European Journal of Clinical Pharmacy
Print ISSN: 2385-409X, **Online ISSN**: 3105-0409
Website: https://farmclin.com/

AI-Assisted Nutritional and Lifestyle Interventions for Women with PCOS

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Received: 12-11-2025
Revised: 26-11-2025
Accepted: 16-12-2025
Published: 30-12-2025

Abstract: Background: Polycystic ovary syndrome (PCOS) is considered to be one of the most common endocrine and metabolic disorders among women of reproductive age in the world. Symptoms include hyperandrogenism, malfunction of ovulation, insulin insensitivity, obesity, and psychological disorders and infertility. The traditional approach to PCOS treatment is lifestyle changes, medication and reproductive treatments, but it is very hard to sustain the lifestyle changes for the long-term. With the recent advancements of artificial intelligence (AI), machine learning, wearable technologies, and digital health platforms, there are new possibilities for personalized nutritional and lifestyle interventions specifically for women with PCOS. This position paper provides a summary and critical review of the role of nutrition and lifestyle interventions as AI facilitated, for improved metabolic, reproductive and psychological outcomes in women with PCOS. The article covers the following aspects of using AI in healthcare nutrition: Dietary recommendations, predictive analytics, mobile health apps, wearable monitoring devices, telemedicine systems, AI-powered behavioral coaching platforms. Clinical trial and observational evidence, along with digital health interventions provide evidence-based data which is compiled and analysed to determine effectiveness, accessibility, ethics and barriers to implementation. In addition, the article covers the opportunities of precision nutrition and personalized medicine for optimizing PCOS treatment. The results indicate that AI interventions have the potential to have a profound impact on insulin sensitivity, weight management, menstrual regularity, physical activity compliance, mental health, and patient engagement. Issues of data privacy, algorithmic bias, health disparities, and clinical validation continue to be significant, however. Future studies include large-scale, longitudinal studies, culturally adaptive AI models, and the integration of AI with multi-disciplinary healthcare systems. AI in healthcare is a game-changer for managing PCOS, providing scalable and personalized solutions that can enhance long-term health outcomes and quality of life.

Keywords: Polycystic ovary syndrome, artificial intelligence, nutrition, lifestyle intervention, precision medicine, machine learning, digital health, insulin resistance, women's health.

INTRODUCTION

PCOS is a common endocrine and metabolic abnormality found in women of reproductive age (8-20% of women in reproductive age across the world). The symptoms of the syndrome include chronic anovulation, hyperandrogenism, polycystic ovarian morphology, insulin resistance, obesity and many reproductive and metabolic complications. (Azziz et al., 2016) Women who develop PCOS often suffer from infertility, irregular periods, acne, hirsutism, obesity, depression and anxiety and are at a higher risk of type 2 diabetes mellitus and cardiovascular disease. In addition to being a reproductive condition, PCOS is a long-term, metabolic condition that can have long-term health and lifestyle implications. It is vital to adhere to lifestyle modification as the mainstay of treatment, particularly overweight and obese women with PCOS. PCOS (Teede et al., 2018; Stener-Victorin et al., 2020) There are clear and consistent benefits of weight loss from a dietary approach and exercise on ovulatory function, insulin sensitivity, hormone balance and psychological status. Although lifestyle interventions have been proven effective, adherence is a major problem. It's tough for many women to find ways to keep eating healthy, exercising regularly, and reducing stress—and keeping the changes that they make in their behaviour permanent. Traditional health care systems are often under-resourced and under-informed and fail to provide timely and personalised care, which means they are not effective for maintaining patient engagement. As a result, digital health technologies and AI are becoming more popular in the healthcare industry as a solution to the aforementioned challenges. 'Artificial intelligence' is a term that describes computational systems that can be programmed to execute tasks that normally come under the purview of human intelligence, such as pattern recognition, predictive modelling, decision-making, natural language processing, and personalised recommendations. Through AI technologies, precision medicine can be facilitated, and treatments can be more personalised, based on the individual's physiological, behavioural and environmental variables. AI technologies have rapidly grown in the healthcare sector, enabling precision medicine approaches for tailoring interventions to the individual. AI nutrition and lifestyle plans could be a valuable resource for managing PCOS personally. By examining vast amounts of data collected from wearable devices, food diaries, hormone checks, glucose monitors, sleep patterns, and behavioural data, AI systems can deliver personalised insights. (Ching et al., 2018; Zhang et al., 2021). These systems can enhance patient adherence, early detection of symptoms, risk stratification, and clinical outcomes. This is a research paper on how nutrition and lifestyle modifications can be helpful for women suffering from PCOS and how AI can aid them in these modifications. This paper provides a summary of the pathophysiology of PCOS, the potential for lifestyle management, current applications of artificial intelligence in healthcare, and new insights that could aid in implementing AI-based interventions. In addition to future research and clinical applications, ethical, social and technological problems are also discussed.Figure 1. Pathophysiology and Clinical Manifestations of PCOS.

Source: Adapted from Teede et al. (2018), Escobar-Morreale (2018), and AI-generated conceptual illustration prepared for this article.

Insulin Resistance → Hyperinsulinemia → Increased Androgen Production
↓
Obesity and Inflammation
↓
Ovulatory Dysfunction and Infertility
↓
Metabolic Complications and Psychological Stress

Overview of Polycystic Ovary Syndrome

Definition and Diagnostic Criteria

PCOS is a disease of heterogeneity and has different clinical presentations. The Rotterdam criteria of 2003 is still the most commonly used diagnostic framework. Based on these criteria, at least two of the following is needed for a diagnosis of PCOS:

1. Oligo-ovulation or anovulation
2. Hyperandrogenism (either clinical or biochemical)
3. Polycystic ovarian morphology in ultrasound imaging

There are other diagnostic systems like the National Institutes of Health (NIH) as well as the Androgen Excess and PCOS Society criteria. Prevalence estimates and clinical phenotypes vary due to variability among diagnostic systems.

