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THE IMPACT OF LIFESTYLE MODIFICATIONS ON POLYCYSTIC OVARY SYNDROME PHENOTYPES: A NARRATIVE REVIEW

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ABSTRACT

Background and Aim: Polycystic Ovary Syndrome (PCOS) affects 5–16% of women of reproductive age and is associated with significant reproductive, metabolic, and psychological consequences. Lifestyle modification, including diet and physical activity, is universally recommended as first-line therapy. However, most clinical studies and guidelines treat PCOS as a homogeneous condition, overlooking the heterogeneity defined by the Rotterdam phenotypes. This reduces the applicability of current recommendations. The novelty of this review lies in focusing on phenotype-specific responses to lifestyle interventions. The aim is to summarize available evidence on dietary approaches, physical activity, supplementation, and behavioral factors across PCOS phenotypes and to identify gaps for future research.

Methods: A narrative review was performed using PubMed, Google Scholar, and ResearchGate. Eligible publications included randomized controlled trials, systematic reviews, meta-analyses, and international guidelines published after 2018. Search terms combined PCOS, phenotype, diet, physical activity, insulin resistance, hyperandrogenism, supplementation, smoking, and sleep.

Results: Evidence indicates that aerobic exercise, high-intensity interval training, low-AGE and high-fiber hypocaloric diets, and selected supplements such as β-hydroxybutyrate and N-acetylcysteine improve metabolic and hormonal outcomes. These effects are most pronounced in classical phenotypes A and B, characterized by hyperandrogenism and insulin resistance. Non-hyperandrogenic phenotypes, such as D, show limited response to interventions targeting androgen excess. Behavioral factors, including smoking and sleep disturbances, aggravate metabolic dysfunctions and worsen outcomes in hyperandrogenic phenotypes.

Conclusions: Lifestyle modification remains central to PCOS management, but its effectiveness is not uniform across phenotypes. Tailoring dietary, exercise, and adjunctive strategies to the endocrine and metabolic characteristics of each phenotype may improve outcomes. Future research should prioritize phenotype-stratified trials to provide evidence-based recommendations that reflect the heterogeneity of PCOS.

INTRODUCTION

Polycystic Ovary Syndrome (PCOS) affects 5–16% of women of reproductive age [1,2]. Its clinical presentation is heterogeneous, arising from different combinations of hyperandrogenism (HA), ovulatory dysfunction (OD), and polycystic ovarian morphology (PCOM), which together define four Rotterdam phenotypes [3]. Phenotypes A (OD + HA + PCOM) and B (OD + HA) are considered classical, while phenotypes C (HA + PCOM) and D (OD + PCOM) are classified as non-classical [4]. Classical phenotypes A and B are more strongly associated with insulin resistance, obesity, and cardiometabolic risk, whereas phenotype D resembles healthy women in many anthropometric and metabolic characteristics.

PCOS is a multifactorial condition with both genetic and environmental determinants [5]. Approximately 60% of patients develop insulin resistance accompanied by hyperinsulinemia, and the prevalence of metabolic syndrome is up to four times higher than in women without PCOS. Nearly 90% of women with PCOS are overweight, and even moderate weight reduction has been shown to improve hyperandrogenism and restore menstrual regularity [6]. Insulin resistance remains the main driver of metabolic complications, while androgen excess contributes additional independent risks [7]. As there is no causal treatment, lifestyle modification, including diet, exercise, and behavioral interventions, is emphasized as the first-line therapeutic strategy.

RELEVANCE AND NOVELTY

Although international guidelines recommend lifestyle interventions for all women with PCOS [8], they rarely differentiate between phenotypes. Most clinical studies also treat PCOS as a homogeneous condition. This uniform approach does not account for important variations in endocrine and metabolic profiles across phenotypes, which may influence the effectiveness of lifestyle therapy.

The relevance of this review lies in the high prevalence of PCOS and the unmet need for more individualized lifestyle recommendations. The novelty consists in focusing on phenotype-specific responses to physical activity, diet, and emerging adjunctive strategies. The objective of this work is to summarize current evidence on lifestyle interventions in PCOS, to assess their impact on distinct phenotypes, and to highlight directions for phenotype-oriented research and clinical practice.

