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Dietary Interventions for Polycystic Ovary Syndrome: A Comprehensive Review

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Abstract
Polycystic Ovary Syndrome (PCOS) is a complex hormonal and metabolic condition that affects a significant proportion of women in their reproductive years. This review outlines the role of dietary management as a primary therapeutic approach in PCOS, emphasizing its influence on insulin resistance, hormonal imbalance, menstrual irregularities, and fertility outcomes. Various dietary models are discussed, including low-glycemic index diets, the Mediterranean and DASH diets, ketogenic and high-protein regimens, plant-based nutrition, and intermittent fasting. The review also highlights the therapeutic potential of specific supplements such as myo-inositol and vitamin D. By integrating findings from recent clinical studies and meta-analyses, the article provides practical guidance for applying dietary strategies in clinical settings. These interventions offer safe, effective, and sustainable options for improving both metabolic and reproductive health in women with PCOS.

Keywords: PCOS, nutrition therapy, insulin sensitivity, glycemic index, Mediterranean diet, myo- inositol, fertility

Introduction

Polycystic ovary syndrome (PCOS) is one of the most common endocrine disorders in women of reproductive age, characterized by hyperandrogenism, oligo-anovulation, and polycystic ovarian morphology (Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group, 2004). The internationally accepted Rotterdam criteria require at least two of these three features for diagnosis, following the exclusion of other etiologies (Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group, 2004). Although PCOS is often recognized for its reproductive symptoms, it is increasingly understood as a complex metabolic condition. Affected women frequently present with insulin resistance, compensatory hyperinsulinemia, dyslipidemia, and an increased risk of type 2 diabetes mellitus (Goodarzi et al., 2011; Diamanti-Kandarakis & Papavassiliou, 2006). Hyperinsulinemia plays a critical role by stimulating ovarian theca cells to produce excess androgens and by reducing hepatic production of sex hormone-binding globulin (SHBG), thereby intensifying hyperandrogenic symptoms and anovulatory infertility (Dunaif, 1997). These metabolic disruptions reinforce the understanding of PCOS as both a reproductive and systemic metabolic disorder.

Chronic low-grade inflammation also contributes to the pathophysiology of PCOS. Elevated levels of inflammatory markers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-

alpha (TNF-α) have been consistently reported in women with PCOS, linking the condition to systemic inflammation often exacerbated by obesity and insulin resistance (Barrea et al., 2019). Emerging evidence indicates that dietary factors can modulate this inflammatory state.

Given the multifactorial nature of PCOS, current international guidelines emphasize lifestyle intervention—including diet, physical activity, and behavioral therapy—as the first-line approach for management across all phenotypes and body weight categories (Teede et al., 2018; Teede et al., 2023). This review explores the current evidence supporting dietary interventions in the management of PCOS. It synthesizes findings from clinical trials, meta-analyses, and mechanistic studies on various nutritional strategies, including low-glycemic index diets, the Mediterranean and DASH dietary patterns, ketogenic and high-protein approaches, plant-based nutrition, and intermittent fasting. In addition, the review highlights the role of targeted micronutrient supplementation—particularly myo-inositol and vitamin D—in improving hormonal profiles, insulin sensitivity, and ovulatory function. By providing an evidence-based overview of dietary therapies, this article aims to support clinicians and dietitians in implementing practical, individualized nutrition plans for women with PCOS.

Methods

A narrative review was conducted by searching scientific literature from electronic databases including PubMed, Scopus, and Google Scholar. The search covered studies published between 2005 and March 2025, using keywords such as “Polycystic Ovary Syndrome,” “PCOS,” “insulin resistance,” “dietary intervention,” “low glycemic index diet,” “Mediterranean diet,” “ketogenic diet,” “myo-inositol,” “vitamin D,” “intermittent fasting,” and “nutraceuticals in PCOS.”

Inclusion criteria were English-language, peer-reviewed human studies that evaluated non-pharmacological interventions such as diet, lifestyle modification, and nutritional supplementation in PCOS. Emphasis was placed on randomized controlled trials, clinical trials, systematic reviews, and meta-analyses that assessed outcomes related to insulin sensitivity, hormonal balance, menstrual regularity, and fertility. Studies involving animal models or in vitro experiments were excluded.

A total of 63 articles that met the inclusion criteria were reviewed. The findings were synthesized narratively to provide an evidence-based summary of dietary strategies and their therapeutic roles in the metabolic and reproductive management of PCOS.

