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Research Progress on Exercise Intervention in the Management of Polycystic Ovary Syndrome

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Abstract: Polycystic ovary syndrome (PCOS) is a common reproductive endocrine disease in women. Its pathogenesis is complex and varies among individuals. It is characterized by hyperandrogenemia, insulin resistance and ovarian dysfunction, accompanied by psychological problems such as anxiety and depression, which have a profound impact on women's health and are one of the causes of infertility. Exercise intervention can relieve the symptoms related to PCOS by improving insulin sensitivity, body composition and sex hormone levels. This paper aims to review the relevant exercise mechanisms to relieve PCOS and improve the effects of exercise on core symptoms in recent years, so as to provide new ideas for further Exploration.

Keywords: Polycystic ovary syndrome; Insulin resistance; Hyperandrogenemia; Ovarian dysfunction; High-intensity interval training

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1. Research background

Polycystic Ovary Syndrome (PCOS) is a common reproductive endocrine and metabolic disorder affecting women of reproductive age, characterized primarily by hyperandrogenism, menstrual irregularities, and difficulty conceiving, often accompanied by psychological issues such as anxiety and depression, which may be associated with imbalances in neurotransmitter levels [1]. In recent years, influenced by factors including unreasonable dietary patterns, reduced physical activity, environmental pollution, and sleep disturbances, the incidence of PCOS has been increasing annually, with a trend toward younger age of onset. Epidemiological data indicate that approximately 6–20% of women of reproductive age worldwide are affected by PCOS, and its impact extends beyond reproductive health to include metabolic complications such as obesity, type 2 diabetes mellitus, cardiovascular disease, and chronic kidney disease, imposing a substantial burden on healthcare systems [2]. The etiology of PCOS remains incompletely understood, but it is currently believed to be closely associated with insulin resistance, hyperandrogenemia, and chronic inflammation, with

evidence of familial clustering and genetic predisposition [3]. Relevant studies have shown that compared with healthy women, PCOS patients, regardless of obesity status, exhibit more pronounced insulin resistance and sex hormone disturbances, along with metabolic abnormalities and reduced mitochondrial respiratory function in abdominal subcutaneous adipose tissue. Moreover, some PCOS patients with body mass index (BMI) and waist-to-hip ratio within normal reference ranges still have significantly higher body fat percentages than healthy control women [4,5]. For clinical diagnosis, the Rotterdam Criteria are the most widely adopted diagnostic framework internationally, requiring at least two of the following three criteria: (1) hyperandrogenemia or clinical signs of hyperandrogenism (e.g., hirsutism); (2) ovulatory dysfunction (oligomenorrhea/amenorrhea); (3) polycystic ovarian morphology (ultrasound showing ovarian volume ≥ 10 cm^3 or antral follicle count > 20) [6].

In terms of management strategies, the international evidence-based guideline for PCOS (2023) has clearly recommended that patients adopt a healthy lifestyle, including a balanced diet and regular physical activity, to achieve or maintain a healthy body weight and improve metabolic and psychological status [7]. Since pharmacological treatments typically target specific symptoms and may be associated with adverse effects, and no curative intervention is currently available, exercise intervention, as a safe, cost-effective, and highly adherent non-pharmacological approach, has gradually become an important component of long-term PCOS management [8]. Existing studies have shown that exercise exerts comprehensive therapeutic effects through multiple mechanisms, including improving insulin signaling pathways, regulating androgen levels, optimizing the ovarian microenvironment, and alleviating chronic low-grade inflammation [9,10]. Therefore, a systematic review of the mechanisms of action of exercise intervention in PCOS and the effects of different exercise modalities holds significant clinical and research value.