OBJECTIVES

The objective of this review is to analyze current evidence on lifestyle interventions in PCOS and to determine how their effectiveness differs across phenotypes. The review seeks to identify which dietary, exercise, and behavioral strategies show the most benefit in classical phenotypes with pronounced metabolic disturbances, and to highlight the need for phenotype-specific recommendations in future guidelines.

METHODOLOGY

A narrative review of the literature was conducted with the aim of identifying studies on lifestyle interventions in Polycystic Ovary Syndrome (PCOS), with specific attention to phenotype-related outcomes. The search strategy included the databases PubMed, Google Scholar, and ResearchGate. Publications from January 2010 to March 2025 were considered. The search terms used were: "Polycystic Ovary Syndrome" OR "PCOS" AND "phenotype" AND ("diet" OR "nutrition" OR "exercise" OR "physical activity" OR "lifestyle" OR "supplementation" OR "insulin resistance" OR "hyperandrogenism" OR "sleep" OR "smoking").

Inclusion criteria were: randomized controlled trials, cohort studies, systematic reviews, meta-analyses, and international clinical guidelines reporting on lifestyle interventions in women with PCOS. Exclusion criteria were: case reports, conference abstracts, non-peer-reviewed articles, and publications without clear data on interventions or without relevance to PCOS phenotypes.

The initial search yielded 226 records. After removal of duplicates and application of inclusion and exclusion criteria, 31 studies were retained for analysis. Studies were categorized according to the type of intervention (diet, physical activity, supplementation, behavioral factors) and where possible, their relevance to specific PCOS phenotypes (A, B, C, D) was noted.

This methodology ensures transparency of the selection process and allows reproducibility of the review.

FINDINGS

PHYSICAL ACTIVITY

Studies that explored the outcomes of various types of physical activity in patients with PCOS are summarized in Table 1. While none of the randomized controlled trials reported distinguishing participants by PCOS subtypes (A-D), most of them evaluated some metabolic and endocrine parameters which are relevant to the differing phenotypes. Exercise regimens such as High Intensity Interval Training (HIIT) and continuous aerobic exercises lead not only to a reduction in insulin resistance, body mass index, waist to hip ratio, and androgen levels, but also an increase in Sex Hormone Binding Globulin (SHBG) levels and enhancement in regularity of menses. These results are particularly important for phenotypes A and B, which tend to involve most of the metabolic disturbances together with hyperandrogenism. For this reason, although quite indirect, the continuous aerobic exercises and HIIT induced benefits are likely to be more pronounced in these phenotypes. Moreover, it was found that although short-term aerobic exercises, both continuous and intermittent, had no influence on the telomere length or inflammation markers, they did lower testosterone levels and improved body measurements in women with PCOS, which would be especially beneficial for women with types A-C PCOS [9]. After continuous aerobic training (CAT), waist and hip circumference, total cholesterol, LDL, and total testosterone decreased. Intermittent aerobic training (IAT) reduced waist circumference, waist-to-hip ratio, total testosterone, and free androgen index (FAI). Women who did not exercise were characterized by greater waist size and higher percentage of body fat. Both types of aerobic training seem effective for treating metabolic problems and high androgen levels in PCOS, but longer studies are needed to understand their effects on telomeres [9].

Table 1 summarizes clinical trials and meta-analyses investigating the metabolic, hormonal, and psychosocial effects of aerobic and interval exercise interventions in women with polycystic ovary syndrome (PCOS). The table highlights study design, population characteristics, intervention type, duration, and main outcomes, with emphasis on phenotype-specific responses, particularly the hyperandrogenic and metabolically affected phenotypes A and B.

Table 1. Summary of original randomized controlled trials and meta-analyses assessing the effects of aerobic and interval exercise in women with PCOS.

