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The Impact of Selected Dietary Interventions and Supplementation on Metabolic and Hormonal Parameters in Women with Polycystic Ovary Syndrome

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ABSTRACT

Background. Polycystic ovary syndrome (PCOS) is the most common endocrinopathy affecting women of reproductive age and the leading cause of anovulatory infertility. Its multifactorial pathophysiology involves hypothalamic-pituitary-ovarian axis dysregulation, hyperandrogenism, and insulin resistance. Given its lifelong nature, dietary interventions constitute a fundamental component of management.

Aim. To evaluate the impact of selected dietary patterns and supplementation strategies on metabolic and hormonal parameters in women with PCOS.

Material and methods. A narrative review was conducted using PubMed and Google Scholar. Keywords searched: "PCOS", "low glycemic index diet", "DASH diet", "Mediterranean diet", "ketogenic diet", "inositol", "vitamin D", "supplementation".

Results. All analyzed dietary patterns demonstrated beneficial effects. The LGI diet improved insulin sensitivity and lipid profile. The DASH diet exerted anti-inflammatory effects and reduced androstenedione while increasing SHBG. The Mediterranean diet reduced the risk of PCOS and type 2 diabetes. The ketogenic diet reduced body weight, HOMA-IR, and androgen levels. Inositol yielded effects comparable to metformin. Vitamin D improved insulin sensitivity and glycemic parameters. Omega-3 and omega-6 supplementation positively influenced cardiovascular risk and demonstrated anti-inflammatory properties.

Conclusions. Dietary modification is an effective component of PCOS management. The DASH diet may offer the most consistent benefit; however, recommendations should be individualized.

Key words: PCOS, diet, insulin resistance, hyperandrogenism, DASH diet, Mediterranean diet, ketogenic diet, inositol, vitamin D

INTRODUCTION

Polycystic ovary syndrome (PCOS) was first described in 1935 by Irving F. Stein and Michael L. Leventhal, which is also the origin of its alternative name — Stein–Leventhal syndrome. In their research, they described the most prominent features of the condition: the presence of polycystic ovaries and amenorrhea. They also observed that some patients exhibited signs of masculinization [1]. However, the history of the disease dates back to ancient Greece and Hippocrates. Over thousands of years, numerous sources have reported cases of women with beards, a reference to the hirsutism characteristic of PCOS [2].

Currently, polycystic ovary syndrome is the most common endocrinopathy affecting women of reproductive age and simultaneously the most frequent cause of anovulatory infertility [3]. According to the literature, the prevalence of the disease is estimated at 11–12% of women based on the diagnosis by Rotterdam criteria [4]; however, due to the heterogeneity of its symptoms, a large proportion of cases remain undiagnosed. Diagnosis is made on the basis of the 2003 Rotterdam criteria [5], requiring the presence of at least two of the following:
1) clinical and/or biochemical hyperandrogenism,
2) ovulatory dysfunction,
3) polycystic ovarian morphology (PCOM) on ultrasound.
As an alternative to ultrasound, measurement of serum anti-Müllerian hormone (AMH) is also accepted [6].

The clinical presentation of PCOS is varied and highly individual. Most commonly, patients present with hirsutism, acne, and androgenic alopecia, and may also experience overweight and obesity, ovulatory disorders leading to infertility, and glucose metabolism disturbances [3]. The clinical picture of the disease also contributes to psychological distress in many patients, partly related to obesity. Furthermore, obesity and central adiposity are

strongly associated with the development of insulin resistance [7][8] Weight reduction is therefore an important component of PCOS management in overweight and obese patients.
Due to the numerous metabolic and hormonal abnormalities involved, appropriate treatment should be initiated as early as possible to reduce the risk of developing type 2 diabetes and cardiovascular disease [9]. The treatment of PCOS includes lifestyle changes and pharmacological treatment. As it is a lifelong condition requiring ongoing management, it is of utmost importance to recommend the adoption of a healthy lifestyle, maintenance of a healthy body weight, and regular physical activity [6]. In the literature, a wide variety of diets can be found; however, not all of them produce the expected results or have a beneficial effect on the health of patients.