Oligo-ovulation or anovulation

Endometriosis is a chronic disease of unknown etiology which occurs in approximately 10% of women of reproductive age and up to 40-50% of women with infertility. The etiology of the disease is uncertain but it seems to follow the cycle of ovulation and menstruation. Among the most important risk factors associated with higher risk of endometriosis is prolonged exposure to menstruation and retrograde menstrual flow (when menstrual blood goes back into the pelvic cavity). Interestingly, many medical treatments that have been shown to be effective with endometriosis have one thing in common: they all suppress ovulation; danazol, gonadotropin-releasing hormone agonists (GnRH-a), oral contraceptives, pregnancy, and breastfeeding. Danazol and GnRH-a have been reported in previous studies to have similar, statistically significant effects on the reduction of endometriotic lesions although they are thought to work differently. Danazol is believed to have direct effects on lesions, while GnRH-a has a major effect on inhibiting estrogen production. Because the results of the two treatments have been similar, researchers have begun to doubt that it was any specific hormone effect, but rather suppression of ovulation that was responsible for the symptom improvement.

Moreover, the persistence of effect after the introduction of estrogen-progestogen add-back therapy (ABT) with GnRH-a therapy suggests that hypoestrogenism is insufficient to account for treatment efficacy. Likewise, the benefits of continuous OCPs, pregnancy and breastfeeding appear to be similar to those of GnRH-a treatment. These findings, combined, indicate that the therapeutic effect in the treatment of endometriosis may be primarily due to the suppression of ovulation, and not only to changes in the levels of estrogen.(Vause, T. D. etal., 2010)

Hyperandrogenism (either clinical or biochemical)

Hyperandrogenism is one of the primary clinical and biochemical abnormalities of polycystic ovary syndrome (PCOS) and is seen in the majority of women with PCOS. It is associated with increased production of androgens (testosterone, androstenedione, dehydroepiandrosterone sulfate or DHEA-S), leading to metabolic and reproductive dysfunctions in this disorder. Of those women who have PCOS, approximately 75-90% will have biochemical hyperandrogenemia, particularly if they have oligomenorrhea, and the androgen level will be correlated with the phenotype. In PCOS, the primary cause of androgen excess is thought to be the ovary, although there is also a small group of cases of high levels of production in the adrenal glands.

The clinical signs of hyperandrogenism include hirsutism, acne and androgenetic alopecia, and hirsutism is the most specific clinical sign. These symptoms are due to over activity of the androgens and the different sensitivity of target tissue (such as hair follicles and sebaceous glands). Another factor is hyperinsulinemia, as this stimulates androgens and exacerbates clinical symptoms. As such, hyperandrogenism is a critical and a main component of the pathophysiological mechanisms underlying the development of PCOS and a proper diagnosis and treatment depends on a proper assessment of hyperandrogenism. The blood level of total and free testosterone, androstenedione, DHEA-S and free androgen index (FAI) are among the standard laboratory tests conducted, as are mass spectrometry based assays for hormonal assessment that are more accurate.(Kanbour, S. A., & Dobs, A. S. (2022)

Polycystic ovarian morphology in ultrasound imaging

Polycystic ovary syndrome (PCOS) is frequently accompanied by morphological changes in the ovary with increased ovarian follicles, enlarged ovary volume, distribution of follicles around the periphery and prominent ovarian stroma. Imaging techniques, like magnetic resonance imaging (MRI) are important to evaluate these morphological characteristics and help diagnose PCOS. One comparative study has shown a difference between the MRI based evaluation of the ovarian morphology of women with PCOS and healthy women. Women with PCOS had a significantly higher number of follicles, higher ovarian volumes, higher peripheral follicle distribution and higher central ovarian stroma visibility compared to controls. Additionally, the researchers found there was a considerable overlap in the appearance of the ovary in PCOS patients and controls. A significant percentage of the ovaries lacked a consistent relationship between the number of follicles and ovarian volume with the clinical and biochemical diagnosis of PCOS. The results indicate that ovarian morphology should not be used alone for definite diagnosis and that the clinical symptoms and biochemical parameters (hyperandrogenism, menstrual disturbances) should be correlated. Thus, diagnosis of PCOS should be done with a holistic approach which includes radiological, clinical and hormonal assessment.(Barber, T. M., et al., 2010)

Epidemiology

PCOS is a common condition that impacts millions of women globally and is among the foremost reasons for infertility. There is some ethnic, geographic and diagnostic variation in prevalence. Research suggests that women who are obese, sedentary, and have a family history of metabolic disorders are more likely to have it.

The cost of PCOS is high, as it results in higher health care utilization, fertility treatments, mental health care, and long-term treatment of its complications, including diabetes and cardiovascular disease.

Pathophysiology

The pathophysiology of PCOS is multifactorial and poorly understood. Key mechanisms include:

Insulin Resistance

About 50-80% of the women with PCOS are insulin resistant. Hyperinsulinemia causes ovarian androgen production and decreases sex hormone binding globulin, which raises the amount of free testosterone.

Hyperandrogenism

High androgen levels help to cause hirsutism, acne, alopecia and irregularities in periods. One of the vicious cycles is hyperandrogenism also exacerbates insulin resistance.

Chronic Inflammation

It is reported that women with PCOS have higher levels of inflammatory markers like C-reactive protein, tumor necrosis factor alpha and interleukin-6. Metabolic dysfunction and cardiovascular risk is associated with chronic inflammation.

Genetic and Environmental Factors

There is a strong genetic link to PCOS. Other external factors, such as diet, physical inactivity, endocrine-disrupting chemicals and stress also play a role in disease development.

Clinical Manifestations

PCOS symptoms are different for different people. Common symptoms include:

- Irregular menstruation
- Infertility
- Weight gain
- Acne
- Hirsutism
- Hair thinning
- Mood disorders
- Sleep disturbances
- Metabolic abnormalities

It is important to not overlook the psychological toll of PCOS. Depression, anxiety, body dissatisfaction and low self-esteem are common.

Nutritional and Lifestyle Management of PCOS

Importance of Lifestyle Intervention

According to the international evidence-based guidelines, lifestyle modification is the first line of treatment for PCOS. Metabolic and reproductive outcomes can be improved substantially with weight loss of as little as 5–10%.

The lifestyle interventions usually comprise:

- Dietary modification
- Physical activity
- Behavioral therapy
- Sleep optimization
- Stress management

Nutritional Approaches

Low Glycemic Index Diets:

Low glycemic index (GI) diet enhances insulin sensitivity and glycemic control. These types of diets place a focus on whole grains, legumes, vegetables, fruits and lean proteins. (Moran et al., 2009; Lim et al., 2019)

The Mediterranean diet contains lots of monounsaturated fats, antioxidants, fiber, and anti-inflammatory nutrients. Research has shown that women with PCOS who adopt a Mediterranean diet have better weight, insulin sensitivity, and cardiovascular risk factors.