2. Exercise-induced amelioration of core symptoms in PCOS

2.1. Exercise and insulin resistance

Insulin resistance (IR) refers to a reduced sensitivity of peripheral tissues to the biological effects of insulin, leading to compensatory hypersecretion by pancreatic β-cells that nevertheless remains relatively insufficient [11]. The prevalence of IR is high among patients with PCOS. Generally, there are abnormalities observed in the insulin signaling pathway and metabolic dysfunction of insulin target tissues. Then, it leads PCOS patients to develop insulin resistance, which can participate in the pathogenesis of PCOS through various mechanisms, including interference with glucose metabolism and modulation of sex hormone synthesis. In the mechanistic study of insulin resistance in PCOS, a classic hypothesis proposes that abnormally increased serine phosphorylation of insulin receptor substrates (IRS) inhibits their tyrosine phosphorylation, thereby blocking downstream insulin signal transduction and leading to insulin dysfunction [12,13]. However, with advancing research, it is now believed that PCOS-related insulin signaling defects may also lie downstream of IRS (e.g., diminished Akt/mTOR signaling) and are closely associated with multiple factors, such as lipotoxicity, mitochondrial dysfunction, endoplasmic reticulum stress, and TGF-β-mediated tissue fibrosis [14,15]. Moreover, IR and hyperinsulinemia are key core features in PCOS patients and are closely related to the long-term metabolic complications of PCOS. Studies have found that the prevalence of metabolic syndrome and IR is higher in obese adolescents, and IR is positively correlated with body composition indices (body mass index, body fat percentage, waist circumference, and subcutaneous fat) and significantly associated with high-density

lipoprotein cholesterol and metabolic syndrome [16].

In terms of exercise intervention, multiple randomized controlled trials have shown that regular moderate-to-vigorous intensity physical activity can significantly improve insulin sensitivity in patients with PCOS, particularly in those who are overweight or obese. A systematic review indicated that a combined regimen of high-intensity interval training (HIIT) and resistance training yielded the greatest improvement in the HOMA-IR index [14,17]. Furthermore, exercise can enhance the body's insulin response by increasing skeletal muscle glucose uptake capacity and improving capillary blood flow. Of note, some lean PCOS patients do not show significant improvement, which may be related to an insufficient upregulation capacity of key proteins in the skeletal muscle insulin signaling pathway [18]. This suggests that future research should develop individualized exercise prescriptions based on different phenotypes.

2.2. Exercise and hyperandrogenemia

Abnormally elevated androgen levels constitute a major driving factor in the pathogenesis of polycystic ovary syndrome and the development of metabolic syndrome, termed "hyperandrogenemia (HA)". Its clinical manifestations primarily include hirsutism, acne, and male pattern hair loss (androgenetic alopecia) [19,20]. HA in PCOS patients mainly originates from excessive androgen secretion by the ovaries and adrenal cortex, with dysregulation of steroid hormone homeostasis being one of the core etiological factors. Studies have shown that IR and HA may form a vicious cycle: hyperinsulinemia promotes ovarian androgen synthesis, while excess androgens in turn exacerbate insulin resistance [21,22]. Furthermore, PCOS patients often exhibit ovarian theca-interstitial hyperplasia and arrested follicular development, indicating that the reproductive microenvironment is chronically exposed to a state of androgen excess [23,24].

Multiple studies have confirmed that exercise interventions can positively affect androgen parameters in patients with PCOS. Research has shown that high-intensity interval training or resistance training can increase sex hormone-binding globulin (SHBG) levels and reduce free testosterone concentrations; both aerobic exercise and HIIT can lower serum testosterone levels and body fat percentage within 16 weeks, while also improving menstrual cycle regularity [25–27]. Among these, HIIT is superior to resistance training alone in reducing serum testosterone and improving body composition. In summary, exercise not only improves metabolic status but also serves as an important means of modulating the androgen environment, thereby exerting positive effects on reproductive health in women with PCOS.

