

Exploring the Impact of Dietary Intervention on Polycystic Ovary Syndrome Management

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Abstract

Polycystic ovary syndrome (PCOS) affects 4-20% of women of reproductive age and is an intricate endocrine and metabolic disorder characterized by polycystic ovarian morphology, hyperandrogenism, and chronic anovulation. Insulin resistance, neuroendocrine disorders, oxidative stress, chronic inflammation, and genetics are all part of its complicated etiology. Since hyperinsulinemia and subsequent androgen excess are caused by metabolic dysfunction, especially insulin resistance, dietary modification has become an essential non-pharmacological strategy for improving clinical outcomes. The benefits of different dietary interventions on metabolic, inflammatory, and reproductive parameters in PCOS are demonstrated by current research. In addition to secondary benefits in menstrual regularity and androgen levels, low glycemic index (GI) and low glycemic load (GL) diets have consistently improved sensitivity towards insulin,

fasting insulin and glycemic regulation. The Mediterranean diet, which is high in phytochemicals, monounsaturated fats and antioxidants has potent anti-inflammatory properties that promote hormone regulation and metabolic balance. Ketogenic diets, high protein hypocaloric diets, plant based models and intermittent fasting are examples of emerging dietary strategies that show promise for lowering body fat, improving insulin dynamics, altering gut microbiota and restoring hormonal balance. By lowering oxidative stress, controlling inflammatory pathways, promoting SHBG production and modifying androgen synthesis important nutrients like dietary fiber, omega-3 fatty acids,

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monounsaturated fats and phytonutrient dense foods contribute mechanistically. Despite encouraging results, there are still significant gaps because of inconsistent study designs, a lack of long term data and the under representation of diverse populations. Overall, data points to dietary intervention as a fundamental and scientifically proven method for improving reproductive health, lowering endocrine disruption and restoring metabolic stability in PCOS affected women.

Introduction

Polycystic Ovarian syndrome is a common health situation caused by an imbalance in hormones in reproductive age. Hormonal imbalance give rise to problems for the ovaries. In conjunction with typical menstrual cycle, the ovaries create the egg that is released once a month. If PCOS is present the egg might not develop normally or might not be released at ovulation as it should be (1). Polycystic ovary syndrome is most frequent hormonal disorder with an occurrence rate of 4-20% in women of reproductive age. It is distinguished by anovulation, Hyperandrogenism, polycystic ovarian morphology, irregular menstrual cycle, acne and weight gain (2).

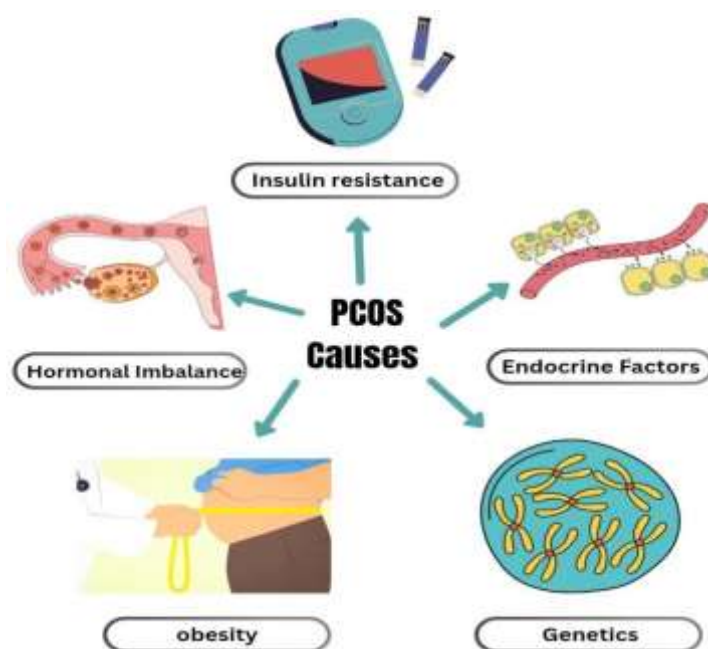


Figure 1. Causes of PCOS

Polycystic Ovary Syndrome (PCOS) has many different and intricate causes. It is believed to develop as a result of hormonal imbalance, genetic predisposition, insulin resistance and obesity. Stress, chronic inflammation and environmental pollutants might also be involved. Since every woman's experience with PCOS is different, knowing the underlying causes can help direct individualized management and treatment (3).

The occurrence of this condition among women is shaped by several factors, such as unhealthy lifestyle habits, poor dietary patterns, insufficient medical care, late diagnosis and a general lack of awareness. Early identification of the disorder, combined with improved nutrition and lifestyle practices, can significantly support faster recovery and enhance a patient's overall quality of life. Many herbal extracts have also been shown to positively influence markers associated with PCOS. This article highlights how food choices and daily habits play a crucial role in managing PCOS. Research suggests that maintaining a balanced diet providing roughly 40% of energy from carbohydrates, 30% from healthy fats and 30% from protein along with regular physical activity can help improve metabolic health and

reduce the intensity of PCOS symptoms. (4).

