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Artificial intelligence in predicting PCOD risk and designing preventive nutrition therapies: A review

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Abstract
Polycystic Ovary Disease/Polycystic Ovary Syndrome (PCOD/PCOS) is one of the most common endocrine and metabolic disorders affecting women of reproductive age, characterized by hormonal imbalance, insulin resistance, menstrual irregularities, and increased risk of long-term metabolic and psychological complications. Early identification and personalized preventive strategies are crucial for effective management of PCOD. In recent years, Artificial Intelligence (AI) has emerged as a powerful tool for predicting disease risk, analyzing complex biomedical data, and supporting precision nutrition approaches. This review explores the application of AI and machine learning techniques in predicting PCOD risk and designing personalized preventive nutrition therapies. It discusses data sources, predictive models, nutritional decision-support systems, clinical implications, challenges, and future perspectives, highlighting AI's potential to transform PCOD prevention and management.

Keywords: Artificial intelligence, PCOD, PCOS, machine learning, predictive analytics, precision nutrition

Introduction
Polycystic Ovary Disease (PCOD), often used interchangeably with Polycystic Ovary Syndrome (PCOS), is a multifactorial disorder affecting approximately 6–20% of women of reproductive age worldwide (Stener-Victorin *et al*., 2024) [25]. The condition is associated with hyperandrogenism, ovulatory dysfunction, polycystic ovarian morphology, insulin resistance, obesity, dyslipidemia, and increased risk of type 2 diabetes and cardiovascular disease (Zeng, 2020) [32]. In addition to physical manifestations, PCOD significantly impacts psychological health, contributing to anxiety, depression, body image issues, and reduced quality of life (Ghose and Krishna, 2025) [10].
Conventional diagnostic approaches rely on clinical symptoms, hormonal assays, ultrasound findings, and exclusion of related disorders (Alzahrani *et al*., 2012) [1]. However, PCOD exhibits marked heterogeneity, making early prediction and individualized intervention challenging (Kumar, 2023) [18]. Nutritional therapy remains a cornerstone of PCOD management, focusing on weight control, glycemic regulation, hormonal balance, and inflammation reduction. With advancements in computational power and data availability, Artificial Intelligence (AI) offers innovative solutions for early PCOD risk prediction and the development of personalized preventive nutrition strategies (Begum and Areen, 2023) [3].

Artificial Intelligence in Healthcare and Nutrition
Artificial Intelligence refers to computer systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, pattern recognition, and decision-making (Bohr and Memarzadeh, 2020) [4]. In healthcare, AI encompasses machine learning (ML), deep learning (DL), natural language processing (NLP), and expert systems (Mah, 2022) [20]. These technologies enable analysis of large, complex datasets to identify patterns not easily detectable by traditional statistical methods (Valafar, 2002) [30].
In the field of nutrition, AI supports dietary assessment, nutrient intake analysis, behavior prediction, and personalized dietary recommendations. The integration of AI with nutritional science has led to the emergence of precision nutrition, which tailors' dietary interventions based on individual biological, behavioral, and environmental characteristics (Tsolakidis *et al*., 2024) [29].

Data Sources for AI-Based PCOD Risk Prediction
AI models for PCOD risk prediction rely on diverse and multidimensional data sources, including:

- Anthropometric data such as body mass index (BMI), waist-to-hip ratio, and body fat percentage serve as fundamental inputs for AI-based PCOD risk prediction (Wang *et al*., 2025) [31], as they reflect obesity patterns and central adiposity closely associated with insulin resistance and hormonal imbalance. Machine learning models use these parameters to identify subtle variations in body composition that may predispose women to PCOD, even before overt clinical symptoms appear, enabling early risk stratification and preventive intervention (Dhanka *et al*., 2025) [8].
- Clinical and hormonal data form the core of PCOD risk prediction models, capturing the endocrine disturbances characteristic of the disorder (Dhanka *et al*., 2025) [8]. Information on menstrual irregularities, serum androgen levels, insulin concentration, and the luteinizing hormone to follicle-stimulating hormone (LH/FSH) ratio allows AI algorithms to detect complex hormonal

patterns and interactions. These data significantly enhance predictive accuracy by reflecting both reproductive and metabolic dysfunctions central to PCOD pathophysiology (Morshed *et al*., 2021) [21].