1.Pathophysiology of PCOS and Dietary Relevance

Figure 1 – PCOS Pathophysiology and Targeted Dietary Strategies

Polycystic Ovary Syndrome (PCOS) is a multifactorial condition shaped by interactions among hormonal dysregulation, metabolic impairment, chronic inflammation, and environmental influences. Each of these

contributes to the clinical features observed in PCOS and offers a pathway for dietary intervention.

1.1 Insulin Resistance and Hyperinsulinemia

Insulin resistance is a hallmark feature of PCOS, affecting up to 75% of women with obesity and approximately 30–50% of those without (Diamanti-Kandarakis & Papavassiliou, 2006). In response, elevated insulin levels stimulate androgen production in ovarian theca cells while inhibiting SHBG synthesis in the liver, leading to an increase in biologically active androgens (Dunaif, 1997).

Dietary Implication: Nutritional strategies such as calorie-restricted, low-glycemic index diets and adherence to Mediterranean-style eating patterns have been associated with improvements in insulin sensitivity and reductions in circulating insulin (Moran et al., 2013).

1.2 Hyperandrogenism

Hyperandrogenism arises from excessive androgen production by the ovaries and adrenal glands, often influenced by hyperinsulinemia and heightened LH activity. This hormonal imbalances contributes to the disruption of follicular development, causing symptoms like acne, hirsutism, and menstrual irregularities (Azziz et al., 2006).

Dietary Implication: Supplementation with inositol isomers (myo-inositol and D-chiro-inositol) has demonstrated efficacy in reducing testosterone levels and improving ovulatory function (Unfer et al., 2017). Diets lower in carbohydrates and higher in omega-3 fatty acids may also help attenuate hyperandrogenism (Cussons et al., 2009).

1.3 Chronic Inflammation

Low-grade inflammation is commonly observed in PCOS and is characterized by elevated pro-inflammatory cytokines such as CRP, TNF-α, and IL-6. These contribute to both insulin resistance and reproductive dysfunction (González, 2012).

Dietary Implication: Anti-inflammatory diets, particularly the Mediterranean diet rich in polyphenols, omega-3 fatty acids, and antioxidants, have been shown to reduce inflammation and improve endocrine outcomes in PCOS (Barrea et al., 2020).

1.4 Obesity and Adipokine Imbalance

Central obesity intensifies insulin resistance and promotes adipokine dysregulation. This includes increased secretion of leptin and resistin and reduced adiponectin, which plays a protective role in metabolic regulation (Barber et al., 2019).

Dietary Implication: Weight loss strategies such as caloric restriction, high-protein meal plans, and consumption of foods with low energy density can help restore hormonal balance and reduce metabolic complications (Teede et al., 2018).

1.5 Oxidative Stress and Gut Microbiota Alterations

Elevated oxidative stress in PCOS has been linked to impaired oocyte maturation and implantation failure. Concurrently, emerging evidence connects gut microbiota imbalance to increased inflammation and insulin resistance through pathways involving intestinal permeability and reduced SCFA production (Qi et al., 2019).

Dietary Implication: Antioxidant-rich foods (e.g., vitamins C, E, selenium) and the use of probiotics and prebiotics such as inulin and fructooligosaccharides (FOS) may help modulate gut microbiota, enhance insulin response, and reduce systemic inflammation (Lindheim et al., 2017).

2.Nutritional Goals in PCOS Management

Nutrition is a central pillar in the long-term management of Polycystic Ovary Syndrome (PCOS). Although pharmacological options are available, dietary and lifestyle modifications remain the first-line therapy as

endorsed by international clinical guidelines (Teede et al., 2018). The primary objectives of nutrition therapy extend beyond weight reduction to include the improvement of insulin sensitivity, hormonal regulation, reproductive function, and mental well-being. These targets are rooted in the multifactorial pathogenesis of PCOS, aiming to address its underlying causes rather than managing symptoms alone.

2.1 Improving Insulin Sensitivity

Insulin resistance (IR) is a key metabolic abnormality in PCOS, affecting approximately 75% of women with obesity and 30–50% of lean individuals with the condition (Diamanti-Kandarakis & Papavassiliou, 2006). Hyperinsulinemia aggravates PCOS symptoms by stimulating ovarian theca cells to produce androgens, reducing hepatic synthesis of sex hormone-binding globulin (SHBG), and impairing normal follicular development and ovulation (Dunaif, 1997). To counteract these effects, dietary strategies such as low-glycemic index diets, energy restriction, and the Mediterranean diet have demonstrated improvements in fasting insulin levels and HOMA-IR scores (Moran et al., 2013). Inositol isomers—particularly myo-inositol and D-chiro-inositol— also offer insulin-sensitizing benefits by modulating post-receptor insulin signaling (Unfer et al., 2017).