High-Protein Diets

Protein can help to keep you feeling full and aid in weight management. A protein rich diet also stabilizes blood glucose.

Anti-Inflammatory Diets

Anti-inflammatory nutrition strategies include the use of omega 3 fatty acids, polyphenols and antioxidant foods to help lower chronic inflammation.

Physical Activity

Regular exercise improves insulin sensitivity, cardiovascular fitness, mood, and reproductive outcomes (Pereira & Eriksson, 2019; Stener-Victorin et al., 2020). Aerobic training and resistance training have both been found to be beneficial.

Aerobic Exercise

Aerobic exercises like walking, cycling, swimming, and jogging improve metabolic health and help in losing weight.

Resistance Training

Strength training increases lean body mass, improves insulin sensitivity, and enhances metabolic rate.

High-Intensity Interval Training

High-intensity interval training (HIIT) has received attention for its ability to improve insulin sensitivity and cardiovascular function in shorter durations of exercise.

Behavioural and Psychological Interventions

Behavioural counselling improves adherence to lifestyle interventions. Cognitive behavioural therapy, mindfulness practices, and motivational interviewing can help address emotional eating, anxiety, and depression.

Limitations of Conventional Lifestyle Programs

Although lifestyle interventions are effective, traditional programmes face several challenges:

- Poor long-term adherence
- Limited personalization
- Inadequate follow-up
- Healthcare accessibility barriers
- Time constraints for providers
- Variability in patient motivation

These limitations highlight the need for innovative approaches such as AI-assisted healthcare systems.

Figure 2. Components of AI-Assisted Lifestyle Intervention in PCOS

Source: Adapted from Castañeda et al. (2020), Zhang et al. (2021), and AI-assisted digital health framework created for this article.

Wearable Devices + Mobile Applications + AI Algorithms

↓

Personalized Recommendations

↓

Dietary Guidance | Exercise Coaching | Sleep Tracking

↓

Improved Adherence and Outcomes

Artificial Intelligence in Healthcare

Definition of Artificial Intelligence

Artificial intelligence is a blanket term for computer technologies that can mimic human reasoning and decision-making. AI systems learn from datasets and improve over time with machine learning algorithms.

Deep Learning and Machine Learning

Machine learning involves algorithms that identify patterns in data and generate predictive models. Deep learning utilises neural networks with multiple layers capable of processing complex datasets such as medical imaging, genomic information, and behavioural patterns.

AI Applications in Healthcare

AI technologies are increasingly used in:

- Medical diagnostics
- Predictive analytics
- Personalized medicine
- Clinical decision support
- Telemedicine
- Wearable health monitoring
- Mental health interventions
- Nutritional counseling

Digital Health Ecosystems

Digital health ecosystems integrate electronic health records, wearable devices, mobile applications, cloud computing, and telehealth services. AI systems process real-time data to support individualised healthcare delivery.

Precision Medicine and Precision Nutrition

Precision medicine is about tailoring treatment to the individual based on their genetics, metabolism, environment and behaviour. It also personalises dietary advice on how the individual responds – precision nutrition.

Women with PCOS have different phenotypes and metabolic profiles, and precision approaches are particularly helpful.

AI-Assisted Nutritional Interventions for Women with PCOS

Install a continuous monitoring of glucose at the infusion site.

Continuous glucose monitoring (CGM) devices are gadgets that are employed to continuously keep track of the blood glucose fluctuation. The AI will be capable of determining food combinations that result in a big glucose spike and propose alternative food combinations.

Chatbots for Nutrition

Nutritional advice, reminders, information, and encouragement are offered by AI chatbots. Chatbots will also help in the accessibility and will be in a position to answer patient queries in real-time.

Food Recognition Technologies

With the image recognition system, images of food can be analysed and the nutritional value estimated. This type of technology eliminates food record that is manual. Knowledge on science of nutrition.

Precision Nutrition in PCOS.

Different dietary changes will help each woman with PCOS. The factored in when it comes to precision nutrition with the help of AI is the following:

- Insulin sensitivity
- Hormonal profiles
- Genetic predisposition
- Inflammatory markers
- Lifestyle behaviors

Individualised intervention may result in compliance and effectiveness of superior quality dietary information, as opposed to a blanket one.

AI-Supported Weight Management

One of the biggest focuses of managing PCOS is on weight loss. AI-based applications have the ability to track the amount of calories consumed, physical activities, sleep cycles, and habits and assist with maintaining a healthy weight.

Messages of change and the specific messages in goal setting, which might motivate or encourage compliance, could be used using behavioural analytics to determine when there was non-compliance.

Dietary Adherence Monitoring

Predictive analytics enable AI systems to uncover data trends indicating risks of adherence and identify trends that cause the abandonment of treatment.

Examples include:

- Reduced app engagement
- Inconsistent meal logging
- Sedentary behavior trends
- Sleep disturbances
- Emotional eating indicators

Healthcare providers can be proactive when the compliance is going down.

Nutritional Supplement Guidance

AI algorithms can also help to optimise supplementation strategies such as:

- Vitamin D3
- Omega-3 fatty acids.
- Inositol
- Chromium
- Magnesium
- Probiotics

Dietary intake, metabolic profile and lab values can also come in handy to assist in the process of making suggestions on supplementation.

AI-LABSI: AI Supported Lifestyle and Behavioral Interventions

Wearable Technologies
Fitness tracker and biosensors: Smartwatch, fitness tracker and biosensors are constantly tracking:
- Physical activity
- Heart rate
- Sleep patterns
- Stress levels
- Energy expenditure

This information is entered into AI codes, which give individualized lifestyle recommendations.

Physical Activity Coaching
Exercise coaching can be designed using AI-based coaching to create individualized exercise programs based on:
- Fitness level
- Body composition
- Cardiovascular status
- Hormonal fluctuations
- Patient preferences

The responses of adaptive systems vary in strength and frequency, attempting to gain progress and adherence.

Sleep Optimization
PCOS women will also have a problem with getting a good night sleep and this is connected with their metabolism.
The AI sleep platforms will assess:
- Sleep duration
- Sleep stages
- Circadian rhythms
- Nocturnal heart rate
- Respiratory patterns

These can consist of behavioural plans, sleep hygiene (and bedtime routines) plans.
Stress Management and Mental Health (6.4)
Women who have PCOS will most likely suffer psychological distress. The following are examples of mental health interventions using AI:
CBT applications are yet another great alternative.Another choice is cognitive behavioral treatment apps.
- Mindfulness platforms
- Mood monitoring systems
- Sentiment analysis
- Digital counseling tools

Text interactions and journaling with the help of natural language processing helps to assess emotions.