Mechanistically, the pathophysiologic centers of PCOS are targeted by diets that lower insulin secretion, glycemic load and systemic inflammation. Low glycemic and low carb diets may reduce insulin spikes and postprandial glucose excursions; Mediterranean and anti-inflammatory diets

center on unrefined grains, fiber, monounsaturated fats and antioxidant rich plant foods that may improve insulin sensitivity and reduce chronic inflammation. Ketogenic diets cause favorable metabolic changes and rapid weight loss in some studies, but sustainability and effects on lipid profiles are still concerns; and seed based interventions, also known as "seed cycling," have been proposed as supplemental therapies with potential benefits on hormone modulation (5).

There are many obstacles and restrictions when it comes to managing PCOS with dietary changes. There are several gaps in the contemporary research on PCOS and diet, including the underrepresentation of diverse populations, as most studies concentrate on high income nations like the US and Australia (6). This limits the findings' applicability to a larger population, especially in developing nations. Additionally, online survey designs and convenience sampling frequently introduce biases into existing studies making them less representative of the priorities and experiences of women with PCOS around the world (7),(8).

A multidisciplinary approach is necessary due to the complexity of PCOS. However, there are few evidence based recommendations for dietary interventions. By examining different dietary interventions, keto diets, low glycemic diet, anti-inflammatory diet, Mediterranean diet and seed cycling and their benefits in managing PCOS symptoms, our article seeks to close this gap. We intend to aid in the creation of more individualized and successful dietary plans for women with PCOS by highlighting areas for further research and synthesizing the body of existing research.

Pathophysiology of PCOS

Insulin Resistance

Insulin resistance (IR) is defined as a reduced cellular response to insulin and is commonly seen in both lean and overweight women with PCOS. It is not directly linked to body fat or androgen levels and is notable for being tissue specific. While the liver, muscle and adipose tissue exhibit diminished sensitivity to insulin, the ovaries and adrenal glands remain responsive. This selective sensitivity allows insulin to stimulate ovarian theca cells, increasing androgen production and promoting follicular growth. Insulin also enhances the activity of key steroidogenic enzymes, including P450c17 and P450scc, particularly when acting alongside chorionic gonadotropin. Its effects further align with luteinizing hormone (LH) and insulin-like growth factor-1 (IGF-1), collectively intensifying ovarian hormone synthesis (9).

Luteinizing hormone (LH) binding sites and the androgen fabricate reciprocation to LH are both increased by hyperinsulinemia. The interaction between LH and insulin increases the expression of CYP450c17 mRNA and the steroidogenic acute regulatory enzyme. The synthesis of androgen is mediated by CYP450c17. Similarly, IR increases CYP17A1 activity by the productive enzyme involved in the synthesis of testosterone and androstenedione on its own. Additionally, hyperinsulinemia affects the pituitary gland which leads to PCOS. The pituitary gland releases LH when its receptors are stimulated by too much insulin. Insulin accumulation affects both the amplitude and frequency of the GnRH and LH pulses stimulating their secretion. Pituitary gonadotropin sensitivity to GnRH enhances insulin's underlying effect on PCOS and hyperinsulinemia raises GnRH neuron activity (9).

Hyperandrogenism

In general, hyperandrogenism (HA) raises the concentration of free testosterone by lowering the SHBG level. Higher levels of testosterone in plasma which can be converted to estrone in adipose tissue have been found in PCOS women. Follicle growth is impacted by increased estrone to estradiol alteration, which also raises the LH to FSH ratio and results in ovulatory dysfunction. AMH upregulation brought by HA may prevent ovulation and follicle development through an alternative mechanism. Moreover, HA lowers IGF-II in follicular fluid and the two variables have a negative relationship. Follicle diameters and the amount of estradiol in follicular fluid are positively correlated with IGF-II. HA indirectly raises LH (9).