2.2 Managing Adiposity and Weight

Excess adiposity, especially visceral fat, contributes to the hormonal and inflammatory dysregulation seen in PCOS. Adipose tissue promotes metabolic dysfunction through increased secretion of pro-inflammatory adipokines (e.g., leptin, resistin) and reduced levels of adiponectin, which plays a protective role in insulin sensitivity (Barber et al., 2019). Even in non-obese women, abnormal fat distribution and metabolic inflexibility are frequently observed. Evidence suggests that a modest weight loss of 5–10% can significantly improve ovulatory function, insulin sensitivity, and reproductive outcomes (Moran et al., 2011). This can be achieved through structured energy-restricted diets, increased protein and fiber intake, and regular physical activity. Additionally, intermittent fasting and time-restricted eating protocols have shown promise in improving metabolic parameters in women with PCOS (Almenning et al., 2015).

2.3 Regulating Menstrual Cycles

Menstrual irregularities such as oligo- or amenorrhea are characteristic of PCOS and reflect chronic anovulation and hormonal imbalance. Restoration of regular ovulatory cycles is essential for reproductive and endocrine health. Clinical trials have shown that dietary interventions aimed at improving insulin sensitivity and achieving weight reduction—such as low-GI diets and inositol supplementation—can lead to significant improvements in menstrual cyclicity (Unfer et al., 2017). Additionally, ketogenic diets have been explored for their rapid effects on hormonal balance, with some studies indicating restoration of ovulation through improved endocrine profiles (Mavropoulos et al., 2005).

2.4 Enhancing Fertility and Ovulation

Infertility in PCOS is largely attributed to anovulation and poor oocyte quality. Nutritional therapy has a direct impact on improving spontaneous ovulation and enhancing assisted reproductive outcomes. Even modest weight loss has been shown to increase ovulation rates and pregnancy success. Supplementation with myo-inositol and D-chiro-inositol has demonstrated improvements in ovarian function and oocyte maturation, particularly in women undergoing IVF (Unfer et al., 2017). Legro et al. (2007) found that lifestyle modification produced fertility outcomes comparable to pharmacologic ovulation induction, underscoring the therapeutic potential of behavioral interventions.

2.5 Reducing Hyperandrogenism

Elevated androgen levels contribute to clinical features such as acne, hirsutism, and anovulation in PCOS. These are often the result of increased insulin levels and an elevated LH/FSH ratio that stimulates androgen

production in the ovaries. Dietary interventions—particularly low- carbohydrate and ketogenic diets—have been shown to significantly reduce total and free testosterone levels (Gower et al., 2013). Nutrients such as zinc and omega-3 fatty acids have been associated with anti-androgenic effects through their influence on inflammation and steroid hormone biosynthesis (Khani et al., 2018). Moreover, vitamin D has been implicated in lowering androgen levels by improving insulin action and increasing SHBG concentrations.

2.6 Supporting Psychological Well-Being

Women with PCOS are at elevated risk for psychological conditions including depression, anxiety, and disordered eating. Hormonal disturbances, infertility, and body image concerns contribute to this burden. Studies estimate that nearly 40% of women with PCOS experience depression, and about 30% suffer from anxiety (Lin et al., 2015). Nutritional factors can influence psychological outcomes through their effects on neurotransmitter synthesis and systemic inflammation. Diets high in omega-3 fatty acids, complex carbohydrates, and micronutrients such as B vitamins, magnesium, and tryptophan are associated with better mood regulation and cognitive function. Furthermore, achieving weight loss is often correlated with enhanced psychological well-being, particularly in women dealing with infertility-related stress (Teede et al., 2018).

3.Overview of Evidence-Based Dietary Interventions

3.1 Low Glycemic Index (GI) Diet

A low glycemic index (GI) diet emphasizes the consumption of carbohydrates that cause a gradual increase in blood glucose and insulin levels, making it particularly beneficial in managing Polycystic Ovary Syndrome (PCOS). Insulin resistance, a hallmark of PCOS, affects up to 70– 80% of women with the condition (Moran et al., 2013). Elevated insulin stimulates ovarian theca cells to produce androgens, contributing to disrupted ovulation and hyperandrogenic symptoms.