PATHOPHYSIOLOGY OF PCOS

The pathophysiology of PCOS is complex and multifactorial. It involves disturbances at multiple levels, including the hypothalamus, pituitary gland, ovaries, as well as glucose metabolism [3] .

The hallmark feature of PCOS is hyperandrogenism caused by excessive androgen secretion by the ovaries. This is driven by elevated GnRH secretion, which in turn stimulates LH hypersecretion. Elevated LH promotes androgen production by thecal cells in the ovaries. At the same time, FSH secretion remains unchanged or is reduced, impairing follicular maturation and development. This leads to follicular arrest, polycystic ovarian morphology, and oligo- or anovulation. The large number of antral and preantral follicles stimulates AMH production, which further amplifies GnRH secretion, perpetuating the cycle.[3] [10].

75–95% of women with PCOS exhibit insulin resistance, which leads to compensatory hyperinsulinemia. Hyperinsulinemia enhances androgen production by stimulating LH secretion via GnRH; furthermore, it contributes to a reduction in hepatic SHBG synthesis, increasing the bioavailability of free androgens. [11] [3]

LOW GLYCEMIC INDEX/GLYCEMIC LOAD DIET

The glycemic index (GI) is a parameter reflecting the effect of specific carbohydrate-containing foods on blood glucose levels, relative to the response following consumption of white bread or pure glucose. The glycemic load (GL), in turn, takes into account both the GI of a product and the quantity of carbohydrates in a given serving [12]. A diet based on low GI foods (LGI diet) is intended to maintain stable blood glucose levels and reduce postprandial insulin spikes. Preferred foods are those with a low GI ($\leq$55), rich in high-quality carbohydrates, as opposed to high GI foods (GI $\geq$70), which cause rapid and pronounced glycemic and insulin surges, leading to metabolic dysregulation [13].

Studies have demonstrated that in overweight or obese patients with PCOS following an LGI diet, reductions in HOMA-IR (a marker of insulin resistance) and fasting insulin were observed compared to patients following a high glycemic index (HGI) diet. The LGI diet also positively influenced the lipid profile by reducing total cholesterol, LDL cholesterol, and triglycerides. In cases of abdominal obesity, a reduction in waist circumference was noted, though without a significant change in body weight. Patients also exhibited a reduction in total testosterone, though without an effect on the free androgen index [14]. Furthermore, a

significant increase in tissue insulin sensitivity was observed, which is an important therapeutic target in PCOS [15][16]. Studies also suggest meaningful improvement in menstrual cyclicity [15]. Additionally, a 12-week dietary intervention demonstrated a significant reduction in non-esterified fatty acid (NEFA) levels. This is particularly beneficial in patients with PCOS, given the well-established associations between elevated NEFA and increased risk of type 2 diabetes and cardiovascular disease [16].

DASH DIET (Diet Approaches to Stop Hypertension)

The DASH diet was originally designed for patients with hypertension; however, due to its numerous benefits with regard to insulin resistance, lipid profile improvement, and reduction of inflammatory and oxidative stress markers, it is also recommended in metabolic diseases [17]. The diet is based on fruits, vegetables, whole grains, fish, nuts, and low-fat dairy products, while limiting red meat, sweets, and sugar-sweetened beverages [18]. As the DASH diet is characterized by a high content of magnesium, vitamin C, dietary fiber, and unsaturated fatty acids, it exerts a marked anti-inflammatory effect, as evidenced by observed reductions in plasma inflammatory markers such as IL-6 and CRP in patients following this dietary model [19].

Research results indicate that the DASH diet has a positive impact on weight loss, reduction of fat tissue volume, and BMI, thereby reducing androstenedione levels and increasing SHBG levels and antioxidant capacity in overweight and obese patients with PCOS. One of the key features of this diet is its richness in magnesium, which enhances antioxidant capacity while simultaneously increasing tissue insulin sensitivity [20].