- Biochemical markers, including fasting blood glucose, lipid profile, and inflammatory markers, provide critical insights into the metabolic status of individuals at risk of PCOD. AI models analyze these parameters to identify early signs of insulin resistance, dyslipidemia, and low-grade chronic inflammation, which are key contributors to PCOD development. Incorporating biochemical data enables more precise differentiation between high- and low-risk individuals (Zhong *et al*., 2021) [33].
- Ultrasound and imaging data play an important role in AI-driven PCOD prediction by objectively assessing ovarian morphology and follicle number. Advanced image-processing and deep learning techniques allow automated extraction of features from ultrasound images, reducing observer bias and improving diagnostic consistency. These data help AI systems recognize polycystic ovarian patterns that may not be evident through clinical evaluation alone (Di Michele *et al*., 2025 [9]; Govindharajan *et al*., 2025) [12].
- Lifestyle factors, including dietary patterns, physical activity levels, sleep quality, and psychological stress, are increasingly integrated into AI-based predictive frameworks. Since lifestyle behaviours strongly influence insulin sensitivity, inflammation, and hormonal balance, AI algorithms analyze these variables to capture modifiable risk factors. This approach supports not only risk prediction but also the design of personalized preventive nutrition and lifestyle interventions (Cruz Fernandez *et al*., 2025) [7].
- Genetic and epigenetic data provide a deeper understanding of individual susceptibility to PCOD by capturing inherited and environmentally influenced molecular variations (Bruni *et al*., 2022) [5]. AI models utilize PCOD-associated genetic polymorphisms and epigenetic markers to uncover gene–environment interactions that contribute to disease risk. The inclusion of these data enhances predictive precision and supports the development of personalized, long-term preventive strategies (Hunter, 2005) [14].

The integration of these heterogeneous datasets enhances predictive accuracy and supports early identification of high-risk individuals.

Machine Learning Models for Predicting PCOD Risk

Various machine learning algorithms have been applied to predict PCOD risk and classify affected individuals:

- Logistic regression and decision tree models are commonly used as baseline approaches for predicting PCOD risk due to their simplicity, interpretability, and ability to identify key contributing factors (Jain *et al*., 2024) [15]. Logistic regression estimates the probability of PCOD based on linear relationships between predictors such as BMI, hormonal levels, and metabolic markers, while decision trees classify individuals by recursively splitting data into risk-based categories. These models are particularly useful in clinical settings where transparency and ease of interpretation are essential for decision-making (Pradhan *et al*., 2022) [23].
- Support vector machines (SVM) are widely applied for PCOD risk classification because of their effectiveness in handling high-dimensional hormonal and metabolic data. SVM models construct optimal decision boundaries that separate PCOD and non-PCOD cases by maximizing the margin between classes (Lakshmi *et al*., 2023) [19]. Their ability to manage nonlinear relationships through kernel functions makes them suitable for capturing complex interactions among endocrine and biochemical parameters (Goodarzi *et al*., 2009) [11].
- Random forest and gradient boosting models have demonstrated high predictive performance in PCOD risk assessment by effectively handling nonlinear relationships and interactions among multiple variables. Random forest models aggregate predictions from multiple decision trees, reducing overfitting and improving robustness, while gradient boosting sequentially refines predictions by minimizing errors (Kalusivalingam *et al*., 2022) [17]. These ensemble methods are particularly valuable for integrating diverse datasets, including anthropometric, biochemical, and lifestyle factors (Lakshmi *et al*., 2023) [19].
- Artificial neural networks (ANN) and deep learning models are increasingly used for advanced PCOD risk prediction due to their capacity for complex pattern recognition and feature learning. These models can automatically identify intricate, non-obvious relationships within large and heterogeneous datasets, including hormonal profiles, imaging data, and genetic information (Chaussabel and Sher, 2002) [6]. Although they offer high accuracy, their clinical adoption requires careful validation and interpretability to ensure trust and effective integration into healthcare practice (Jain *et al*., 2024) [15].

Studies report high accuracy, sensitivity, and specificity of ML models compared to conventional diagnostic methods. AI-based models can detect subtle interactions between metabolic, hormonal, and lifestyle factors, enabling early risk stratification before clinical symptoms become severe (Anwar *et al*., 2025) [2].

Role of AI in Nutritional Assessment for PCOD

Accurate dietary assessment is critical for PCOD management. AI-powered tools such as mobile applications, image-based food recognition systems, and wearable devices facilitate real-time monitoring of dietary intake and lifestyle behaviors. Machine learning algorithms analyze food images to estimate portion sizes, nutrient composition, and glycemic load (Szczuko *et al*., 2016) [26].

AI systems can identify dietary patterns associated with insulin resistance, inflammation, and hormonal imbalance, enabling nutrition professionals to design targeted interventions. These tools reduce reporting bias and improve adherence to dietary recommendations (Hemanth *et al*., 2025) [13].

AI-Driven Preventive Nutrition Therapies for PCOD

AI enables the design of personalized preventive nutrition therapies by integrating individual health data with evidence-based dietary guidelines. Key applications include:

- Personalized meal planning based on insulin sensitivity, BMI, and metabolic profile
- Prediction of glycemic response to specific foods

- Optimization of macronutrient distribution and micronutrient adequacy
- Recommendation of functional foods, dietary fiber, antioxidants, and anti-inflammatory nutrients

AI-based decision-support systems continuously adapt dietary recommendations based on user feedback and physiological responses, supporting long-term lifestyle modification (Mundt *et al*., 2025) [22].

Role of AI in Weight Management and Lifestyle Modification

Weight management is a primary goal in PCOD prevention. AI-powered platforms integrate dietary data, physical activity tracking, and behavioral analytics to promote sustainable weight loss. Predictive models identify barriers to adherence and provide personalized feedback, reminders, and motivational strategies (Hemanth *et al*., 2025) [13].