Several randomized controlled trials (RCTs) and meta-analyses support the role of low-GI diets in improving metabolic and reproductive parameters. Marsh et al. (2010) found that women with PCOS on a low-GI diet experienced greater menstrual regularity and reduced testosterone levels compared to those on a conventional diet. Palomba et al. (2010) demonstrated that low-GI diets improved ovulation rates and increased sex hormone-binding globulin (SHBG), thereby lowering free androgen levels. These effects were more pronounced when combined with calorie restriction.

Galletly et al. (2007) reported significant improvements in insulin resistance, weight loss, and hormonal balance among women assigned to low-GI diets, as opposed to low-fat diets. In a study by Calcaterra et al. (2021), adolescent girls with PCOS who adhered to a low-GI diet showed improved oocyte quality and spontaneous ovulation, even without pharmacological intervention.

Importantly, the benefits are not limited to obese phenotypes. Barr et al. (2013) found that lean women with PCOS also experienced improvements in insulin sensitivity and LH/FSH ratios following a low-GI dietary regimen. Saadati et al. (2021) further noted significant enhancements in ovulation rates and menstrual regularity with a low-GI intervention.

Long-term adherence to low-GI diets can sustain these benefits. Becker et al. (2015) demonstrated that a year-long intervention resulted in lasting reductions in insulin resistance and androgen levels. These outcomes were linked to higher dietary fiber intake, reduced consumption of processed foods, and improved satiety, all of which support compliance.

3.2 Mediterranean Diet

The Mediterranean Diet (MedDiet) is a nutrient-dense, anti-inflammatory dietary pattern grounded in the traditional eating habits of populations living along the Mediterranean Sea. It emphasizes a high intake of vegetables, fruits, whole grains, legumes, nuts, and olive oil, moderate consumption of fish and dairy, and limited intake of red meat and processed foods. The MedDiet has been extensively studied for its metabolic and cardiovascular benefits and is now increasingly recognized for its positive effects on Polycystic Ovary Syndrome (PCOS) management.

PCOS is frequently associated with insulin resistance and chronic inflammation—two targets effectively modulated by the MedDiet. Clinical trials have demonstrated that adherence to this dietary model improves insulin sensitivity, reduces androgen levels, and supports menstrual regularity. For example, Karakosta et al. (2023) reported significant decreases in fasting insulin, total testosterone, and improved ovulation rates following a MedDiet intervention in women with PCOS. Similarly, Villani et al. (2024) observed increased sex hormone-binding globulin (SHBG) concentrations and enhanced menstrual regularity, suggesting improved endocrine outcomes.

The anti-inflammatory properties of the MedDiet are pivotal to its effectiveness. It provides a rich source of antioxidants (e.g., vitamins A, C, and E), polyphenols, and omega-3 fatty acids, which suppress pro-inflammatory cytokines such as CRP, IL-6, and TNF-α. A meta-analysis by Papadaki and Nolen-Doerr (2022) found significant reductions in systemic inflammatory markers in women with PCOS adhering to a Mediterranean-style diet. Additionally, Esposito et al. (2011) showed improved endothelial function and decreased insulin resistance in women with metabolic syndrome and PCOS who followed the MedDiet.

Another strength of the MedDiet lies in its adaptability across cultures and dietary preferences. In India, a vegetarian version of the MedDiet was developed using ingredients like whole grains, pulses, nuts, fruits, and mustard oil in place of olive oil. Bhargava et al. (2022) found that Indian women with PCOS following this adapted MedDiet experienced improved lipid profiles, increased ovulatory frequency, and better adherence due to cultural compatibility.

Furthermore, longitudinal studies suggest sustained benefits of the MedDiet on both metabolic and psychological outcomes. A 12-month follow-up by Stefanaki et al. (2021) confirmed long-term improvements in insulin resistance, weight management, and depressive symptoms among PCOS participants. These findings highlight the MedDiet's comprehensive benefits on metabolic health and mental well-being—two critical facets of PCOS care.

In adolescents and young adults, early adoption of the MedDiet has shown promise in mitigating the long-term risk of metabolic syndrome and type 2 diabetes. Calcaterra et al. (2021) emphasized the association between MedDiet adherence and reduced visceral adiposity, improved glucose metabolism, and better body image satisfaction in teenage girls with PCOS.