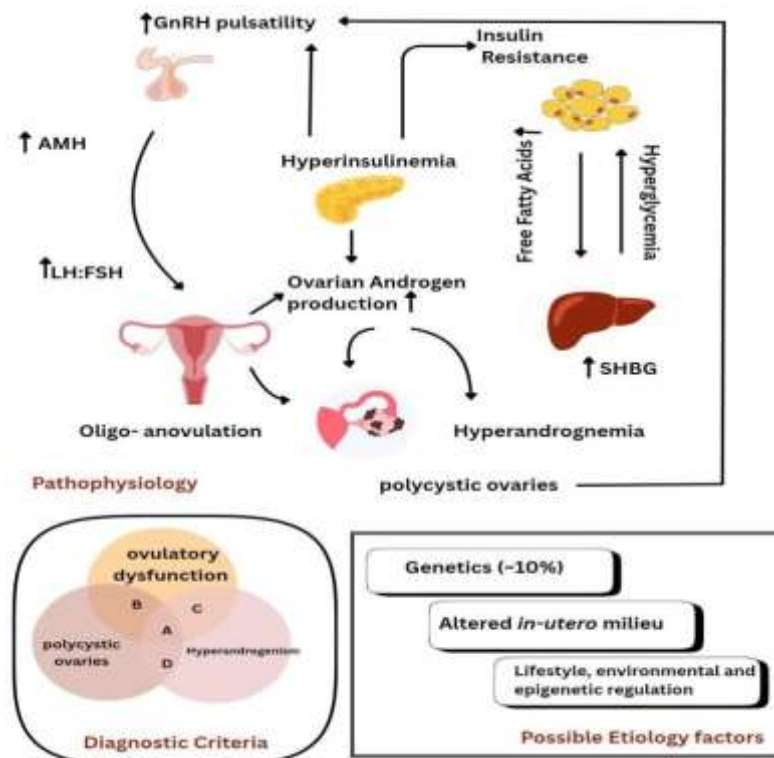


Figure 2. Pathophysiology of PCOS

Dysregulation of Gonadotropin and Neuroendocrine

The aberrant pulsatility of gonadotropin releasing hormone (GnRH) from the hypothalamus which results in increased secretion of luteinizing hormone in comparison to follicle stimulating hormone (FSH) is a crucial element in the pathophysiology of PCOS. This high LH/FSH ratio promotes anovulation and the syndrome's multiple small follicles by suppressing normal follicular development and stimulating excessive androgen production in ovarian theca cells (10).

Chronic Inflammation

The start and progress of Polycystic Ovary Syndrome (PCOS) are significantly influenced by persistent low-grade inflammation. Women with PCOS often exhibit raised inflammatory biomarker's levels such as C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF- α) and interleukin-18 (IL-18) indicating persistent systemic inflammation. By affecting follicular development, changing the synthesis of steroid hormones and encouraging insulin resistance, this inflammatory state interferes with normal ovarian function (11). Visceral fat releases pro-inflammatory cytokines that interfere with normal insulin

receptor activity, leading to elevated insulin levels. This increase in insulin further stimulates the ovaries to produce increased androgens, creating a reinforcing cycle that links insulin resistance, hyperandrogenism, and chronic inflammation. The ongoing inflammatory state also contributes to oxidative stress, which damages ovarian cells and plays a significant role in anovulation and infertility (10).