By analyzing behavioral patterns, AI systems can support stress management, sleep optimization, and physical activity planning, all of which are crucial for hormonal balance in PCOD (Rai and Singh, 2024) [24].

Clinical and Public Health Implications

The integration of AI into PCOD risk prediction and nutritional therapy has significant clinical and public health implications. Early identification of at-risk individuals allows timely lifestyle interventions, reducing disease severity and long-term complications. AI-driven nutrition tools can be scaled for community-level screening and intervention, particularly in resource-limited settings (Teke *et al*., 2025) [27].

In clinical practice, AI serves as a decision-support tool, complementing healthcare professionals rather than replacing them. It enhances diagnostic accuracy, improves patient engagement, and supports personalized care.

Future Perspectives

Future research should focus on integrating multi-omics data, gut microbiome analysis, and real-time physiological monitoring into AI models. Longitudinal studies and randomized controlled trials are needed to validate AI-driven nutrition interventions. The development of explainable AI models will enhance clinical trust and adoption.

Table 1: Applications of Artificial Intelligence in Predicting PCOD Risk and Designing Preventive Nutrition Therapies (Hemanth *et al*., 2025) [13]

AI Application Area	Data Inputs Used	AI / ML Techniques	Key Outcomes	Relevance to PCOD Management
PCOD Risk Prediction	Anthropometric data (BMI, WHR), hormonal profile, biochemical markers	Logistic regression, Decision trees	Early identification of high-risk individuals	Enables preventive interventions before clinical manifestation
Hormonal Pattern Analysis	Androgen levels, insulin, LH/FSH ratio	Support Vector Machines (SVM), Random forest	Improved classification accuracy of PCOD cases	Captures complex endocrine interactions
Metabolic Risk Assessment	Fasting glucose, lipid profile, inflammatory markers	Gradient boosting, Ensemble models	Detection of insulin resistance and metabolic syndrome	Supports early metabolic management
Ultrasound Image Analysis	Ovarian morphology, follicle count	Deep learning, Convolutional Neural Networks (CNN)	Automated and objective PCOD diagnosis	Reduces observer bias and diagnostic variability
Dietary Intake Assessment	Food frequency data, meal images, nutrient intake	Machine learning, Image recognition	Accurate nutrient and glycemic load estimation	Improves dietary monitoring and compliance
Personalized Nutrition Planning	Metabolic profile, lifestyle data, dietary patterns	AI-based decision support systems	Customized meal plans and nutrient recommendations	Enhances effectiveness of preventive nutrition therapy
Weight and Lifestyle Management	Physical activity, sleep, stress levels	Predictive analytics, Behavioral ML models	Improved adherence to lifestyle modification	Addresses obesity and stress-related PCOD risk
Genetic Risk Stratification	PCOD-associated genetic polymorphisms	Machine learning, Deep learning	Identification of genetically susceptible individuals	Supports precision nutrition and long-term prevention
Clinical Decision Support	Integrated clinical, dietary, and lifestyle data	Hybrid AI models	Evidence-based treatment recommendations	Assists clinicians in personalized PCOD care

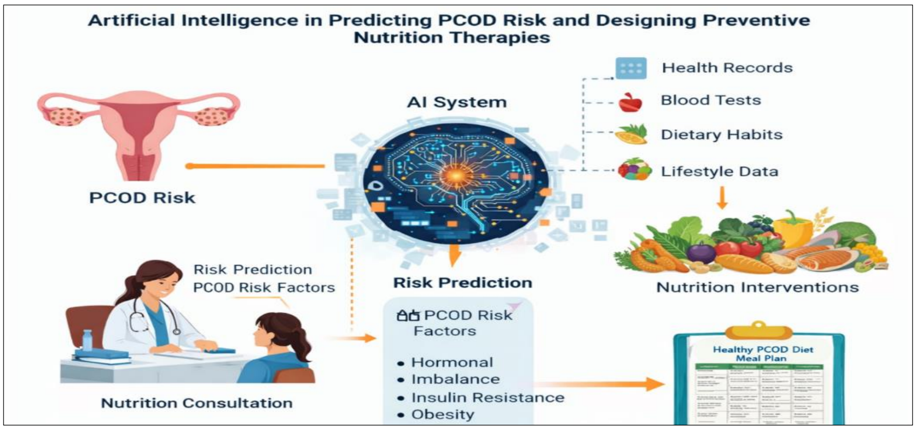

Fig 1: AI-Driven Framework for PCOD Risk Prediction and Personalized Nutrition Interventions

Conclusion

Artificial Intelligence holds significant promise in predicting PCOD risk and designing personalized preventive nutrition therapies. By leveraging complex datasets and advanced analytical techniques, AI enables early detection, targeted nutritional interventions, and sustainable lifestyle modification. Integrating AI with nutritional science and clinical practice represents a transformative approach to PCOD prevention and management, with the potential to improve health outcomes and quality of life for women worldwide.

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