3.3 DASH Diet (Dietary Approaches to Stop Hypertension)

The DASH (Dietary Approaches to Stop Hypertension) diet is a nutrient-rich, heart-healthy dietary pattern originally designed to lower blood pressure. It emphasizes fruits, vegetables, whole grains, low-fat dairy products, lean proteins, and limits saturated fats, sodium, and added sugars. This profile aligns closely with the metabolic management needs of women with PCOS, particularly those experiencing insulin resistance, dyslipidemia, and chronic inflammation.

Evidence supports the DASH diet as an effective intervention for improving reproductive and metabolic outcomes in PCOS. In a randomized controlled trial by Asemi et al. (2014), women with PCOS following the DASH diet for 12 weeks showed significant reductions in fasting insulin, HOMA-IR scores, and free androgen index (FAI), along with increases in SHBG levels. These improvements were associated with

better menstrual regularity and weight loss.

Shang et al. (2020) reported that adherence to a DASH-style diet led to improved lipid profiles, reduced inflammatory markers such as CRP and TNF-α, and enhanced ovulatory function. A meta- analysis by Papavasiliou and Papakonstantinou (2017) confirmed the diet's effectiveness in reducing androgen levels and improving insulin sensitivity, particularly in overweight and obese women with PCOS.

The DASH diet's high fiber and micronutrient content (including potassium, magnesium, and calcium) helps regulate insulin metabolism and reduce oxidative stress. Furthermore, its low sodium content may reduce hyperaldosteronism, a contributor to metabolic dysfunction in PCOS (Behboudi-Gandevani et al., 2020).

In adolescent girls with PCOS, the DASH diet has been associated with improved BMI trajectories, reduced hirsutism, and enhanced psychological well-being, as observed in longitudinal cohort studies (Khodabandehloo et al., 2021).

3.4 High-Protein and Low-Carbohydrate Diets

High-protein and low-carbohydrate diets promote satiety, reduce insulin secretion, and facilitate weight loss through enhanced lipolysis. These mechanisms directly target insulin resistance and androgen excess in PCOS. Gower et al. (2013) and Foroozanfard et al. (2017) observed reductions in fasting insulin and testosterone levels following high-protein dietary interventions.

A systematic review by Muhammed Saeed et al. (2025) reported that these diets improved ovulatory frequency, reduced menstrual irregularity, and lowered free androgen index. When combined with exercise and caloric control, outcomes were even more pronounced. Such diets also improve oocyte quality and endometrial receptivity in fertility treatment contexts (Papavasiliou & Papakonstantinou, 2017).

3.5 Ketogenic Diet

The ketogenic diet (KD) is a high-fat, very-low-carbohydrate dietary protocol that induces a metabolic state of ketosis, where ketone bodies become the primary fuel source in place of glucose. By sharply reducing carbohydrate intake, KD directly targets hyperinsulinemia and insulin resistance—core pathophysiological features of PCOS.

Short-term studies have shown promising metabolic and reproductive improvements with KD in women with PCOS. In a pilot trial by Mavropoulos et al. (2005), participants following a ketogenic regimen experienced substantial weight loss, improved free testosterone levels, increased SHBG, and restored ovulatory cycles within 24 weeks. Leandro et al. (2024) found that KD led to a 50% reduction in fasting insulin levels and improved ovarian morphology in overweight PCOS patients.The benefits of KD include reduced insulin demand, enhanced lipolysis, and modulation of the gut microbiota, all of which contribute to improved hormonal profiles. A systematic review by Gower and Goss (2023) reported significant reductions in androgen levels, improved menstrual cyclicity, and decreased inflammatory markers in PCOS subjects following KD protocols.

However, concerns about long-term adherence and safety remain. Potential risks include micronutrient deficiencies (e.g., B vitamins, selenium, magnesium), menstrual irregularities upon refeeding, and gastrointestinal side effects. Hence, clinical guidelines recommend KD only under medical supervision and for short durations (Pirola et al., 2024).

Despite these limitations, KD may offer a rapid therapeutic effect for obese or treatment-resistant PCOS cases, especially when other dietary strategies have failed to produce substantial outcomes.