Author, Year	Study design	Country	Participants characteristics	Type of exercise	Duration time	Study population	Metabolic results	Phenotype relevance
Ribeiro et al. [9], 2021	randomised controlled clinical trail study	Brazil	patients divided into 2 groups (<30 and >30 kg/m^2) and then assigned to three grups with different type of training and the control group)	continuous and intermittent aerobic training	16 weeks	87	CAT – ↓ total testosterone, ↓ total cholesterol, ↓ LDL; ↓ WC and HC; improved anthropometric indices IAT – ↓ total testosterone, ↓ FAI; ↓ WC and WHR Non-training CG – ↓ total cholesterol; ↑ WC and body fat % Meta-analysis – moderate ↑ VO_2peak (24.2%; 90%	The greatest benefits are likely observed in phenotype A, as this group shows the most pronounced metabolic and androgenic disturbances; the reductions in WC, WHR, LDL, TC, total testosterone, and FAI reported in the study indicate improvements in key features of metabolic and hyperandrogenic PCOS, which are

							CL 18.5–30.1), ↓ HOMA-IR (−36.2%; 90% CL −55.3 to −9.0), ↓ WC (−4.2%; 90% CL −6.0 to −2.3) .	characteristic of this phenotype.
Patten et al. [10], 2020	meta-analysis and a systematic review	diverse populations across Australia, Europe, North and South America, and Asia	women with PCOS, age between 18-40 depending on the study, BMI from normal to obese (mean BMI 27-22kg/ m^2), hyperandrogenic or oligo-ovulatory PCOS	HIIT and moderate-intensity training	12 weeks	777	Moderate ↑ VO_2peak 24.2% (90% CL 18.5–30.1) ↓ HOMA-IR −36.2% (90% CL −55.3 to −9.0) ↓ waist circumference −4.2% (90% CL −6.0 to −2.3)	The greatest impact might be seen in women with the metabolic phenotype of PCOS (phenotype A), characterized by hyperandrogenism, oligo/anovulation, and polycystic ovarian morphology, in whom improvements in HOMA-IR, waist circumference, and VO_2peak are particularly relevant.
Mohammadi et al. [11], 2023	randomized controlled study	Iran	age: 23.8 ± 5.3 years, weight: 82.4 ± 9.7 kg, BMI: 30.33 ± 3.99 kg/m2	HIIT	8 weeks	28	HIIT – ↓ BMI, ↓ WHR, ↓ visceral fat, ↓ insulin, ↓ HOMA-IR, ↓ LDL, ↓ atherogenic index, ↓ total cholesterol, ↓ cortisol ($P < 0.05$) Control group – no significant changes ($P > 0.05$) Significant differences between groups for all variables except VAI, FBG, HDL, TG, and AIP ($P < 0.05$)	The greatest benefits are likely seen in PCOS phenotype A (OA + HA + PCOM), as it combines hyperandrogenism and metabolic disturbances, and HIIT improves metabolic parameters and insulin resistance.
Lopes et al. [12], 2018	randomized controlled study		age:18-39, allocated randomly to 1 of 3 groups	Intermittent and continuous aerobic	16 weeks	69	CAT (16 weeks) – ↑ total FSFI score; ↑ satisfaction & pain domains; ↓ WHR; ↓ testosterone IAT (16 weeks) – ↑ total FSFI score; ↑ desire, excitation, lubrication, orgasm, satisfaction domains; ↓ testosterone Both CAT & IAT – ↓ anxiety & depression	The greatest benefits are likely seen in PCOS phenotypes A and B (hyperandrogenic), as reductions in testosterone and improvements in sexual function and anxiety/ depression are particularly relevant for women with excess androgens.

							scores Clinical implication – aerobic training may improve mental and sexual health in women with PCOS	

According to Patten, HIIT was more effective than moderate-intensity continuous training (MICT) in improving mental health outcomes, including symptoms of depression, anxiety, and stress. Both interventions improved health-related quality of life as measured by validated questionnaires. Results show that exercise interventions lead to significant improvements in VO2peak (peak oxygen uptake), body composition, and insulin sensitivity, especially when compared to groups that did not engage in exercise. These findings suggest that HIIT may be a particularly promising strategy for enhancing psychological well-being in overweight women with PCOS, although further large-scale research is needed to confirm these results [10]. In line with the study by Patten et al., findings provided by Mohammadi et al. indicate that variables such as WHR, IR, LDL remained unchanged in control groups [10,11]. Another randomized trial that investigated the relationship between various types of physical activity and their impact on functional status (or life quality) of women with PCOS found that intermittent aerobic exercise appears to be more effective than continuous aerobic activity in improving sexual function among women with PCOS [12].

