that these benefits are accompanied by objective resynchronization of the circadian system, as reflected in chronotype and the diurnal cortisol rhythm.

Several mechanisms may account for the observed effects. Morning-timed physical practice, together with fixed wake time and scheduled morning sunlight exposure, acts as a potent external time cue (zeitgeber) that advances the phase of the master circadian pacemaker. The regular practice of asana, slow pranayama and meditation enhances parasympathetic tone and reduces sympathoadrenal and hypothalamic-pituitary-adrenal activation, thereby lowering evening cortisol and restoring the normal circadian amplitude of the cortisol rhythm [5, 7]. Normalization of the evening decline of cortisol permits the nocturnal rise of melatonin, whose ovarian actions support folliculogenesis and ovulation [6]. Improved insulin sensitivity, reflected in the reduction of HOMA-IR, attenuates the insulin-driven stimulation of theca-cell androgen production, which in turn reduces total testosterone and restores the gonadotropin balance [4]. The recovery of regular menstrual cycles in nearly two-thirds of the yoga group indicates that these physiological changes translated into a clinically relevant reproductive benefit.

The findings have practical implications for naturopathic and integrative management of PCOS. The intervention is inexpensive, safe, culturally acceptable and feasible in routine clinical and community settings, and it addresses a dimension of the disorder, namely circadian misalignment, that is not corrected by pharmacological ovulation induction [14]. Given the high prevalence of sleep disturbance and

psychological distress in PCOS [15], circadian-focused yogic care may represent a valuable adjunct to the lifestyle management recommended by international guidelines [2].

The study has certain limitations. It was conducted at a single centre with a modest sample size and a 12-week intervention period, so the durability of the effects remains unknown. Circadian function was assessed by validated questionnaires and two-point cortisol sampling rather than by actigraphy, dim-light melatonin onset or serial melatonin measurements. The analysis was restricted to participants who completed the study, and menstrual regularity was based on self-reported cycle records. Participants could not be blinded to the intervention, which is inherent to trials of behavioural therapies. Future multicentre trials with objective circadian biomarkers, longer follow-up and comparison with pharmacological chronotherapies are warranted.

5. Conclusion

A 12-week structured yogic intervention, practised in the morning and combined with sleep-hygiene counselling, effectively resynchronized circadian rhythm, improved sleep quality and restored the diurnal cortisol slope in women with PCOS and circadian rhythm imbalance. These changes were accompanied by significant improvements in reproductive hormones, insulin resistance, body mass index and menstrual regularity. Structured yoga may therefore be recommended as a safe, low-cost and holistic adjunct in the management of PCOS, particularly in women presenting delayed sleep-wake timing and evening chronotype.

Acknowledgement

The authors are grateful to the participants of the experiment as well as to the personnel of the Apex School of Naturopathy and Yogic Sciences, Apex University, Jaipur, for the cooperation in the implementation of the intervention and analysis in the laboratory conditions.

Ethical Approval

The study protocol was approved by the Institutional Ethics Committee of Apex University, Jaipur.

Informed Consent

Written informed consent was taken from all subjects before recruiting them in the experiment.

Funding Source

None. The study was self-funded by the authors.

Conflict of Interest

According to the authors, there is no conflict of interest on the part of this publication.

References

1. Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group, "Revised 2003 Consensus on Diagnostic Criteria and Long-Term Health Risks Related to Polycystic Ovary Syndrome", *Human Reproduction*, 2004, 19 (1), 41-47.
2. H.J. Teede, M.L. Misso, M.F. Costello, et al., "Recommendations from the International Evidence-Based Guideline for the Assessment and Management of Polycystic Ovary Syndrome", *Human Reproduction*, 2018, 33 (9), 1602-1618.
3. H.F. Escobar-Morreale, "Polycystic Ovary Syndrome: Definition, Aetiology, Diagnosis and Treatment", *Nature Reviews Endocrinology*, 2018, 14 (5), 270-284.
4. R.L. Rosenfield, D.A. Ehrmann, "The Pathogenesis of Polycystic Ovary Syndrome (PCOS): The Hypothesis of PCOS as Functional Ovarian Hyperandrogenism Revisited", *Endocrine Reviews*, 2016, 37 (5), 467-520.
5. G.P. Chrousos, "Stress and Disorders of the Stress System", *Nature Reviews Endocrinology*, 2009, 5 (7), 374-381.
6. H. Tamura, Y. Nakamura, A. Korkmaz, et al., "Melatonin and the Ovary: Physiological and Pathophysiological Implications", *Fertility and Sterility*, 2009, 92 (1), 328-343.
7. T. Stalder, C. Kirschbaum, B.M. Kudielka, et al., "Assessment of the Cortisol Awakening Response: Expert Consensus Guidelines", *Psychoneuroendocrinology*, 2016, 63, 414-432.
8. D.J. Buysse, C.F. Reynolds, T.H. Monk, et al., "The Pittsburgh Sleep Quality Index: A New Instrument for Psychiatric Practice and Research", *Psychiatry Research*, 1989, 28 (2), 193-213.
9. J.A. Horne, O. Ostberg, "A Self-Assessment Questionnaire to Determine Morningness-Eveningness in Human Circadian Rhythms", *International Journal of Chronobiology*, 1976, 4 (2), 97-110.
10. R. Nidhi, V. Padmalatha, R. Nagarathna, et al., "Effect of a Yoga Program on Glucose Metabolism and Blood Lipid Levels in Adolescent Girls with Polycystic Ovary Syndrome", *International Journal of Gynaecology and Obstetrics*, 2012, 118 (1), 37-41.
11. R. Nidhi, V. Padmalatha, R. Nagarathna, et al., "Effects of a Holistic Yoga Program on Endocrine Parameters in Adolescents with Polycystic Ovary Syndrome: A Randomized Controlled Trial", *Journal of Alternative and Complementary Medicine*, 2013, 19 (2), 153-160.
12. M.E. Ratnakumari, N. Manavalan, D. Sathyanath, et al., "Study to Evaluate the Changes in Polycystic Ovarian Morphology after Naturopathic and Yogic Interventions", *International Journal of Yoga*, 2018, 11 (2), 139-147.
13. M.C. Pascoe, D.R. Thompson, C.F. Ski, "Yoga, Mindfulness-Based Stress Reduction and Stress-Related Physiological Measures: A Meta-Analysis", *Psychoneuroendocrinology*, 2017, 86, 152-168.
14. R.S. Legro, R.G. Brzyski, M.P. Diamond, et al., "Letrozole versus Clomiphene for Infertility in the Polycystic Ovary Syndrome", *New England Journal of Medicine*, 2014, 371 (2), 119-129.
15. A. Dokras, E. Stener-Victorin, B.O. Yildiz, et al., "Androgen Excess-Polycystic Ovary Syndrome Society: Position Statement on Depression, Anxiety, Quality of Life, and Eating Disorders in Polycystic Ovary Syndrome", *Fertility and Sterility*, 2018, 109 (5), 888-899.