MEDITERRANEAN DIET

The Mediterranean diet was built on the dietary patterns prevalent in the 1960s, primarily in Crete, but also throughout the rest of Greece and southern Italy. The lifestyle of that era, tied to agricultural and domestic labor, required regular physical activity and a plant-based diet derived from locally grown produce [21]. The foundation of the diet consists of fruits, vegetables (including legumes), whole grain products, and extra-virgin olive oil (EVOO). Processed foods, added sugar, and saturated fatty acids are consumed only occasionally. Together, these characteristics make the Mediterranean diet rich in numerous vitamins and minerals, carotenoids, unsaturated fatty acids, and polyphenolic compounds [8].

Research results indicate that the Mediterranean diet positively influences weight loss and BMI reduction, an effect that is amplified when accompanied by regular physical activity and a caloric deficit [22]. Moreover, studies suggest a significant 23% reduction in the risk of developing type 2 diabetes [23]. In patients already diagnosed with type 2 diabetes, the Mediterranean diet produced significant reductions in glycated hemoglobin (HbA1c), as well as decreases in fasting glucose, total cholesterol, and triglycerides [24]. It has also been demonstrated that adherence to this dietary pattern is associated with a reduced risk of developing PCOS [25].

Polyphenolic compounds — present in abundant quantities in the Mediterranean diet — are gaining increasing scientific attention. Numerous studies highlight their anti-inflammatory, cardioprotective, antioxidant, and potentially anti-carcinogenic properties [26].

Furthermore, a beneficial effect of polyphenols has been demonstrated on fertility disorders, insulin resistance, hyperglycemia, hyperlipidemia, obesity, and type 2 diabetes associated with PCOS [27].

KETOGENIC DIET

The ketogenic diet is characterized by very low carbohydrate intake, moderate protein consumption, and unrestricted fat intake. The goal of carbohydrate restriction is to induce a state of nutritional ketosis, which occurs when carbohydrate intake constitutes less than 15% of daily caloric requirements or amounts to no more than 50 g per day [28].

In the KEMEPHY study, women with PCOS were placed on a ketogenic diet combined with a Mediterranean diet. After 12 weeks, patients demonstrated significant reductions in body weight, BMI, and waist circumference. Additionally, relevant metabolic and endocrinological changes were observed. Reductions in fasting glucose, fasting insulin, and HOMA-IR were noted, indicating a beneficial effect on insulin resistance. Furthermore, the lipid profile improved significantly, with reductions in triglycerides, total cholesterol, and LDL cholesterol, alongside an increase in HDL cholesterol. The study also reported reductions in plasma LH, total testosterone, free testosterone, and DHEAS, together with increases in estrogens, progesterone, and SHBG, suggesting an improvement in hormonal homeostasis in women with PCOS [29]. Multiple studies confirm the positive impact of the ketogenic diet on glucose metabolism, hyperandrogenism, hormonal balance, and body composition in overweight and obese patients with PCOS [30][31].

SUPPLEMENTATION

INOSITOL

Inositol is an organic compound that, due to its structural characteristics, belongs to the sugar family. The term encompasses a group of nine stereoisomers, of which myo-inositol and D-chiro-inositol are the most widely distributed in the human body. Although myo-inositol is sometimes classified as a B-group vitamin, it is synthesized endogenously from glucose. Inositol and its derivatives serve as important structural components of cell membranes. Additionally, they act as precursors of second messengers involved in numerous metabolic pathways related to TSH, LH, FSH, and insulin signaling. Rich dietary sources of inositol include citrus fruits and legumes [32].

In clinical studies, inositol has demonstrated beneficial effects on body composition and hormonal balance. Participants showed reductions in BMI, regularization of the menstrual cycle, decreases in total testosterone and androstenedione, an increase in SHBG, and a reduction in fasting glucose. Moreover, no adverse effects of inositol supplementation were observed, in contrast to metformin treatment [33]. In some studies, the effects of inositol supplementation in patients with PCOS were comparable to those of metformin therapy [34]. However, in accordance with the 2023 international guidelines, due to a lack of high-quality evidence, no specific recommendations regarding dosage or formulation have been established for adults and adolescents with PCOS [6].