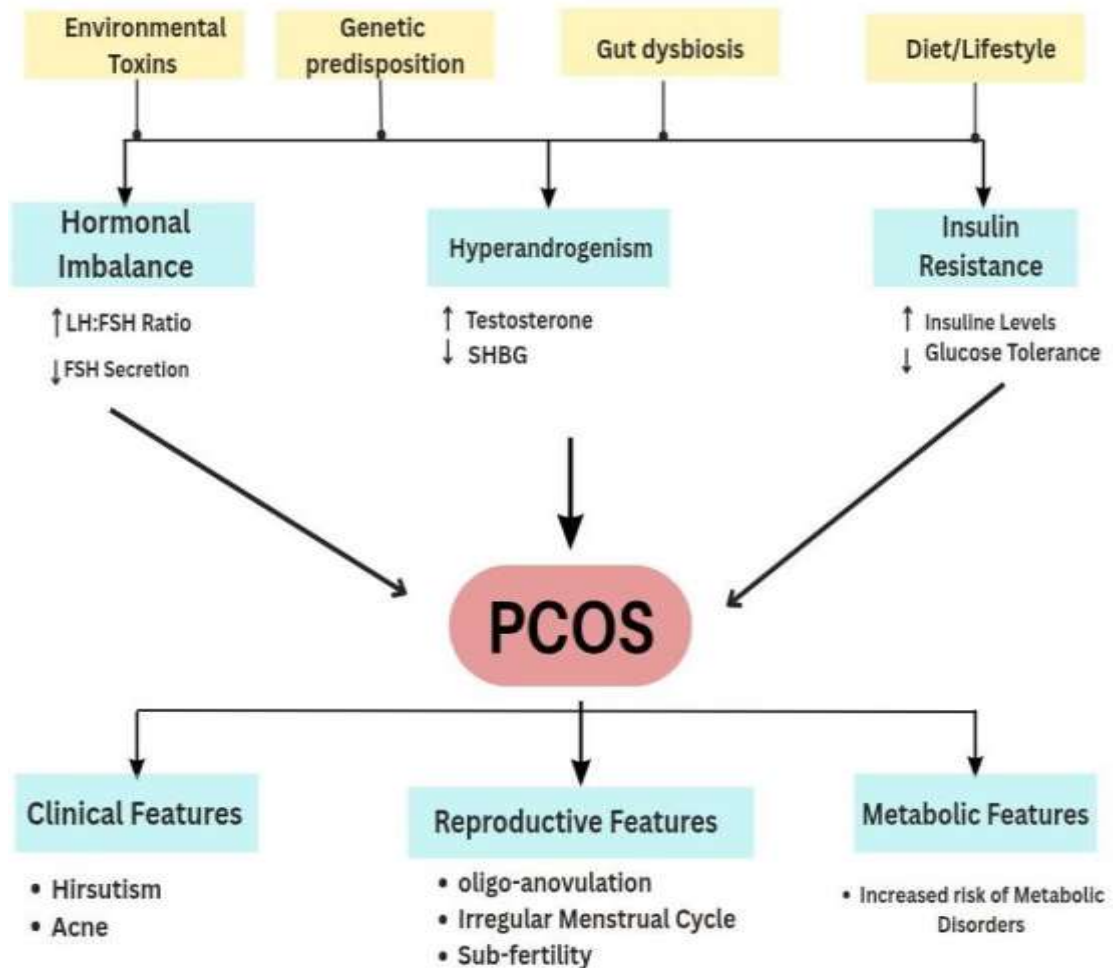


Figure 3. Mechanism of Chronic Inflammation

Dietary patterns and their effect on PCOS

Low Glycemic Index and Glycemic Load Diets

The number of Carbohydrates has been associated to an accelerated possibility of PCOS. The pathophysiology of polycystic ovary syndrome (PCOS) is largely dependent on insulin and glucose homeostasis, both of which are regulated by dietary glycemic index and glycemic load (GL). Up to 75% of lean and 95% of obese women with PCOS have insulin resistance, which interferes with glucose metabolism, encourages androgen excess and affects ovulatory function. While diets heavy in fiber, whole grains, fruits and legumes improve insulin sensitivity by reducing postprandial glucose fluctuations, diets heavy in refined carbohydrates and saturated fats exacerbate insulin resistance. Research continuously demonstrates that following a low GI or low GL diet improves insulin sensitivity and dramatically lowers fasting insulin levels and HOMA-IR scores (12).

Low glycemic index (GI) diets support not only metabolic stability but also healthier hormone regulation. While a few short term studies reported minimal hormonal changes, many interventions have shown encouraging improvements, including higher levels of sex hormone binding globulin (SHBG) and anti-

Müllerian hormone (AMH), along with reductions in total testosterone and androstenedione. Adopting low GI or low glycemic load (GL) eating patterns can also promote weight loss, lower body mass index and reduce waist and hip measurements outcomes that play a crucial role in improving both metabolic function and reproductive health in women with PCOS (13).

Mediterranean diet

The Mediterranean diet has gained significant recognition in recent years as a reliable and well-studied nutritional model. It encourages a generous intake of fruits, vegetables, fish, seafood, legumes and nuts, with whole grains serving as the primary source of carbohydrates. The diet also promotes the use of vegetable oils rich in unsaturated fatty acids especially olive oil in place of animal fats that contain higher levels of saturated fats. Because it provides high quality carbohydrates and allows for healthy fat consumption, the Mediterranean diet helps moderate insulin resistance and supports better overall metabolic health (14).

Although the exact molecular mechanisms by which the Mediterranean diet alleviates the symptoms of polycystic ovarian syndrome (PCOS) are still being studied, its effectiveness is strongly associated with its anti-inflammatory and antioxidant properties. Research, including findings from the PREDIMED trial, has shown that following a MedDiet can reduce adhesion molecule activity in immune cells and the expression of inflammatory markers such as TNF- α , IL6, MCP-1 and CRP. The health benefits of the diet are mostly due to the high intake of plant based foods, which are high in bioactive compounds such as flavonoids, carotenoids, polyphenols and omega-3 fatty acids that lower inflammation and oxidative stress (15).

Hypocaloric high protein diets (HPDs)

A recent meta-analysis found that HPDs, which account for 25-35% of total energy consumption provide additional benefits for weight loss when compared to isocaloric diets with conventional protein content (12-18%). It is believed that these hypocaloric HPDs enhance satiety and decrease FFM loss, which can support resting energy expenditure and enhance the psychological health and self-esteem of weight loss participants (16).

Women with PCOS may respond well to high-protein diets (HPDs), as they often have reduced lean body mass and may find calorie restricted diets difficult to follow due to physiological and appetite-related challenges. However, recent meta-analytic evidence shows no significant differences between HPDs and isocaloric standard protein diets in outcomes such as weight, BMI or waist circumference. Because the studies assessed body composition using varied methods, their results could not be reliably combined. While HPDs may assist overweight women with PCOS in weight control, their specific effects particularly on body composition are still not fully established (17).

Ketogenic diet (KD)

In the past few years, ketogenic diets (KDs) have acquired popularity as a safe and efficient dietary approach for improving metabolic health and managing conditions like insulin resistance. A "ketogenic diet" (KD) is a high fat, low carb and normal protein diet in which fat typically makes up over 70% of total caloric intake. As a substitute energy source, this diet causes the liver to produce ketone bodies mainly acetoacetate and β hydroxybutyrate which results in a catabolic state of ketosis (defined by blood ketone levels > 0.5 mM) and appetite suppression (18). Even though KD is not a calorie deprivation diet, it has a noteworthy effect on PCOS by activating adenosine monophosphate activated protein kinase

(AMPK) and silent mating type information regulation 2 homologue 1 (SIRT1). SIRT1 and AMPK enhance insulin sensitivity and have a beneficial impact on glucose homeostasis once they are activated (19).