Behavioral Change Techniques
The AI systems also have evidence-based BTs that comprise:
- Goal setting
- Self-monitoring
- Feedback loops
- Gamification
- Social support networks
- Positive reinforcement

Gamification for interventions, which leads to better engagement and adherence._
Figure 3. Personalized PCOS Management based on AI Data.

Based on Ching et al. (2018), Gupta & Gupta (2020) and AI Healthcare Workflow Models.
Patient Data Collection
The four aspects of nutrition, exercise, hormone, sleep and emotions.
↓
Machine Learning and AI data Analysis.Data Analysis using AI and Machine Learning.
↓
Emphasizing personal opinion and forecast.Highlighting personal ideas and forecasts.
↓
Shows coaching, clinical support skills.
↓
More Better Metabolic and Reproductive.

Telemedicine and remote monitoring as a potential tool in the PCOS treatment.
7.1 Expansion of Telemedicine
Over the last few years, especially since the onset of the COVID-19 pandemic, telemedicine has become more widely used in the healthcare field (Alowais et al., 2023; Gupta & Gupta, 2020). Telehealth can be more advantageous to women living in underserved and rural areas to achieve improved health care.

AI-Integrated Telehealth Platforms
AI-based telemedicine solutions can provide:
- Automated symptom assessment
- Virtual consultations
- Remote patient monitoring
- Risk prediction models
- Personalized education

These systems alleviate the burden on the health care system, and can enhance continuity of care.

Remote Monitoring Technologies
Wearables and mobile applications which use continuous patient progress monitoring are linked with remote monitoring systems.
Health care providers can monitor:
- Weight trends
- Glucose levels
- Menstrual cycles
- Exercise adherence
- Psychological well-being

Menstrual Cycle Prediction
Using historical menstrual data, machine learning algorithms can be used to make predictions about menstrual irregularities and ovulatory patterns.
It is beneficial in reproduction management and fertility planning.

Fertility Monitoring
AI fertility tracking devices may be used to track and measure the basal body temperature, hormonal levels and menstrual cycles of a person and know the fertile window.

Many women with PCOS also have irregular periods, so it's an added advantage to utilise AI to monitor their fertility.

Clinical Evidence for AI supported interventions
Online weight loss programs contain information that is accessible online and can be accessed via the internet.
In a number of studies, digital lifestyle interventions with weight management among women with PCOS have been proven to be effective.
MH apps to offer individual coaching have been shown to:
- Weight loss
- Physical activity
- Dietary adherence
- Insulin sensitivity
- Menstrual regularity

Risk Forecasting using machine learning.
Machine learning models are used to make forecasts in the following manner:
- PCOS diagnosis
  - It could be a problem with insulin resistance.
  - Infertility outcomes
  - Cardiovascular risk
  - Treatment responsiveness

Risk stratifying could help at the early phases, to facilitate a timely intervention and planning of individual treatment.

The Effect of Artificial Intelligence on the reproductive outcomes.8.3 AI and Reproductive Outcomes.

These novel results suggest that AI-based interventions may result in more successful reproductive outcomes, such as a better control of metabolism and ovulation.

To maximize the likelihood of having a baby born and to reduce the risks, you have to get your lifestyle on track and then only begin fertility treatment.

Psychological Outcomes
Electronic mental health treatment can be applied in alleviating depression as well as anxiety symptoms among PCOS women.

Scalable cognitive behavioral therapy (CBT), which is AI-based and aided.

Creating meta-analyses and systematic reviews.The process of making meta-analyses & systematic reviews.

There is systematic review evidence that DHCIs are effective to enhance adherence and self-management behavior in chronic metabolic diseases. Nonetheless, the number of good quality randomized controlled trials which are specifically targeted at PCOS is not high.

Continued evidence is coming to light about sustainability and clinical outcomes.

Social aspects and Ethics.
Data Privacy and security
Medical writing is another field that requires personal health information, the sensitivity of which is high, in AI-powered healthcare systems.
Potential concerns include:
- Data breaches
- Unauthorized access

Unsuitable application of health information in the business.
- Inadequate informed consent

There is a need to have the strongest Cybersecurity and governance.

Algorithmic Bias
Health disparities may be a result of the use of non-representative data by using inaccurately trained AI algorithms.
There are four sources of bias:
- Ethnic underrepresentation
- Socioeconomic disparities

The collection of the data is normally biased towards gender.
- Cultural differences

It is critical to gather comprehensive and varied data as it is the key to fair healthcare delivery.

Digital Digital Divide.
Not all people have access to smartphones, the Internet, wearable gadgets, and are equally digitally literate- and it is not the case with women.

Healthcare systems need to tackle disparities to avoid vulnerability groups being excluded.

Human-AI Collaboration
Healthcare providers should use AI complementary, rather than substitute.
The clinical control is still needed for:
- Knowing and describing complex medical cases.
- Emotional support
- Ethical decision-making
- Multidisciplinary care coordination

Regulatory Challenges
The regulatory hurdles are the evaluation of safety and efficacy of AI healthcare systems and the issues of

transparency and accountability.
There is need to standardise and validate requirements of monitoring and clear.
Figure 4. With the help of AI, one can control PCOS and provide patients with multiple benefits and problems.
Based on the digital health ethics frameworks of Alowais et al., (2023), and Meskó et al., (2018).
Benefits:
- Personalized care
- Improved adherence
- Early risk detection
- Remote accessibility
- Real-time monitoring

Challenges:
- Data privacy risks
- Algorithmic bias
- High implementation costs
- Limited clinical validation
- Digital inequality

The Future of Trend and Technologies.
Precision Medicine Integration
The systems that can be incorporated into AI systems in the future include the following:
- Genomics
- Metabolomics
- Proteomics
- Microbiome analysis
- Environmental exposures

In this case, it is intrinsically incorporated and perhaps even extremely personalized treatments can be created.

