

Polycystic Ovary Syndrome in Ethnic Populations of India: A Comprehensive Meta-Analysis and Review

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Abstract Polycystic Ovary Syndrome (PCOS) is a complex endocrine disorder affecting a substantial proportion of women worldwide, with a significant impact on reproductive, metabolic, and psychological health. In recent years, the prevalence of PCOS in different ethnic populations has gained considerable attention, particularly in India, a country with diverse ethnic groups. This review paper aims to provide a comprehensive analysis of the available literature on PCOS in various ethnic populations of India through a meta-analysis of relevant studies. The paper focuses on the prevalence, clinical manifestations, genetic factors, and the impact of environmental and lifestyle factors on PCOS among different ethnic groups in India. Furthermore, potential areas for future research and interventions to address the unique challenges faced by each ethnic population have been discussed. The research findings underscore the need for ethnically diverse studies to provide accurate prevalence rates, identify unique genetic variations, and tailor interventions for different ethnic groups. This review has also shed light on the challenges faced by women with PCOS from diverse backgrounds, including misdiagnosis, cultural stigmatization, and limited access to healthcare. The implications of this research for policy and healthcare are far-reaching. Policymakers can use the evidence to develop inclusive healthcare policies, improve awareness, and

promote equitable access to healthcare for women with PCOS. By working together, collaborative efforts among researchers, healthcare institutions, community organizations, and policymakers can pave the way for a brighter future, where all women with PCOS receive the support and care they need to lead healthier lives, regardless of their ethnic backgrounds.

Keywords Polycystic Ovary Syndrome, Ethnicity, India, Meta-analysis, Women's Health

1. Introduction

Polycystic Ovary Syndrome (PCOS) is one of the most common endocrine disorders affecting approximately 8-21% of women of reproductive age globally [1]. Characterized by hyperandrogenism, oligo or anovulation, and polycystic ovaries, PCOS contributes significantly to reproductive, metabolic, and psychological morbidity in women [2]. In India, a country with a rich source of diverse ethnic populations, the impact of PCOS is even more pronounced due to variations in genetic, environmental, and lifestyle factors [3].

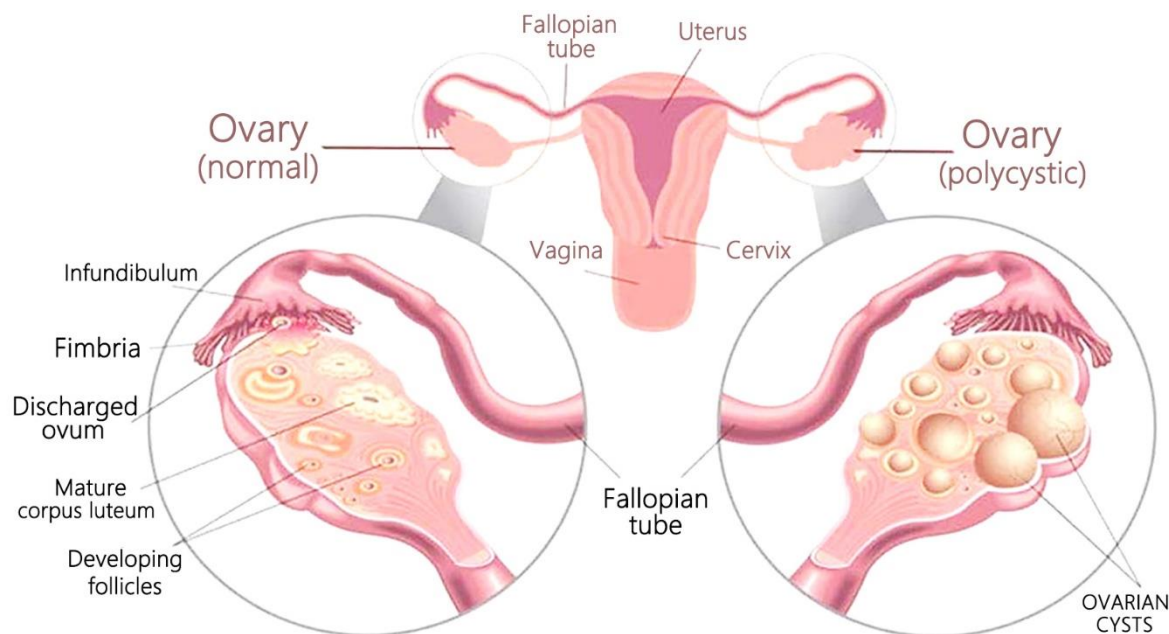


Figure 1. Polycystic Ovary Syndrome (PCOS)