A very low calorie ketogenic diet (VLCKD), was substantially linked to bettering anthropometric and cardio metabolic outcomes in an umbrella review that included 17 meta-analyses of 68 RCT results. Obesity and overweight are common in PCOS afflicted women, which makes IR and hormone abnormalities worse. Because the body burns fat rather than glucose when it is in the metabolic state of ketosis, the ketogenic diet may lead to more successful weight loss. Research has shown that in PCOS women, a ketogenic diet improves insulin sensitivity, SHBG levels and reproductive hormone levels while lowering androgen levels. Long term use is not advised though because of its high fat and low carbohydrate content which can have detrimental effects on the body due to its lower nutritional value (5).

Anti-Inflammatory and Plant Based Diets

Diets high in phytochemicals and centered on plant based substances may be able to improve insulin resistance and hyperandrogenism by addressing the inflammatory mechanisms that underlie the development of PCOS. Fruits, vegetables and whole grains are examples of foods high in phytochemicals which are well known for their ability to help control weight, improve glycemic control and reduce complications. Phytochemicals, a diverse group of naturally occurring plant compounds, are recognized for their antioxidant and anti-inflammatory properties and for their role in regulating fat and carbohydrate metabolism. To better assess the impact of diets rich in these compounds, researchers developed the Dietary Phytochemical Index (DPI). This index helps measure the overall phytochemical content of an individual's diet and provides insight into how these compounds influence health. Studies have shown that higher DPI scores are associated with reduced inflammation and lower blood glucose levels across various clinical settings (20).

Calorie Restriction and Intermittent Fasting

Fasting practices particularly intermittent fasting (IF), have become popular in integrative medicine as a non-pharmaceutical lifestyle approach that can help people lose weight and improve their health in recent decades. By lowering caloric intake and reprogramming the metabolism, IF has been demonstrated to have the ability to improve insulin resistance and decrease adiposity. Improved metabolic efficiency, improved cognitive acuity and a longer lifespan are just a few of the health benefits it can bring about (21).

Alternate day fasting (ADF), time restricted feeding (TRF) and the 5:2 diet are the types of intermittent fasting that have been studied the most. In ADF, feeding days that permit unrestricted food consumption are interspersed with fasting days, when energy intake is limited to water or very few calories. This program has the potential to lower body weight, improve insulin sensitivity and lower fasting glucose levels all of which are critical for managing PCOS (21).

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In women with PCOS, intermittent fasting has become a potentially effective

treatment strategy due to the intricate connection between metabolic dysfunction and reproductive health. Intermittent fasting has the potential to improve menstrual regularity, support ovulatory function and restore hormonal balance by addressing the main causes of PCOS including insulin resistance, hyperinsulinemia and hyperandrogenism. Additionally its beneficial effects on metabolic outcomes and weight loss may support improved reproductive health (22).

Case Studies: Dietary Interventions in PCOS Table 1. Case Study: Dietary

Diet Type	Title	Design	Main Outcomes in PCOS	Ref
Low glycemic index diet	Effects of a Low Glycemic Diet on the Reproductive and Clinical Profile of Women with PCOS	systematic review and Meta-analysis	Low glycemic diets play an important role in lowering PCOS risk and supporting improvements in both clinical symptoms and biochemical markers.	(23)
Mediterranean diet	Association of Mediterranean Dietary Patterns and Prime Diet Quality Score with PCOS	Case control study	Finding suggest that high adherence to Med diet and PDQS is associated with reduces risk of developing PCOS.	(24)
Ketogenic diet	Comparative Effects of Portfolio, Moderate Carb, and Ketogenic Diets in Obese and Overweight Women with PCOS	Randomized trial; 12 weeks	Reported decreases in body weight, fat mass, fasting glucose, and enhanced hormonal balance.	(25)

Intervention in PCOS

Low Calorie Ketogenic diet	Potential Applications in the Treatment of PCOS Among Adolescents	Review	Indicated improvements in weight and insulin resistance in adolescents with PCOS, with attention to nutritional monitoring.	(26)
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High Protein diet	Cardiometabolic and Reproductive Outcomes Associated with High Protein Diets in Women with PCOS	Systematic review and Meta-analysis	Showed slight improvement in insulin resistance, body composition findings varied across studies.	(27)
Intermittent Fasting	8-Hour Time Restricted Feeding as a Potential First-Line Dietary Intervention	6-week intervention	Participants showed weight reduction and improvements in insulin levels and inflammatory markers.	(28)
Plant Based	The Dietary Phytochemical Index and Its Relationship with PCOS	A Case control Study	Higher phytochemical intake was associated with better metabolic parameters in women with PCOS.	(20)
Anti-Inflammatory	AI-Assisted Nutrition Strategies and Their Influence on Diet Quality in Adolescents with PCOS	A pilot clinical trial	Reported improvements in hormonal regulation and inflammatory markers.	(29)