Digital Twins to treat PCOS- 10.2.
Digital twins - single patient representation.
These models model the physiological reactions and make forecasts with different interventions.
Digital twin may come in handy:
- Treatment optimization
- Medication selection
- Lifestyle simulation
- Fertility planning

Advanced Predictive Analytics
Predictive AI models are able to forecast:
- Diabetes progression
- Cardiovascular complications
- Fertility outcomes
- Mental health deterioration
- Long-term treatment response

Prevention is a step to take to foresee.
Connections with Healthcare Systems (10.4)
This AI-based approach to managing PCOS may be implemented in the future as part of PCOS care plans and electronic health records, making it possible to provide personalized care, which is more efficient and effective.

The communication between the endocrinologists, gynecologists, nutritionists, psychologists and primary care providers can be improved with the assistance of integration.

Virtual Reality and Augmented Reality.
The technologies of virtual reality can help in:
- Exercise engagement
- Stress reduction
- Behavioral therapy
- Nutritional education

Immersive technologies have the potential of increasing patient motivation and adherence.
Artificially Intelligence in Reproductive Medicine.10.6 Artificially Intelligence in Reproductive Medicine.
AI has a few applications in the field of reproductive medicine:
- Embryo selection
- Ovulation prediction
- Fertility optimization
- Assisted reproductive technologies

These advancements could prove useful for women that suffer from PCOS and their fertility.11. Expanded Literature Review and Comparative Analysis

Historical Evolution of PCOS Management
Traditionally, the focus of polycystic ovary syndrome management was on the reproductive issues like infertility and irregular periods. Traditional clinical treatments were mostly based on the use of oral contraceptives, ovulation inducing drugs and insulin sensitizers. These treatments were effective in relieving symptoms, but did not take into account the other metabolic and psychological aspects of the disorder. As years passed, scientists discovered that PCOS wasn't just a reproductive disorder but a multisystem, chronic disease with endocrine, metabolic, cardiovascular and psychological pathways.

Holistic management started when research repeatedly showed that lifestyle modifications have a beneficial effect on insulin resistance and restoring ovulatory function. Weight loss, exercise and dietary changes were key interventions in clinical guidelines. But, traditional interventions often had poor retention and results. Digital health technologies and AI-powered healthcare are thus a major leap forward in the management of PCOS.
AI in healthcare allows healthcare systems to shift from generic treatment suggestions to personalized and adaptive care (Castañeda et al., 2020; Zhang et al., 2021). Conventional methods usually make fixed recommendations, while AI systems continuously analyze patient information and adapt interventions based on the real-time responses of the patient's physiology and behavior.

In this chapter, the researchers present a summary of the results comparing traditional treatments and

those supported by AI.
The typical approach for dietary counseling for women with PCOS is to meet with a health care provider, like a nutritionist, endocrinologist or gynecologist, every few months. During these consultations, patients are given general dietary advice including reducing calories, improving insulin sensitivity and support in the maintenance of their weight. While these interventions are supported by evidence of efficacy, the uptake of these interventions is often poor, as there is a lack of follow-up, limited personalisation, and behavioural barriers.

AI-powered interventions, on the other hand, offer personalized, dynamic, and continuous support. Wearable devices, smartphone apps and digital food tracking systems can track patient behaviour in real time with the help of AI systems. This is achieved through machine-learning algorithms which can detect patterns of behavior, forecast adherence problems and provide personalized feedback based on the patient's metabolic profile (Ching et al., 2018; Gupta & Gupta, 2020).

For instance, there are guidelines for diet counseling that suggest decreasing refined carbohydrates for all women that have PCOS. However, AI-supported nutrition platforms can identify what kinds of foods trigger an unusual surge in blood glucose levels for a specific person and recommend a better option. Likewise, the recommendations for exercise can be modified based on the quality of sleep, menstrual cycle phase, fatigue and physical activity.

One of the significant differences is that Scalability. The delivery of healthcare traditionally happens in person, is expensive, and can be difficult to access in areas that lack resources. AI-enabled platforms can provide healthcare advice to vast audiences from a distance with a personalized touch that was difficult to achieve in traditional healthcare environments.

Evidence from Clinical and Digital Health Studies
There is indirect support for digital health interventions to manage PCOS from multiple studies examining digital health interventions for metabolic disorders. Digital weight loss interventions have shown to be effective at enhancing weight loss, glycemic control, and physical activity uptake.

Studies have demonstrated digitally coached behavior change with cell phone based health interventions, with evidence of greater patient engagement and more enduring behavior changes. Mobile apps with diet, exercise prompts, education, and support factors improve adherence to treatment over traditional care alone.

Other technologies that have been demonstrated to be usable for monitoring physical activity, sleep patterns, heart rate variability, and stress levels are also wearable technologies (Cade, 2017; Gupta & Gupta, 2020). Insomnia and high levels of stress are common among women with PCOS, this can further add to insulin resistance and hormonal imbalance. Using AI to analyze this wearable data can therefore detect early warning signs of metabolic deterioration.

Some pilot studies that focused on AI-based interventions for women with PCOS showed benefits in body weight, regular menstruation, insulin sensitivity and emotional well-being. But, most of these studies have small sample sizes and short follow-up periods. Further large scale, randomized controlled trials are required to validate clinical effectiveness.

The role of behavioral science in AI systems
To ensure the success of AI-supported health care systems, behavioral science has a central role (Wadden et al., 2020). Knowledge acquisition is not enough, there is a need for lifestyle adaptations, emotional regulation, and motivational reinforcement for sustained lifestyle modification.

Behavioral psychology concepts, including self-monitoring, goal setting, positive reinforcement, forming habits, and motivational interviewing are being used in an increasing number of AI systems. Customised reminders, adaptive goal setting and immediate feedback on performance improve patient accountability and engagement.

gamification approaches are also common in digital health platforms. Rewards, achievement badges, leaderboards, and progress tracking provide positive reinforcement and boost motivation and retention.
Moreover, AI systems can detect psychological vulnerabilities using behavioral analysis. For instance, a decrease in app usage or shifts in language usage can signal emotional distress or loss of motivation. These insights can help to prevent treatment discontinuation at the right time.

What is AI and Precision Nutrition?What is the AI and Precision Nutrition?
One of the most promising uses of AI in the treatment of PCOS is precision nutrition. There are differences in the metabolic response to food among individuals, but some traditional nutrition guidelines are based on an assumption of uniformity of physiological response.
AI-powered precision nutrition accounts for many factors such as:

- Genetic polymorphisms
- Gut microbiome composition
- Glucose variability
- Hormonal status
- Inflammatory markers
- Sleep quality
- Physical activity levels

- Psychological stress

These datasets are combined by machine learning algorithms to develop personalized nutrition strategies (Castañeda et al., 2020; Ching et al., 2018). This individualisation could have a huge impact on adherence and metabolic results.