3.6 Plant-Based Diets

Plant-based diets, including vegetarian and vegan dietary patterns, are rich in dietary fiber, complex carbohydrates, phytoestrogens, unsaturated fatty acids, and anti-inflammatory micronutrients. These elements play crucial roles in modulating insulin resistance, oxidative stress, and endocrine dysfunction associated with Polycystic Ovary Syndrome (PCOS) (Koliaki & Katsilambros, 2022).

The phytoestrogens found in plant-based foods such as soy, flaxseeds, and legumes act as selective estrogen receptor modulators (SERMs), potentially balancing estrogen levels and lowering androgen excess in PCOS. High-fiber intake helps regulate insulin by slowing glucose absorption, reducing insulin spikes, and supporting a favorable shift in gut microbiota composition. This, in turn, can lower inflammation and promote hormonal balance (Silva, 2021).

Clinical evidence supports the benefits of plant-based diets in improving ovulatory frequency, reducing androgen levels, and aiding weight management. Gautam et al. (2025) observed significant improvements in fasting insulin, menstrual cyclicity, and quality of life scores in women with PCOS following a whole-food plant-based diet for 12 weeks. Additionally, plant- based nutrition has been associated with increased levels of sex hormone-binding globulin (SHBG) and decreased free androgen index (FAI).

However, it is important to note the potential for nutritional gaps, including deficiencies in vitamin B12, iron, zinc, iodine, and omega-3 fatty acids. Adequate dietary planning or supplementation is required to ensure the diet remains nutritionally complete and metabolically effective.

3.7 Intermittent Fasting (IF) and Time-Restricted Feeding (TRF)

Intermittent Fasting (IF), particularly Time-Restricted Feeding (TRF), involves alternating periods of eating and fasting, often in formats such as 16:8 (16 hours fasting, 8 hours eating) or early Time- Restricted Feeding (eTRF). This strategy has gained popularity in PCOS management due to its impact on insulin sensitivity, androgen regulation, and synchronization of circadian rhythms.

Circadian biology governs hormonal fluctuations, glucose metabolism, and reproductive function. Disrupted eating patterns misalign circadian gene expression in ovarian granulosa cells, contributing to irregular ovulation and hormonal imbalance. By aligning food intake with light-dark cycles, IF restores the temporal control of metabolic processes, which can favorably impact reproductive health (Koppold et al., 2024).

In a pilot study by Leandro et al. (2024), women with PCOS practicing TRF exhibited decreased fasting insulin, improved LH/FSH ratios, and increased ovulation frequency over an eight-week period. Dušková (2023) highlighted IF's role in lowering androgen levels, improving SHBG, and reducing systemic inflammation.

Additionally, IF enhances sleep quality by modulating melatonin and cortisol rhythms, which are often disrupted in PCOS. Improved sleep supports better leptin-ghrelin balance, reducing cravings and improving energy expenditure. This metabolic and endocrine alignment creates a feedback loop supporting both physiological and psychological health in women with PCOS.

4.Micronutrients and Supplements

4.1 Inositol (Myo-Inositol & D-Chiro-Inositol)

Inositols are naturally occurring compounds functioning as insulin second messengers, with distinct but complementary roles in PCOS management. Myo-inositol (MI) enhances glucose uptake, supports follicle-stimulating hormone (FSH) signalling, and improves oocyte quality. D- chiro-inositol (DCI), on the other hand, contributes to insulin-mediated androgen regulation. However, excess DCI may exacerbate androgen excess in ovarian tissue—a phenomenon referred to as the "DCI paradox." Therefore, supplementation in a 40:1 MI:DCI ratio, mimicking physiological levels in ovarian tissue, is considered

most effective.

Clinical trials indicate that combined MI and DCI supplementation significantly improves insulin sensitivity, lowers HOMA-IR, and reduces hyperinsulinemia in both lean and obese PCOS patients. Dinicola et al. (2014) concluded that MI+DCI combinations outperformed single- compound therapy in improving glucose metabolism.

MI has also been found to restore spontaneous ovulation and menstrual regularity. A randomized trial found that MI-based ovulation induction produced comparable success rates to clomiphene citrate, but with superior tolerability. MI additionally improves oocyte quality, endometrial receptivity, and pregnancy outcomes in assisted reproductive technology (ART) settings (Ciotta et al., 2011; Kamenov & Gateva, 2020; Tatone et al., 2024). Supplementation lowers serum testosterone, improves LH/FSH ratio, and increases SHBG levels, thereby benefiting dermatologic manifestations like hirsutism and acne (Unfer et al., 2020).