Nutritional Components and Micronutrient Supplementation

Role of dietary fiber

Given its ability to improve insulin sensitivity, glycemic control and hormone balance, dietary fiber is now acknowledged as a crucial element in the management of these metabolic and reproductive issues. The information provided here demonstrates the basic importance of fiber which is a major PCOS preventive factor. In PCOS dietary fiber is also known to have a direct impact on hormonal balance. One of the primary features of PCOS is frequently hyperinsulinemia, which is exacerbated by high androgen levels. Diets high in fiber may reduce hyperinsulinemia, which will reduce the production of androgens (30).

Biro et al. (2022) further supported the idea that fiber intake is directly linked to hormonal effects by stating that females who consumed more fiber had noticeably higher testosterone levels. Dietary fiber is also a significant component of dieting and may be specifically to blame for the failure of PCO syndrome to respond to such cases. Better fiber consumption can keep a person full for longer and balance blood sugar levels, which reduces the need for calories. Making changes to lifestyle may also help with weight loss (30).

Lim et al. (2019) reported that diets rich in low glycemic, high fiber foods were highly effective for long term weight loss and for managing PCOS related obesity and metabolic disturbances. Similarly, a study by Wang et al. (2022) involving women with PCOS found that higher fiber intake had a notable impact on hormonal regulation and increased egg production. These benefits were largely attributed to the positive influence of dietary fiber on gut microbiota, which plays a key role in hormone balance and reducing inflammation (30).

Women with PCOS have the potential to experience stable blood sugar levels and ovulatory problems when following a low glycemic index diet which is frequently high in dietary fiber. These diets cause a very low glycemic response because carbohydrates are absorbed and digested very slowly. Douglas et al. (2006) reported that women with PCOS who used low GI, high fiber diets during specific period experienced regular menstruation and lower blood sugar levels than those who followed high GI diets. Along with fiber's influence on lipid metabolism another crucial element enters the picture. It has recently been shown that soluble fiber is an excellent way to lower triglycerides and low-density lipoproteins (LDL) (30).

Role of Fat

In PCOS dietary fat quality seems to influence metabolic and endocrine outcomes more so than total fat. Evidence from recent reviews and meta analyses indicates that in women with PCOS substituting unsaturated fats (particularly marine omega-3 PUFAs) for saturated fat can reduce systemic inflammation (e.g., ↓hs-CRP, ↑adiponectin) and slightly improve insulin sensitivity and certain metabolic markers (31).

On the other hand, high fat patterns that are high in saturated fat are associated with pro inflammatory lipid mediators, insulin resistance and metabolic exacerbation including in adolescent PCOS, highlighting the risks associated with poor fat quality (32),(33). More comprehensive analyses of nutrition strategies for PCOS also find that while excess saturated fat may exacerbate hyperandrogenism and cardio metabolic risk, omega-3 fatty acid and other unsaturated fats have anti-inflammatory and insulin sensitizing effects (30).

Comparison of Fat Quality and Its Effects in Women with PCOS

Table 2. Types of Fat

Type of Fat	Influence on PCOS Metabolism and Hormones	Role on Inflammation or Oxidative Stress	Strength of Evidence	Ref.
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<p>Saturated fats</p>	<p>Diets high in saturated fat are repeatedly linked with worse insulin sensitivity and higher triglyceride and androgen levels among women with PCOS.</p>	<p>These fats promote systemic inflammation and may amplify oxidative stress, both of which aggravate metabolic dysfunction.</p>	<p>Observational and small clinical studies confirm these trends; long term trials remain limited.</p>	<p>(33),(34)</p>
<p>Monounsaturated fats (MUFA)</p>	<p>MUFA rich foods help improve lipid balance and vascular function, supporting overall cardio metabolic health in PCOS.</p>	<p>The polyphenols in olive oil reduce inflammatory signaling and protect endothelial cells from oxidative injury.</p>	<p>Supported by interventional studies in women; mechanistic pathways consistent with PCOS management goals</p>	<p>(35),(36)</p>
<p>Omega-3 polyunsaturated fats (PUFA)</p>	<p>Several meta analyses show that omega-3 supplementation lowers insulin resistance and CRP levels, and may modestly reduce circulating androgens.</p>	<p>EPA and DHA act as anti-inflammatory mediators, suppressing TNF-α and IL-6 while improving antioxidant status.</p>	<p>Evidence consistent but effect sizes vary across trials; best outcomes seen with ≥ 8 weeks intake.</p>	<p>(31), (37)</p>
<p>Mixed unsaturated fats</p>	<p>Higher nutrient consumption correlates with better glucose regulation and lower odds of insulin resistance in PCOS.</p>	<p>Their natural antioxidants and fibers contribute to a reduction in low grade inflammation.</p>	<p>Mostly observational data; RCTs are emerging.</p>	<p>(34)</p>