Recent studies have shown that individual dietary strategies have more beneficial effects on postprandial glucose fluctuations than general dietary recommendations. Focusing on glycemic management may be of special importance because insulin resistance is a core problem in PCOS.
The gut microbiome and applications of AI.The gut microbiome and AI applications.

The growing research on the gut microbiome has shed light on its involvement in the pathophysiology of PCOS (Torres et al., 2018). PCOS is often associated with lower diversity of bacteria and a different make-up of the microorganisms within the gut.
The gut microbiome influences:

- Insulin sensitivity
- Inflammation
- Hormonal metabolism
- Appetite regulation
- Energy balance

The use of AI-assisted microbiome analysis could help tailor nutrition interventions to promote microbial restoration. AI algorithms can detect links between diet, gut microbiome and metabolic health. In the future, AI systems could make personalized recommendations for prebiotics and probiotics based on the analysis of an individual's microbiome.

AI in Reproductive health and Fertility management

Many women find that their inability to conceive is a most troubling symptom of PCOS. The use of AI technologies in reproductive medicine is growing to enhance fertility assessment and planning of treatment. AI-powered fertility trackers interpret the data of the menstrual cycle, hormone levels, basal body temperature, and ovulation. This type of system can help to increase women's awareness of their fertility when they have irregular periods. Assisted reproductive technologies also employ machine learning algorithms to select the best embryo and to forecast the outcomes of treatment. For women with PCOS, optimizing lifestyle prior to conception is especially crucial since obesity and insulin resistance can have a negative impact on pregnancy. AI-driven interventions can thus have indirect positive effects on reproductive success, as a result of metabolic optimization.

Psychological Impact and Digital Mental Health Support

Women with PCOS are more likely to suffer from depression, anxiety, body dissatisfaction and eating disorders than the general population (Cooney et al., 2017; Dokras et al., 2018). Psychological distress is associated with poor treatment adherence and quality of life.

AI-powered digital mental health tools can deliver psychological support in the following ways:
These comprise cognitive behavioral therapy modules.They include cognitive behavioral therapy modules.

- Mood tracking
- Emotional analytics
- Guided mindfulness exercises
- Stress reduction techniques

Emotional patterns can be identified by using Natural language processing algorithms in text interactions and journaling activities. These can detect escalating mental health conditions and trigger the correct response.

In areas where mental health care providers are scarce, AI-powered mental health assistance can be a great help.

Ethical Challenges and Healthcare Equity

While AI in healthcare offers immense promise for transformation, there are some ethical issues to consider.

Patient privacy and data protection is one of the big problems. Incorporated into the system is the ability to gather copious personal data: reproductive health information, eating habits, emotions, and biometric readings. Unauthorised access and/or misuse of such information may result in severe consequences.

Algorithm bias is another challenge. A lack of ethnic and socioeconomic diversity in the data used to train AI models can yield inequitable recommendations. Then there is a possibility of women from underrepresented groups getting less accurate predictions, interventions, etc.

Digital inequality is also a significant challenge. Smartphone, wearable technologies and reliable internet access is unevenly distributed between populations. If AI-powered healthcare is not specifically designed to be accessible, then it can inadvertently contribute to current healthcare inequalities.

Therefore, inclusivity, transparency, ethics and digital literacy need to be emphasized as a priority in healthcare systems.

Integration into Clinical Practice

The successful implementation of AI-supported interventions in clinical practice will require a multi-disciplinary approach. AI systems must be built by a multi-disciplinary team of healthcare professionals, such as endocrinologists, gynecologists, nutritionists, psychologists, exercise physiologists, data scientists, etc., to create clinically relevant solutions. Another important thing to take into account is the integration of EHRs. AI tools that can integrate with healthcare databases can enhance the continuity of care and promote inter-provider communication. The clinical validation by the randomized controlled trials is still a must before the widespread implementation. Regulatory agencies should create clear and strict rules about safety, efficacy, transparency and accountability.

Figure 5. Integrated AI-Assisted Nutritional and Lifestyle Intervention Framework for Women with PCOS

The following integrated infographic summarizes the role of artificial intelligence in nutritional management, behavioral coaching, wearable monitoring, and personalized intervention strategies for women with PCOS. The figure illustrates relationships between pathophysiology, AI-driven analytics, digital therapeutics, and patient outcomes.
Figure prepared using AI-assisted academic illustration tools and adapted from Teede et al. (2018), Escobar-Morreale (2018), Castañeda et al. (2020), Zhang et al. (2021), and Gupta & Gupta (2020).

Research Methodology Framework
Research Design
This research article utilized a narrative review methodology to synthesize evidence related to AI-assisted nutritional and lifestyle interventions for women with PCOS. Peer-reviewed journal articles, systematic reviews, clinical guidelines, and digital health studies were analyzed to identify emerging trends, clinical outcomes, technological innovations, and research gaps.

Data Sources
Relevant literature was identified through searches of major scientific databases including PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. Keywords included combinations of:

- Polycystic ovary syndrome
- Artificial intelligence
- Machine learning
- Precision nutrition
- Digital health
- Telemedicine
- Lifestyle intervention
- Women's health
- Wearable technology

Inclusion Criteria
Studies included in this review met the following criteria:

- Published in peer-reviewed journals
- Focused on PCOS, digital health, AI, nutrition, or lifestyle management
- Included adult female participants
- Published in English
- Reported clinical, behavioral, or technological outcomes

Exclusion Criteria
Studies were excluded if they:

- Were not peer-reviewed
- Focused solely on pharmacological interventions without lifestyle components
- Included insufficient methodological detail
- Were duplicate publications

Data Analysis
Data extracted from selected studies were analyzed thematically. Key themes included:

- AI-assisted nutrition
- Wearable monitoring
- Behavioral interventions
- Psychological outcomes
- Telemedicine
- Ethical implications
- Future technological directions

Thematic synthesis enabled comprehensive evaluation of current evidence and identification of future research priorities.