DIET

Dietary care is an important topic in management of PCOS. In a recent study by Ozdemir et al. 44 women in the age range between 19-35 followed an energy-restricted standard-advanced glycation end products diet (S-AGEs) or an energy-restricted low-advanced glycation end-products diet (L-AGEs). In that study the authors investigated how a diet low in advanced glycation end products (AGEs) compares to a standard AGE-containing weight-loss diet in influencing the metabolic and hormonal profiles of overweight women with phenotype A PCOS [13]. In the L-AGEs group, the reduction in fasting glucose was significantly greater than in the S-AGEs group. Following the dietary intervention, participants in the L-AGEs group demonstrated significant improvements from baseline in several parameters, including reductions in waist-to-hip ratio, LDL-cholesterol, tumor necrosis factor α (TNF-α), total testosterone (TT), free androgen index (FAI), and anti-Müllerian hormone (AMH). Additionally, levels of SHBG significantly increased. In contrast, the S-AGEs group showed no statistically significant changes in these metabolic or hormonal markers. According to Beyond weight reduction, limiting dietary intake of AGEs led to notably greater improvements in both metabolic and endocrine profiles in women with phenotype A PCOS. In the other work researchers divided 57 women with PCOS and BMI>27 into three groups: group with a diet only (D), group with an exercise only (E) and the group with both diet and exercise (DE). BMI, waist circumference, and total cholesterol levels significantly decreased in both the D and DE groups. In the D group, additional improvements were observed, including significant reductions in low-density lipoprotein (LDL) levels and insulin resistance as measured by the Homeostasis Model Assessment (HOMA) index. In the E group, increased physical activity was accompanied by reductions in BMI and waist circumference. The most significant predictor of BMI reduction was increased dietary fibre intake ($\beta = -0.44$, $p = .03$), whereas a reduction in trans fatty acid intake was associated with a decreased insulinogenic index [14]. Toscani's study explored whether the protein content of a diet (30% vs. 15%) influences body weight, composition, and hormonal profile in women with PCOS. Both diets, matched for caloric intake (20–25 kcal/kg/day), resulted in similar reductions in weight, BMI, body fat, and total testosterone. Metabolic and lipid parameters remained stable regardless of diet composition. These findings suggest that calorie reduction, rather than protein content, is the key factor driving improvements in body composition and hormonal balance in the short term [15]. Therefore, hypocaloric diets and dietary modifications are particularly important for insulin-resistant PCOS phenotypes, especially phenotypes A and B, due to their pronounced metabolic disturbances. Determining the most effective hypocaloric diet for women with PCOS will require studies with larger populations, ideally conducted across multiple centers [16].

Ketogenic diets are known to reduce androgen and glucose levels in women with PCOS. However, the specific effect of β-hydroxybutyrate (BHB) is not yet fully understood; current evidence suggest that the main ketone body, β-hydroxybutyrate, reduces inflammation by suppressing the NLRP3 inflammasome and NF-κB [17] signaling and improving gut microbiota, while the ketogenic diet lowers triglycerides, improves insulin sensitivity, and decreases systemic inflammation [18,19]. Ritting et al. sought to investigate whether BHB supplementation alone can acutely decrease circulating levels of androgens and glucose in women with PCOS [20]. In this study, 20 women with PCOS received BHB supplementation. Blood BHB levels rose to 2.4 mM in the treatment group, compared to 0.1 mM in the control group ($p < .001$). BHB led to lower androgen levels, including testosterone, free testosterone, androstenedione, and 11-ketotestosterone, with the most significant drop seen in 11-ketotestosterone ($p = .020$). Fasting glucose also decreased by about 10% ($p < .001$). These results suggest that BHB supplementation may quickly reduce androgen and glucose levels in women with PCOS, implicating potential for ketone-based therapies. Those may be particularly beneficial for women with hyperandrogenic and metabolically active PCOS phenotypes, such as phenotype A (hyperandrogenism, oligo/anovulation, and polycystic ovarian morphology) and phenotype B (hyperandrogenism and oligo/anovulation). These subtypes are characterized by elevated androgen levels and, frequently, insulin resistance—both of which were positively impacted by BHB. In phenotype C (hyperandrogenism and polycystic ovaries with preserved ovulation), the effect may be present but less pronounced due to relatively milder metabolic involvement. Conversely, in phenotype D (oligo/anovulation and polycystic ovaries without hyperandrogenism), the impact of BHB is likely limited to glucose metabolism, as androgen levels are typically within normal range [20, 21].