Overall quality (dietary pattern)	fat Diets emphasizing unsaturated over saturated fats improve insulin response and lipid control.	Low inflammatory dietary patterns align with lower CRP and better metabolic resilience.	Syntheses and comprehensive reviews favor improving fat quality rather than severe fat restriction.	(34),(30)
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**Mechanisms Linking Diet to PCOS Pathophysiology
Impact on Insulin Resistance and Glucose Metabolism**

One of the main characteristics of PCOS and a key focus of dietary treatment is insulin resistance. In skeletal muscle, adipose and hepatic tissues women with PCOS often have reduced insulin sensitivity which leads to hyperinsulinemia and consequent androgen excess. By affecting calorie intake, glycemic load and macronutrient composition, dietary interventions modify insulin dynamics. By enhancing postprandial glucose control and lowering circulating insulin levels, diets high in complex carbs, soluble fiber and unsaturated fats have been demonstrated to improve insulin sensitivity. On the other hand by raising oxidative stress and changing lipid metabolism, high glycemic and high saturated fat diets worsen IR (30).The capacity of ketogenic and low glycemic index (LGI) diets to lower fasting glucose, insulin and HOMA-IR indices in women with PCOS has drawn attention. For example, a 2023 meta-analysis by Cannarella et al. showed that short term ketogenic dietary therapies improved menstrual regularity by restoring ovulatory cycles and dramatically reduced fasting insulin (18).

Similar to this, following a Mediterranean style diet that includes whole grains, legumes, olive oil and fish high in omega-3 fatty acids improves insulin receptor sensitivity and glucose absorption by upregulating GLUT-4 expression and lowering pro inflammatory cytokines. Moreover, dietary antioxidants such as carotenoids, polyphenols and vitamin E enhance pancreatic β cell activity and reduce glucose intolerance (38). Diet has a direct impact on ovarian androgen production and follicular maturation through regulation of glucose insulin homeostasis. Increased insulin sensitivity restores ovulatory function, reduces androgen production and lessens ovarian theca cell stimulation. Therefore, addressing insulin resistance by diet improves metabolic parameters and corrects important PCOS reproductive problems. Cutting back on carbohydrates has proven to be quite beneficial for managing PCOS. For instance, in obese and overweight women with PCOS an LCKD (low carb, ketogenic diet) is an efficient way to reduce weight and enhance fasting insulin and free testosterone levels. Over the course of the trial insulin sensitivity was significantly improved on average and some women even regained fertility. Additionally low carb diets significantly affect BMI, HOMA-IR and cholesterol content particularly when interventions run longer than four weeks, according to a meta-analysis of controlled trials (30).

Modulation of Androgen Synthesis and SHBG Levels

The degree of hyperandrogenism a characteristic of PCOS, is determined by both sex hormone binding globulin (SHBG) concentrations and androgen production

both of which are influenced by diet. Elevated levels of free testosterone result from the suppression of hepatic SHBG synthesis caused by excess insulin and obesity. On the other hand, dietary habits that increase insulin sensitivity also reduce circulating androgens and thereby increase SHBG synthesis. By affecting hepatic metabolism and steroidogenesis diets high in monounsaturated fats, omega-3 fatty acids and phytoestrogens from flaxseed and soy may regulate androgenic activity (39).

LH driven ovarian androgen synthesis is decreased by low glycemic and high fiber diets because they attenuate insulin secretion. It has been demonstrated that in women with PCOS the Mediterranean diet which places a strong emphasis on plant based foods and minimal processed sugars raises SHBG and lowers free androgen index levels. Additionally by restoring the balance of the hypothalamic pituitary ovarian (HPO) axis, calorie restriction that results in modest weight loss (5–10%) significantly improves menstrual cyclicity and SHBG levels (15).

Furthermore, the enzymes involved in androgen biosynthesis are regulated by specific dietary micronutrients. Zinc and vitamin D, for instance alter the activity of 17α -hydroxylase and aromatase which affects the conversion of testosterone to estrogen. Green tea, berries and flaxseeds are examples of foods high in polyphenols that also inhibit 5α -reductase activity which lowers the conversion of testosterone to the more potent dihydrotestosterone (DHT) (40).

Influence on Gut Microbiota and Inflammation

According to new research, the composition of the gut microbiota influences inflammation, immunological response and metabolism all of which are critical components of PCOS pathophysiology. Reduced Bacteroidetes to Firmicutes ratio decreased short chain fatty acid (SCFA) producers and an overgrowth of pro inflammatory species are all signs of altered gut microbial diversity (dysbiosis) in women with PCOS. By adjusting this microbial imbalance dietary interventions can reduce insulin resistance and systemic inflammation (41).