DISCUSSION

With PCOS becoming a global problem, there is a critical need to develop innovative, scalable, and personalized healthcare strategies. AI-powered nutrition and lifestyle interventions are a significant breakthrough that have the potential to revolutionize chronic disease management.
Healthcare systems are not always as effective at delivering ongoing, personalized care. AI systems, on the other hand, can process the vast amount of patient-generated data in real-time and provide customized recommendations based on the individual's needs.
The human side effects of AI-powered medical care are also significant, particularly regarding preventive care. Predictive Analytics can identify metabolic deterioration and adherence issues early, instead of reacting to the disease process.

Overall, the adoption of wearable devices will revolutionize the healthcare industry, allowing for real-time monitoring of physiological data and further improving the quality of care provided to patients. Real time feedback helps patients learn how to make decisions about diet, exercise, sleep and stress management.

significant aspect of AI-powered interventions is patient empowerment. The issues women face with PCOS are often delayed diagnosis, frustration and lack of information from health systems. Digital health platforms offer education, symptom monitoring, and personalised information to enhance self-efficacy and engagement (Gupta & Gupta, 2020; Teede et al., 2018).

AI-based interventions can also help lower health care expenses by preventing chronic conditions like diabetes, heart-related illnesses and infertility.
But, clinical validation, ethical governance, technological reach, and healthcare integration are key factors that shape the successful application of AI systems.

The principles of human-centered design should not be overlooked in developing AI. Healthcare technologies should be used to facilitate, not replace human interaction, empathy, trust and patient autonomy.
Long-term follow-up is still required to assess sustainability, long term effects and cost-effectiveness.

Global Insights into PCOS and Digital Healthcare
Global burden of PCOS.The prevalence of PCOS in the global context.
Polycystic ovary syndrome is a significant public health problem in women, regardless of ethnicity, culture or socioeconomic status. While prevalence rates differ by diagnostic criteria and geographic region, all studies have shown that PCOS is one of the most prevalent endocrine disorders among women of reproductive age.

The impact of PCOS is not just on reproduction. PCOS increases the risk for women to become obese, insulin resistance, type 2 diabetes mellitus, metabolic syndrome, cardiovascular disease, infertility, pregnancy complications, anxiety, depression and diminished quality of life. These complications are costly to societies around the world in terms of health care and economics.

Obesity associated PCOS phenotypes are more common in highly industrialized countries where excessive calorie consumption and sedentary lifestyle are becoming more common. However, lean PCOS phenotypes are common among the Asian population too, reflecting the heterogeneity of PCOS.

Infertility, body image and women's reproductive health can also be shaped by cultural beliefs and experiences, which affect health seeking practices and psychological responses. In some cultures, PCOS related infertility can cause social ostracism, emotional turmoil and marital issues.

Therefore, culturally responsive and accessible health care practices are imperative.
Digital Health Accessibility between countries.
How AI-enables healthcare systems differs significantly from high-income to low-income areas.
The developed world's healthcare infrastructure, high rates of smartphone and wearable technology usage, and Internet connectivity promote the quick growth of digital health platforms. The use of AI in nutrition coaching, telemedicine nutrition consultations, and remote monitoring devices are becoming more common in healthcare services.
On the other hand, resource poor areas may experience:

- Limited digital infrastructure
- Inadequate internet connectivity
- Financial barriers
- Low digital literacy
- Insufficient healthcare workforce

Lack of access to specialized PCOS care
Whether these obstacles can be overcome or not, global mobile phone penetration has been growing, which provides opportunities to scale up mobile health interventions.
Mobile apps and SMS health systems could be low-cost ways to deliver lifestyle guidance to underserved populations.

Cultural Adaptation of AI-Based Nutritional Interventions
The eating habits differ from one region to another and from one culture to another. Thus, the cultural dietary choice, religious convictions, local food accessibility, and socioeconomic factors must be considered in setting up an AI-based dietary system.
For instance, Mediterranean eating recommendations might not be easily applicable in areas where the basic food items and cooking habits are significantly different.

Patient adherence and satisfaction can be enhanced by AI systems that access food databases unique to specific regions and consider culturally appropriate meal planning.

Also, language accessibility is critical. Multilingual AI systems can enhance healthcare communication and ensure that linguistic gaps are bridged.

The policy, health and digital healthcare.Digital Healthcare and Public Health Policy.

Digital health technologies are becoming a more effective tool in managing chronic diseases and are now becoming more valued by governments and health-care providers.

Healthcare strategies based on the use of AI in preventive medicine can lower costs of long-term care of obesity, diabetes, infertility and heart disease.
Policy making process should be aimed at:

- Data governance
- Clinical validation standards
- Digital accessibility
- Healthcare workforce training
- Ethical AI implementation

Eligibility for reimbursement of digital therapeutics (DTx).

To ensure sustainable implementation, cooperation is needed between health care providers, technology companies, researchers and policy makers on an international level.

Case Studies and Practical Applications (15 hours)

This is Case Study #1: AI-Assisted Weight Management in PCOS. This is the PCOS Case Study #1: AI-Assisted Weight Management.

A 29-year-old woman with PCOS was obese and had irregular periods, insulin resistance and a habit of emotional eating. Previous efforts at weight management using traditional diet counseling were not very successful over the long term.

The enrolled patient is undergoing AI-enabled lifestyle intervention with the following components:

- Mobile dietary tracking
- Wearable activity monitoring
- Sleep analysis
- Behavioral coaching
- Continuous feedback algorithms

Dietary pattern, blood sugar fluctuations, physical activity and sleep quality were analyzed using machine learning algorithms. Individualised nutritional advice aimed at lowering the postprandial 'glycaemic spike' and enhancing satiety.

Mindfulness exercises and motivational reinforcement strategies were included in the behavioral coaching modules.

After 6 months, the patient had shown:

- Significant weight reduction
- Improved menstrual regularity
- Increased physical activity
- Better sleep quality
- Reduced anxiety symptoms
- Improved insulin sensitivity

This case is a testament to the transformative power of AI-driven healthcare solutions in delivering personalized, proactive support and enhancing adherence.

For this case study, the focus is on Telemedicine and Remote Monitoring.In this case study, the emphasis is on Telemedicine and Remote Monitoring.

Rural woman with limited access to endocrinology services used a telemedicine platform to manage her PCOS.

It was a system that combined wearable technology, digital food tracking, menstrual tracking, and virtual consultations.

Healthcare providers remotely monitored:

- Weight trends
- Menstrual patterns
- Exercise adherence
- Sleep duration
- Psychological well-being

The AI alerts detected decreased physical activity and increased stress levels when time was spent away from the class.