SLEEP DISTURBANCES

Sleep problems, especially obstructive sleep apnea (OSA) are often associated with PCOS, however exact mechanisms are unknown. Researchers were searching for a correlation between sleep disturbances and levels of SHBG, serum sex hormones and sleeping difficulties. Their finding shows that SHBG may have a more significant role in OSA among women with PCOS than hyperandrogenism, whereas other sleep disturbances are associated with a less pronounced SHBG profile. Thus OSA treatment may be particularly important in women with the insulin-resistant phenotypes A and B of PCOS [22]. Moreover, Decrinis et al. study shows that women with PCOS are more likely to experience depression, anxiety, and sleep problems, such as sleep apnea, and these issues are linked to higher BMI and insulin resistance [23, 24]. A summary of sleep disturbances across populations of women with PCOS, taking into account different phenotypes, is presented in Table 2.

Table 2. Sleep disturbances in women with PCOS, including phenotype-specific characteristics

Authors, Year	Type of study	Study population	Country	Patient characteristics	Results
Decrinis et al. [23], 2025	a cross-sectional study	587	Germany, Austria, Switzerland	patients with PCOS, particularly phenotypes A and B	BMI and insulin resistance – independent factors linked to OSA ($p < 0.001$) Anxiety (GAD-7) – median score in the moderate range Anxiety and depression (HADS-A/HADS-D) – moderate to severe anxiety: 52.0%; depression: 27.8% Positive correlation between HADS-A ($r = 0.122$) and HADS-D ($r = 0.223$) with BMI ($p < 0.01$)
Jafar et al. [22], 2025	a systematic review and meta-analysis	patients from 9 studies	Australia, United Kingdom	patients with PCOS	Sleep disturbances – 46.0% with OSA; 56.0% with other sleep problems SHBG – significantly lower in women with PCOS and OSA vs. without OSA ($p < 0.00001$) Other hormones – no differences in testosterone, DHEAS, androstenedione, or estradiol No significant associations between sex hormones, SHBG, or hyperandrogenism and sleep disturbances

SMOKING

The results of the epidemiological studies suggest that compared to the general female population, women with PCOS are more likely to smoke. It is well evidenced that smoking is usually associated with higher insulin resistance and other metabolic dysfunctions. In a recently published study conducted on a group of 626 women with PCOS, it was found that those who never smoked had lower hirsutism scores at baseline compared to women who used to smoke [25]. They also had lower total testosterone levels than current smokers. By the end of the study, current smokers had higher insulin levels and higher grade of insulin resistance than at the beginning and compared to non-smokers ($p < 0.01$). Smoking did not affect the chances of ovulation, but live birth rates were slightly higher (though not significantly) in women who had never smoked or who had quit smoking. These findings suggest that smoking may worsen metabolic and hormonal features, such as insulin resistance and elevated testosterone levels, which are more characteristic of hyperandrogenic PCOS phenotypes, especially phenotype A (hyperandrogenism + oligo/anovulation + polycystic ovaries) and phenotype B (hyperandrogenism + oligo/anovulation). In contrast, phenotypes without elevated androgens (like phenotype D) may be less affected by smoking. Therefore, smoking may have the strongest negative impact on women with PCOS who already present with androgen excess and metabolic disturbances [25].

FIBER INTAKE

A diet rich in fiber may have beneficial effects on certain phenotypes of polycystic ovary syndrome, particularly those associated with insulin resistance and hyperandrogenism. According to Cutler's cohort study, enhancing fiber and magnesium intake may support the management of insulin resistance and androgen excess in PCOS patients [26]. Moreover, a high-fiber diet has the potential to alleviate chronic metabolic inflammation, restore reproductive function, and influence the secretion of the brain–gut peptides. When combined with acarbose, it may lead to more significant improvements in PCOS phenotypes, potentially through modulation of the gut microbiota [27,28].