2.3. Exercise and ovarian dysfunction

Chronic low-grade inflammation is considered a key pathogenic factor in PCOS. In PCOS patients, macrophages and neutrophils constitute the predominant immune cell populations, which can secrete various pro-inflammatory cytokines, including IL-1, IL-6, IL-18, and TNF-α. The concentrations of these inflammatory cytokines are elevated in both serum and follicular fluid of patients, regardless of obesity status [28]. Recent studies suggest that IL-1 plays a particularly prominent role in PCOS-related chronic inflammation, and the local inflammatory environment driven by IL-1 may affect follicular development and ovarian fibrosis [29].

Furthermore, elevated oxidative stress levels also exacerbate ovarian damage. Animal studies have shown that regular exercise can improve ovarian function in PCOS rats, and the exercise-induced myokine Irisin reduces inflammatory responses and oxidative stress by inhibiting the IRE1α-TXNIP/ROS-

NLRP3 pathway, thereby improving follicular function and ovarian fibrosis [30]. Clinical studies have also demonstrated that aerobic exercise can reduce serum levels of IL-6, TNF-α, and C-reactive protein in patients, suggesting that exercise may ameliorate the ovarian microenvironment through anti-inflammatory and antioxidant mechanisms, thereby enhancing ovulatory function and fertility [28].

3. Different exercise types and PCOS

In recent years, an increasing number of studies have focused on the differential effects of various exercise types on the improvement of clinical symptoms in PCOS patients. Exploring different forms of exercise interventions, such as aerobic exercise, resistance training, and high-intensity interval training, has become a hot topic in current research. According to the international PCOS guideline recommendations, to prevent weight gain, at least 150 minutes of moderate-intensity exercise or at least 75 minutes of vigorous-intensity exercise per week is advised; for weight loss and prevention of weight regain, at least 250 minutes of moderate-intensity exercise or at least 150 minutes of vigorous-intensity exercise per week is recommended [7].

Existing studies have shown that different exercise modalities each have advantages for improving insulin resistance, androgen levels, ovarian function, and psychological health, but overall, they can offer multiple benefits to PCOS patients. These will be described by type in the following sections.

3.1. High-intensity interval training

HIIT is a form of high-intensity interval training characterized by alternating cycles of high-intensity and low-intensity exercise. It has been found to effectively increase maximal oxygen consumption (VO_2max) and sex hormone-binding globulin levels in the PCOS patients, improve metabolic and cardiorespiratory fitness, and ameliorate insulin resistance and menstrual cycle regularity [31].

An 8-week RCT showed that HIIT significantly improved aerobic capacity, insulin resistance and sensitivity, blood lipid levels, and inflammatory and cardiovascular parameters in women with PCOS [10]. Another study comparing HIIT with combined training (resistance plus aerobic) found that both reduced BMI and free androgen index, but HIIT was superior in improving VO_2max [32]. Furthermore, a 12-week HIIT intervention demonstrated better effects to reduce serum testosterone levels and body fat compared with resistance training alone [25]. In summary, HIIT offers multiple benefits for PCOS patients, particularly in enhancing cardiorespiratory fitness and improving ovarian function, and has become a research hotspot for improving outcomes in PCOS.

3.2. Aerobic exercise

Aerobic exercise is also a commonly used exercise type for improving outcomes in PCOS patients. Studies have shown that regular aerobic exercise not only improves cardiorespiratory fitness but also exerts positive effects on ovarian hormone levels and oxidative stress-related parameters. In a 12-week aerobic exercise study, PCOS patients demonstrated significant improvements in cardiovascular fitness, anti-Müllerian hormone (AMH) levels, and oxidative stress markers (malondialdehyde, superoxide dismutase, and total antioxidant capacity) [33]. Another randomized controlled trial indicated that both continuous aerobic training and intermittent aerobic training effectively reduced testosterone levels, improved body composition, and enhanced quality of life in PCOS patients [34]. In summary, aerobic exercise plays a stable role in improving

metabolic health, regulating endocrine function, and enhancing quality of life, and is suitable for PCOS patients with poor baseline fitness or difficulty adhering to high-intensity exercise.