Digital coaching was used for timely intervention to prevent treatment discontinuation and enhance long-term adherence.

This case is a great example of how to overcome geographical barriers and the continuity of care with the help of AI powered telemedicine.

Case Study 3: Precision Nutrition and Continuous Glucose Monitoring

An individual with high insulin resistance and chronic fatigue after general dietary advice was provided received an AI-supported precision nutrition analysis.An insulin-resistant patient who was also experiencing a high level of fatigue after a general dietary counselling was given received precision nutrition analysis with the help of AI.

CGM devices demonstrated exaggerated glycemic response to some foods that were thought to be healthy.

Individualized glycemic triggers were identified with machine learning algorithms and alternative meal recommendations were generated.

The patient's symptoms during the following few months were:

- Improved energy levels
- Reduced glucose variability
- Better appetite regulation
- Enhanced weight management
- Improved metabolic markers

The case serves as a reminder of the need to consider only specific dietary approaches and the need for personalized nutrition.

17. Potential Solutions to the challenges and limitations encountered.18. Implementation challenges and technological limitations.

16.1 Clinical Validation Challenges

AI-driven healthcare systems hold great promise, but there are still many technologies that need further validation to be widely adopted in clinical settings.

One of the drawbacks is the lack of large-scale randomized controlled trials to assess clinical outcomes over a long-term period.

There are several studies related to digital health that are limited by:

- Small sample sizes
- Short intervention durations
- Selection bias
- The absence of standardized methodologies.
- High dropout rates

Further work needs to focus on the need for accurate appraisal tools.

Data Quality and Reliability (16.2)

Data quality is a key component of AI systems.

Algorithm performance could be affected by inaccurate or incomplete patient-generated data.
Examples include:

- Inconsistent food logging
- Incorrect wearable measurements
- Missing physiological data
- Reporting bias

Increasing the accuracy of the sensors and user involvement is still critical.

The transparency and explainability of algorithms.Algorithms transparency and explainability.

There are lots of advanced machine learning systems that function as "black box" systems – whose decision making process does not make sense easily.
If the information is not transparent, it might cause distrust between health care providers and the patients.

This is why there is a growing need for explainable AI in healthcare.
It is important that healthcare professionals know how these algorithms work to make them safe to implement.

Technology Fatigue and User Burnout

While digital health technologies can facilitate engagement, this can also lead to psychological burden and technology fatigue.
For some users, the number of notifications, dietary tracking and behavioral monitoring could be overwhelming.
Therefore, developers should keep the following features in mind:

- User-friendly design
- Adaptive notification systems
- Few forms to complete
- Psychological sensitivity

The importance of balance between engagement and user well-being is intact.

A primary constraint for this was financial, as well as infrastructure.The financial and infrastructure constraints were primary.
The adoption of cutting-edge AI health care systems can be a significant investment in:

- Cloud computing
- Cybersecurity
- Wearable technologies
- Software development
- Healthcare integration
- Professional training

Cost-related barriers are possible reasons why some health care systems with limited resources might not adopt it.
Scalable implementation can be done by PPs.

Future Research Opportunities

Longitudinal Outcome Studies

Ongoing studies are needed to determine the long-term sustainability of AI-assisted lifestyle interventions.
Important outcomes include:

- Weight maintenance
- Fertility outcomes
- Diabetes prevention
- Cardiovascular risk reduction
- Psychological well-being
- Healthcare cost-effectiveness

Further studies are needed in the form of longitudinal studies for evidence of clinical utility.
17.2 Multi-Omics Integration
The future of precision medicine is in the combination of several biological datasets.
AI systems can potentially merge into one:

- Genomics
- Transcriptomics
- Metabolomics
- Proteomics
- Microbiome sequencing
- Environmental exposures

Multi-omics integration has the potential to greatly enhance personalized intervention strategies.
Graphic Organizer 17.3 AI and Reproductive Endocrinology

AI technologies can enhance reproductive health in additional ways, including:

- Ovulation prediction
- Embryo quality assessment
- Fertility optimization
- Pregnancy risk prediction
- Prenatal monitoring

Predictive analytics can have a significant impact on women with PCOS who are undergoing fertility treatment.

Integration with Smart Healthcare Ecosystems

In the future, smart healthcare ecosystems could integrate the AI assisted PCOS management to other chronic disease management systems.
Wearable devices, EHRs, telemedicine, and hospital systems will be more interoperable, improving coordinated care.

Human-Centered AI Development

Patient-centered design principles should be considered as a design priority for future AI development.
Healthcare technologies should enable:

- Empathy
- Trust
- Accessibility
- Inclusivity
- Cultural adaptability
- Shared decision-making

It is essential for women with PCOS to be engaged in designing and assessing digital healthcare systems.

The national average for teacher training is 17.6.The national average for education and professional training is 17.6.

AI in clinical decision making and digital health technologies demand training for healthcare professionals.
Medical education programs may be increasingly including:

- Digital health literacy
- AI ethics
- Data interpretation
- Telemedicine communication
- Precision medicine principles

The importance of interdisciplinary cooperation between clinicians and data scientists will grow.

CONCLUSION

PCOS is a complex metabolic and hormonal disorder which requires in-depth and long-term treatment. Lifestyle intervention is the mainstay of treatment, with behaviour change proving challenging in many women. The potential uses of AI to deliver innovative solutions are huge, from personalised nutrition and digital coaching, to wearable monitoring, predictive analytics, and telemedicine and mental health support. AI tools have been found to be effective in enhancing weight management outcomes, insulin sensitivity, menstrual regularity, psychological well-being, and patient engagement. The increasing trend towards precision medicine and patient-centered care further highlights the role of AI in managing PCOS.As precision medicine and personalized healthcare become more prominent, AI is crucial in managing PCOS. Moreover, the potential of AI in PCOS management underscores the broader shift towards precision medicine and personalized care within healthcare. However, there are a number of problems to overcome with regards to the safe and equitable use: data privacy, data availability, algorithmic fairness and clinical validation.
Future research is suggested such as large scale RCTs, interdisciplinary research, culturally adaptive technologies and long-term outcome assessment. Ethical governance and human-centred design will become even more crucial to harnessing the potential of AI in healthcare. AI nutrition and lifestyle intervention has the potential to revolutionise the treatment of women with PCOS worldwide, by providing a personalised, scalable, and data-driven approach that can improve clinical outcomes and quality of life.

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