DISCUSSION

The present review highlights the role of lifestyle interventions in the management of Polycystic Ovary Syndrome (PCOS) and demonstrates that their effects may differ depending on phenotype. The synthesis of available studies confirms that dietary modification, structured physical activity, and selected supplements exert measurable benefits on metabolic and hormonal parameters [6,9,10,11,13,14,15,16,20,21,27,29, 30, 31]. However, the magnitude of these effects varies.

Classical phenotypes A and B, which are characterized by hyperandrogenism and insulin resistance, appear to benefit most from interventions targeting weight reduction and insulin sensitivity [4,8]. In contrast, non-classical phenotypes C and D, with milder endocrine or metabolic profiles, show less pronounced improvements in androgen excess or insulin resistance, although general health benefits remain evident [4].

One of the key findings of this review is the insufficient stratification of clinical studies by phenotype. Most randomized controlled trials and meta-analyses report outcomes in heterogeneous PCOS populations [9,10,13,21], making it difficult to draw precise conclusions about differential responses. This gap underscores the need for future phenotype-oriented clinical trials.

Another important aspect concerns behavioral factors such as smoking and sleep. Both are frequently overlooked in guidelines [8], yet available data suggest that smoking exacerbates hyperandrogenism and worsens metabolic profiles [25], while sleep disturbances contribute to insulin resistance and weight gain [22]. These findings emphasize the necessity of integrating behavioral modification into lifestyle counseling for PCOS patients.

The review also shows that supplementation with agents such as N-acetylcysteine and β-hydroxybutyrate may have additional benefits [20, 29], but evidence remains preliminary and limited to small cohorts. More robust trials are required to validate their role in standard management.

Several limitations of this review should be acknowledged. The methodology relied on narrative synthesis rather than systematic review standards, which limits reproducibility. The number of included studies was relatively small, and many lacked phenotype-specific analysis. In addition, heterogeneity in study design, sample size, and outcome measures complicates the interpretation of results.

Overall, this review underscores the clinical relevance of tailoring lifestyle interventions to PCOS phenotypes. By recognizing differences in metabolic and hormonal profiles, healthcare providers may be able to design more effective, individualized treatment strategies. Future research should focus on large-scale, phenotype-stratified trials that would provide the evidence base needed for personalized recommendations.

CONCLUSIONS

Polycystic Ovary Syndrome is a heterogeneous endocrine disorder with distinct phenotypes that differ in metabolic and hormonal characteristics. Current guidelines recommend lifestyle modification as the first-line management for all women with PCOS, yet accumulating evidence indicates that the effectiveness of interventions depends on phenotype. Aerobic exercise and high-intensity interval training have been shown to improve insulin resistance, androgen levels, and body composition, particularly in classical phenotypes A and B, which are characterized by hyperandrogenism and metabolic dysfunction. Dietary approaches, including low-AGE and high-fiber hypocaloric diets, yield comparable benefits in these phenotypes. Adjunctive strategies such as β-hydroxybutyrate and N-acetylcysteine supplementation demonstrate additional promise, though their effects require confirmation in larger trials.

Women with non-hyperandrogenic phenotypes, especially phenotype D, appear less responsive to interventions targeting androgen excess, highlighting the need for differentiated therapeutic approaches. Behavioral factors such as smoking and sleep disturbances further aggravate metabolic and reproductive outcomes and should be considered in comprehensive patient management.

These findings underscore the importance of moving beyond uniform recommendations toward phenotype-specific lifestyle strategies. Tailoring interventions to clinical and metabolic profiles may improve treatment outcomes and quality of life. Further phenotype-stratified research is required to provide the evidence base for developing individualized, guideline-based care in PCOS.

DISCLOSURE

AUTHORS' CONTRIBUTIONS

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All authors have read and agreed with the published version of the manuscript.

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CONFLICT OF INTEREST

Authors declare no conflicts of interest.

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