VITAMIN D

Vitamin D is a steroidal organic compound obtained by the body partly through biosynthesis in the skin upon UVB radiation exposure. It is subsequently converted — through a series of metabolic transformations in the liver and kidneys — to its biologically active form: 1α,25-dihydroxycholecalciferol (calcitriol) [35].

Vitamin D plays a key role in calcium homeostasis and hormonal regulation, making an adequate serum level essential for proper physiological function. An increased risk of vitamin D deficiency has been observed in patients with PCOS [36]. Studies show that vitamin D supplementation in women with PCOS has a beneficial effect on tissue insulin sensitivity and reduces fasting glucose and fasting insulin levels. It may also positively influence the lipid profile and hyperandrogenism, although the evidence for the latter remains inconclusive [37].

OMEGA-3 AND OMEGA-6 FATTY ACIDS

Polyunsaturated fatty acids (PUFAs) are long-chain fatty acids containing two or more unsaturated double bonds, classified into two main families: omega-3 (n-3) and omega-6 (n-6).The human body is incapable of synthesizing omega fatty acids independently; therefore, an appropriate selection of a balanced diet is essential.. Dietary sources of omega-3 fatty acids and omega-6 fatty acids are found primarily in plant foods such as green leafy vegetables, vegetable oils, and seeds, as well as in deep-sea fish [38].

Omega-3 PUFAs, which have a known safety record, have gained attention as a potential adjunct therapy for women with PCOS, not only for reducing the clinical features of this condition but also for reducing cardiovascular disease risk [39]. A meta-analysis by Huang and Zhang (2023) comprising 7 clinical controlled studies with 574 patients demonstrated that supplementation with ω-3 PUFAs resulted in significant reductions in total cholesterol and triglyceride levels, as well as a decrease in insulin resistance as measured by HOMA-IR and a reduction in testosterone levels [40]. Notably, no significant effects were observed on BMI, fasting blood glucose, HDL-C, or Ferriman-Gallwey scores [40].

These findings are further supported by a meta-analysis of 11 randomized controlled trials involving 816 patients, which confirmed that n-3 PUFA supplementation may be an effective intervention for alleviating metabolic disturbances in PCOS, with supplementation lasting more than 8 weeks proving more beneficial for improving insulin resistance and lipid profiles [41].The mechanisms underlying these effects involve modulation of peroxisome proliferator-activated receptors (PPARs), which influence lipid metabolism and insulin sensitivity, as well as direct anti-inflammatory actions reflected in reductions of circulating inflammatory markers.

Intervention	Insulin resistance	Lipid profile	Androgens	SHBG	Body weight/BMI	Other
LGI diet	↓ HOMA-IR, ↓ fasting insulin, ↑ insulin sensitivity,	↓ TC, ↓ LDL-C, ↓ TG	↓ total testosterone	—	↓ waist circumference (no significant change in body weight)	↓ NEFA, ↑ menstrual regularity
DASH diet	↑ insulin sensitivity	—	↓androstenedione	↑ SHBG	↓ body weight, ↓ fat tissue, ↓ BMI	↓ IL-6, ↓ CRP, ↑ antioxidant capacity
Mediterranean diet	↓ fasting glucose, ↓ HbA1c	↓ TC, ↓ TG	—	—	↓ body weight, ↓ BMI	↓ risk of T2DM (−23%), ↓ risk of PCOS, anti-inflammatory, antioxidant effects
Ketogenic diet	↓ HOMA-IR, ↓ fasting insulin, ↓ fasting glucose	↓ TC, ↓ LDL-C, ↓ TG, ↑ HDL-C	↓ LH, ↓ total & free testosterone, ↓ DHEAS	↑ SHBG	↓ body weight, ↓ BMI, ↓ waist circumference	↑ estrogens, ↑progesterone
Inositol	↓ fasting glucose	—	↓ total testosterone, ↓ androstenedione	↑ SHBG	↓ BMI	↑ menstrual regularity, no adverse effects
Vitamin D	↑ insulin sensitivity, ↓ fasting glucose, ↓ fasting insulin	positive effect (inconclusive)	possible ↓ hyperandrogenism (inconclusive)	—	—	↑ calcium homeostasis
Omega-3 PUFAs	↓ HOMA-IR	↓ TC, ↓ TG,	↓ testosterone	—	no significant effect on BMI	anti-inflammatory (↓ PPARs modulation), ↓ cardiovascular risk