High fiber, plant based diets and Mediterranean style patterns improve intestinal barrier integrity, lower endotoxemia and down regulate TNF- α and IL-6 secretion by increasing SCFA production especially butyrate and propionate enhancing microbial diversity. On the other hand, Western style diets high in refined sugars and saturated fats encourage gut permeability which makes it easier for lipopolysaccharide (LPS) to enter the bloodstream and cause chronic low grade inflammation, a known cause of PCOS pathology (42).

Interventions involving probiotics and prebiotics have also shown promise in the treatment of PCOS. Daily probiotic supplementation for 12 weeks significantly decreased fasting insulin, TNF α and hs CRP levels while improving menstrual regularity, according to a randomized controlled trial by. As microbiota modulators, fermented foods and polyphenols (found in berries, flaxseeds and green tea) support anti-inflammatory species like Bifidobacterium and Lactobacillus (43).

Interaction between Diet, Oxidative Stress and Reproductive Hormones

Insulin resistance, ovarian dysfunction and infertility in PCOS are all influenced by oxidative stress which is an imbalance between reactive oxygen species and antioxidant defenses. Overproduction of ROS causes ovarian cells to undergo lipid peroxidation, DNA damage and apoptosis which impairs folliculogenesis and lowers the quality of oocytes. In order to control oxidative stress and shield reproductive tissues from harm diet is essential (44).

Vitamins C, E, polyphenols, flavonoids and omega-3 fatty acids are all found in antioxidant rich dietary patterns such as the Mediterranean and anti-inflammatory diets. These nutrients neutralize ROS and strengthen endogenous antioxidant

enzymes like glutathione peroxidase (GPx) and superoxide dismutase (SOD). The study showed that following a diet high in antioxidants enhanced PCOS women's total antioxidant capacity and restored regular menstrual cycles. Similarly, by reducing postprandial hyperglycemia and advanced glycation end products (AGEs), which are known to disrupt insulin signaling and steroidogenesis, low glycemic and plant based diets lessen oxidative stress (45).

Furthermore, inflammation and oxidative stress work together increased ROS triggers NF- κ B signaling, which in turn upregulates pro inflammatory cytokines that exacerbate IR and hyperandrogenism. Coenzyme Q10, vitamin D and selenium are among the nutrients that have been demonstrated to improve ovulatory outcomes while reducing oxidative stress. In addition to their antioxidant properties polyphenol compounds such as curcumin and resveratrol inhibit androgen biosynthesis by suppressing the expression of the CYP17A1 gene in ovarian theca cells (45).

Research Gap

Though there are still significant research gaps, dietary modification has become a crucial non pharmacological strategy in the management of polycystic ovary syndrome (PCOS). The majority of studies are brief, have small sample sizes and don't compare the long term efficacy of different dietary strategies like low glycemic, Mediterranean, ketogenic and anti-inflammatory diets. Thus, there is little data on the safety and sustainability of these interventions.

The majority of the current literature is based on Western populations, which makes it challenging to extrapolate results to women in developing nations with diverse dietary and cultural contexts. There are also few mechanistic studies examining the ways in which particular nutrients affect oxidative stress, hormone regulation and gut microbiota. A lot of studies evaluate diet alone, ignoring how it interacts with other aspects of lifestyle like stress management, physical activity and sleep.

Strong evidence based dietary guidelines are also hampered by the absence of standardized dietary protocols and consistent outcome measures. Large scale, varied and long term studies that combine molecular, metabolic and behavioral insights should be the focus of future research in order to create individualized, culturally sensitive dietary plans for women with PCOS.

Conclusion

PCOS is a complex endocrine and metabolic condition that develops through the interaction of hormonal imbalance, insulin resistance, chronic inflammation and genetic factors. Its hallmark features include hyperandrogenism, irregular ovulation, and polycystic ovarian morphology, all of which contribute to both metabolic complications and reproductive difficulties. This review highlights that dietary modification is one of the most effective non-pharmacological approaches for managing PCOS symptoms and addressing key aspects of its underlying physiology. Evidence discussed here demonstrates that targeted dietary changes can influence several major processes involved in PCOS, including inflammation, oxidative stress, insulin resistance and excess androgen production. Low glycemic index diets help stabilize blood glucose levels, reduce hyperinsulinemia, lower androgen concentrations, and support the return of regular ovulatory cycles. Similarly, the Mediterranean diet rich in antioxidants, fiber and monounsaturated fats promotes better hormonal balance, enhances insulin sensitivity, and reduces systemic inflammation. Although more research is needed to determine their long term viability, ketogenic and high protein diets provide metabolic advantages like weight loss, enhanced insulin sensitivity and lipid regulation. The important relationship between diet, immunity and endocrine function is demonstrated by the

fact that anti-inflammatory and plant-based diets high in phytonutrients and fiber also improve the composition of the gut microbiota and lower pro inflammatory cytokines. The balance of macronutrients and micronutrients is also crucial. Omega-3 fatty acids and unsaturated fats enhance lipid metabolism and lower oxidative stress, while a sufficient intake of dietary fiber supports glycemic control and hormonal stability.

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