4.2 Vitamin D

Vitamin D influences multiple aspects of PCOS pathophysiology, including insulin signaling, ovarian steroidogenesis, AMH modulation, and SHBG expression. Up to 85% of women with PCOS have suboptimal vitamin D status, correlating with elevated testosterone, higher BMI, and anovulatory cycles (Han et al., 2024).

Supplementing with 1000–4000 IU/day of vitamin D has been shown to improve insulin sensitivity, regulate AMH and follicular development, increase SHBG levels, and promote menstrual regularity. Kaur et al. (2024) demonstrated that vitamin D supplementation significantly improved ovulatory outcomes and reduced testosterone levels in deficient PCOS women, especially when co-administered with inositol.

Co-supplementation with MI shows synergistic effects, including enhanced endocrine profiles (reduced FAI, LH/FSH ratio), faster restoration of menstrual cycles, and improved conception rates (Katyal et al., 2024).

4.3 Zinc

Zinc is essential for enzymatic activities related to insulin function, steroid synthesis, and antioxidant defense. Zinc modulates 5α-reductase activity, reducing conversion of testosterone to dihydrotestosterone (DHT). Deficiency is linked to increased androgen levels, irregular menses, and acne. Supplementation (typically 30–50 mg/day as zinc gluconate or picolinate) has been shown to reduce testosterone and fasting insulin levels (Esmaeilinezhad et al., 2020).

4.4 Magnesium

Magnesium plays a critical role in glucose metabolism, insulin receptor signaling, and inflammatory modulation. Subclinical magnesium deficiency in PCOS contributes to insulin resistance and elevated oxidative stress. Co-supplementation with vitamin D, vitamin E, or omega- 3 fatty acids yields superior outcomes in reducing HOMA-IR, testosterone levels, and improving menstrual cyclicity (Jamilian et al., 2017). Doses of 250–400 mg/day, particularly as citrate or glycinate forms, are effective.

4.5 Chromium

Chromium, particularly chromium picolinate, enhances insulin receptor activity and GLUT-4 translocation. It may also regulate appetite and reduce cravings, benefiting women with disordered eating patterns. Bahadori et al. (2020) reported improved glucose control and menstrual regularity with 200 µg/day of chromium. Typical effective doses range from 200–1000 µg/day.

4.6 N-Acetylcysteine(NAC)

NAC, a precursor to glutathione, functions as an antioxidant and insulin sensitizer. Studies confirm that

NAC improves insulin sensitivity, lowers testosterone and LH levels, and increases spontaneous ovulation. Kazerooni et al. (2010) found NAC comparable to metformin in enhancing ovulation with fewer side effects. It also improves embryo quality and reduces risk of ovarian hyperstimulation in ART settings. Recommended doses range from 600 to 1800 mg/day, administered in divided doses.

Conclusion

Polycystic Ovary Syndrome (PCOS) presents a multifaceted clinical and metabolic challenge, manifesting through reproductive, endocrine, inflammatory, and metabolic dysfunctions. The growing body of evidence underscores the efficacy of individualized, evidence-based dietary interventions in mitigating these pathophysiological disturbances. Nutritional strategies such as low glycemic index diets, Mediterranean and DASH dietary patterns, high-protein and low- carbohydrate approaches, and emerging protocols like intermittent fasting have demonstrated significant benefits in improving insulin sensitivity, hormonal regulation, menstrual regularity, and fertility outcomes.

In addition to macronutrient composition and dietary patterns, targeted micronutrient supplementation—particularly with inositol, vitamin D, zinc, magnesium, chromium, and N- acetylcysteine—further enhances therapeutic outcomes by addressing insulin resistance, oxidative stress, and androgen excess. These interventions offer a non-pharmacological, sustainable, and patient-centric model for long-term management.

Current clinical guidelines advocate lifestyle and dietary modification as first-line therapy for all women with PCOS, irrespective of phenotype or body weight. Integrating these dietary approaches into clinical practice requires a personalized framework, considering the patient's metabolic profile, reproductive goals, and psychosocial context. Continued research is essential to refine dosage, duration, and long-term safety of various dietary protocols and nutraceutical combinations. Ultimately, diet remains a cornerstone in the comprehensive care of PCOS, offering tangible improvements in both clinical outcomes and quality of life.

Credit Authorship Contribution Statement

All authors equally contributed to Conceptualization, Methodology, Formal Analysis, Investigation,

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