Legend: ↓ = decrease/reduction; ↑ = increase/improvement; — = no significant effect or no data reported; TC = total cholesterol; TG = triglycerides; LDL-C = low-density lipoprotein cholesterol; HDL-C = high-density lipoprotein cholesterol; T2DM = type 2 diabetes mellitus;

NEFA = non-esterified fatty acids; HbA1c = glycated hemoglobin; PPARs = peroxisome proliferator-activated receptors.

DISCUSSION

While the evidence supporting dietary intervention in PCOS is compelling, translating these findings into routine clinical practice poses several important challenges. Adherence to any specific dietary pattern over the long term is influenced by a range of personal, cultural, socioeconomic, and psychological factors. A dietary recommendation that is theoretically optimal but poorly tolerated or incompatible with a patient's lifestyle is unlikely to produce sustained benefit. Therefore, the process of dietary counseling should be patient-centered, with the clinician presenting available evidence while accounting for individual preferences and practical constraints.

An important consideration is the phenotypic heterogeneity of PCOS itself. Women with PCOS present with varying degrees of insulin resistance, hyperandrogenism, and body weight dysregulation, which may differentially influence the response to dietary interventions. For instance, patients with predominant insulin resistance and obesity are likely to benefit most from dietary patterns that reduce postprandial glycemia and promote caloric restriction, such as the LGI or ketogenic diet. Conversely, lean patients with PCOS presenting primarily with hyperandrogenism and ovulatory dysfunction may respond more favorably to the anti-inflammatory properties of the DASH or Mediterranean dietary patterns. Future clinical guidelines would benefit from stratifying dietary recommendations according to the predominant metabolic phenotype of the patient.

A further consideration relevant to clinical practice is the role of combined dietary and supplementation strategies. The interventions reviewed in this article are not mutually exclusive; in practice, supplementation with inositol, vitamin D, or omega-3 fatty acids may be integrated alongside a structured dietary pattern to achieve additive or synergistic benefits. For example, myo-inositol supplementation alongside an LGI diet may offer compounding improvements in insulin sensitivity, while vitamin D supplementation could augment the anti-inflammatory and metabolic benefits of the Mediterranean or DASH diet in patients with documented deficiency. Clinicians should consider assessing baseline nutritional status, including vitamin D serum levels and dietary omega-3 intake, before initiating supplementation.

It should also be acknowledged that the evidence base reviewed in this paper has several limitations. Many of the included studies were of short duration, involved relatively small sample sizes, and employed heterogeneous definitions of PCOS, dietary interventions, and outcome measures. The lack of standardization across trials makes direct comparisons challenging and limits the strength of conclusions that can be drawn. Moreover, many studies did not adequately control for confounding variables such as physical activity levels, caloric intake, or concomitant pharmacological treatment. Long-term, well-powered randomized controlled trials with standardized dietary protocols are needed to provide stronger evidence and to establish definitive recommendations for dietary management in women with PCOS.

CONCLUSIONS

Dietary modifications across all described dietary patterns demonstrated beneficial effects on key metabolic and hormonal parameters in women with PCOS. Each approach carries distinct advantages: the LGI diet excels in improving insulin sensitivity and lipid profile; the DASH diet is notable for its anti-inflammatory effects and broad metabolic benefits; the Mediterranean diet offers additional cardioprotective and anti-diabetic properties; and the ketogenic diet shows particular promise for rapid hormonal rebalancing and weight reduction in obese patients.

Comparative evidence suggests that the DASH diet may offer the most consistent overall benefit for patients with PCOS [42]. However, the clinical decision to implement any dietary strategy remains individualized and should be determined collaboratively between the patient and a qualified specialist, taking into account personal preferences, comorbidities, and long-term adherence potential.

DISCLOSSURE

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AI

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. **AI** were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

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