3.3. Physical resistance training

PRT is a form of anaerobic exercise that enhances muscle strength and endurance through resistance against an external force. Studies have shown that after four months of resistance training, PCOS patients exhibited significant improvements in muscle strength, along with reduced body fat, increased lean body mass, and amelioration of hyperandrogenism [35]. In another 16-week study comparing aerobic exercise and PRT, both modalities improved anthropometric measures, metabolic dysfunction, and hyperandrogenemia in PCOS patients, with no significant difference in effects between the two [36]. Therefore, PRT can improve body composition, metabolic function, and hyperandrogenemia in PCOS patients, with notable efficacy in enhancing muscle strength, making it particularly suitable for PCOS patients with low muscle mass or concomitant obesity.

3.4. Summary comparison of exercise modalities

Table 1. Comparison of exercise modalities

Exercise Type	Intervention Duration and Frequency	Main Improved Parameters	Advantages	Limitations	Suitable Population
HIIT	8–12 weeks, 3–4 times/week	Insulin sensitivity ↑, VO_2max ↑, Testosterone ↓, Body fat ↓	Time-efficient, improves multiple parameters	High intensity, potential for poor adherence	Young adults, overweight/obese PCOS patients with good cardiorespiratory fitness
Aerobic exercise	12–16 weeks, 3–5 times/week	Cardiorespiratory fitness ↑, Anti-Müllerian hormone (AMH) ↑, Oxidative stress ↓, Testosterone ↓	Easy to promote, high safety profile	High safety profile, slower onset of effects, requires long-term adherence	All PCOS patients, especially those with cardiovascular risk or poor baseline fitness
Resistance training	12–16 weeks, 2–3 times/week	Muscle strength ↑, Body fat ↓, Lean body mass ↑, Androgens ↓	Significant improvement in body composition, strength gain	Limited effect on cardiorespiratory fitness when used alone	PCOS patients with obesity or low muscle mass, those seeking improved body shape and metabolic function

Table 1 is primarily based on findings from recent randomized controlled trials and systematic reviews of HIIT, aerobic exercise, and resistance training [9,23,25,26,30–35]. These findings suggest that exercise intervention has definite efficacy in improving PCOS, although further large-scale studies are still needed for validation.

4. Conclusion

In recent years, research on the application of exercise intervention in the management of polycystic ovary syndrome (PCOS) has continued to deepen, and its efficacy and value have gradually gained widespread recognition. A large body of studies has shown that regular exercise not only effectively improves insulin resistance, reduces androgen levels, optimizes body composition, and restores ovulatory function, but also alleviates chronic inflammation and improves psychological status and quality of life. As a safe, cost-

effective, and highly adherent non-pharmacological treatment, exercise intervention offers significant advantages in promoting metabolic homeostasis, improving reproductive health, and enhancing overall quality of life, thereby providing important support for long-term comprehensive management of PCOS. Notably, HIIT has demonstrated particularly prominent comprehensive efficacy in recent studies.

However, current research on exercise intervention still has certain limitations. Most trials have limited sample sizes and short follow-up periods, lacking systematic evidence on long-term efficacy and safety. Considerable heterogeneity in exercise prescription design across studies results in insufficient comparability and reproducibility of findings. Moreover, studies on individualized interventions tailored to different PCOS phenotypes remain relatively scarce. Future efforts should focus on conducting multicenter, large-sample, long-term follow-up clinical trials, combined with basic mechanistic research, to further elucidate the role of exercise in inflammation regulation, oxidative stress, and gut microbiota homeostasis. Additionally, digital health technologies should be utilized to enhance patient exercise adherence, and integrated management models combining exercise with nutritional management, psychological intervention, and pharmacotherapy should be explored.

In summary, exercise intervention has unique and irreplaceable advantages in PCOS management. With the continuous accumulation of high-quality evidence-based data, its clinical application value in improving metabolic, endocrine, and psychological health will be further enhanced, laying a solid foundation for achieving precise and long-term management of PCOS.

Disclosure statement

The authors declare no conflict of interest.

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