Figure 1 shows the difference between a normal ovary and a polycystic ovary. Polycystic ovary syndrome (PCOS) is also known as hyperandrogenic anovulation or Stein–Leventhal syndrome which is a multifactorial and polygenic endocrine disorder. This syndrome is often associated with growth and dysfunctional ovaries, excessive androgen levels, and insulin resistance causing a risk factor for diseases like cardiovascular disease, type 2 diabetes mellitus (DMT2) [4,5], metabolic syndrome [3], depression and anxiety [6,7]. In the earlier days, PCOS was considered as a disorder of adult women, but recent evidence showed that it is a lifelong syndrome that can occur among female adolescents also. According to the Rotterdam diagnostic criteria, indeed, the PCOS prevalence in adolescents varies from a minimum of 3% to a maximum of 26% [8]. Several hypotheses have emerged to explain the pathophysiology of PCOS. In the beginning, an excess of intrauterine androgens was considered as a factor causing this disease. Subsequently, insulin resistance was believed to be responsible for PCOS and hyperandrogenemia onset. An intrinsic defect in theca cells can cause the secretion of high levels of androgens due to the intrinsic activation of steroidogenesis [9]. This dysregulation can affect granulosa cells which produce up to 4 times higher levels of the anti-Müllerian hormone (AMH) in PCOS patients [10–12]. Other than these, PCOS syndrome has also been associated with an increase in glycol-oxidative stress [13], which is able to induce IR and hyperandrogenism in such patients [14].

1.1. Overview of PCOS in Different Ethnic Populations

Different ethnic cultures can have dramatically variable PCOS prevalence rates and clinical symptoms. According

to recent studies [15,16], ethnic variations in body composition, metabolic parameters, genetic profiles, and lifestyle choices may be important contributors to the variety of the PCOS phenotype.

Asian women tend to have more metabolic irregularities than Caucasian women, whereas African-American women with PCOS have been found to have greater rates of hirsutism, a disorder marked by excessive hair growth, than their Caucasian counterparts [17,18].

The tremendous socio-cultural and genetic variety in India, a nation with over 2,000 unique ethnic groupings, contributes to the fragmented knowledge of PCOS [19].

Despite this, it is acknowledged that various ethnic populations have different illness frequencies and symptomatology, highlighting the urgent need for further investigation. In order to have a unique understanding of the etiology, pathophysiology, and treatment of PCOS in Indian women, it is important to research the ethnically specific characteristics that are associated with the condition.

In conclusion, knowing the specifics of the condition within India's varied ethnic communities is vital for devising effective and individualized treatment interventions given the stark ethnic inequalities in PCOS expression.

2. Methods

2.1. Study Design

This study was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist. Before starting the literature

search, the study framework was designed as per the PRISMA guidelines. No further adjustments were made after that. The aim and objective of the study were to conduct a systematic review and meta-analysis to assess the current situation of PCOS among the ethnic female population of India.

2.2. Search Strategy and Selection Criteria

Using search phrases relevant to PCOS and Indian ethnic communities, we carried out an extensive and methodical search of electronic databases, including PubMed, Embase, and Web of Science. "Polycystic Ovary Syndrome," "PCOS," "India," "ethnicity," and combinations of these phrases were among them. In order to find any other research that could have been overlooked during the first database search, we additionally looked through the reference lists of the discovered papers.

The eligibility criteria were pre-defined before conducting the literature search. Studies completed in India, published in English from the beginning to July 2023, and involving people who had been given a PCOS diagnosis in accordance with the Rotterdam criteria were included in the selection criteria [20]. If studies did not specify the diagnostic criteria applied or were not published as peer-reviewed original research publications, they were eliminated. Studies were disqualified if they employed animal models, failed to define PCOS clearly, or failed to separate data by ethnic groups.

The initial search from PubMed, Scopus, and Google Scholar yielded a total of 132 articles. After the initial removal of duplicates, and screening from abstracts and titles, only 30 relevant articles were undertaken for full-text review for eligibility. Furthermore, on the exclusion of 12 articles for various reasons, 18 articles were included in the quantitative synthesis.

2.3. Data Extraction and Quality Assessment

Using a standardized data extraction form, two independent reviewers collected data from the studies that were included. The study's citation, study methodology,

sample size, ethnic group, and information on PCOS prevalence and clinical symptoms were all included in the data that was extracted. Discussion or contact with a third reviewer was used to settle any disagreements amongst reviewers.

The Newcastle-Ottawa Scale (NOS) for observational studies was used to rate the quality of each research [21]. This tool evaluates the non-randomized studies' quality based on their selection, comparability, and outcome evaluation.

2.4. Meta-analysis Methodology

The meta-analysis was performed using the random-effects model to calculate the pooled prevalence and the 95% confidence intervals (CI) for PCOS in different ethnic populations in India. Statistical heterogeneity among studies was evaluated using the I² statistic. An I² value >50% was considered to represent substantial heterogeneity. All analyses were conducted using STATA version 15.0 software.

Table 1 presents a selection of studies included in the meta-analysis focusing on the prevalence of Polycystic Ovary Syndrome (PCOS) in various regions of India.

Kusuma et al. [22] conducted a cross-sectional study in Telangana, reporting a PCOS prevalence of 11.5%. Nidhi R et al. [23] investigated the prevalence of PCOS in South India and found it to be 9.13%. Vijaya K et al. [24] conducted a study in Pondicherry, revealing a prevalence of 11.7%. Additionally, Ganie et al. [25] examined PCOS prevalence in Kashmir, reporting a rate of 28.9%, while Gill H et al. [26] studied the prevalence among Indian women from Lucknow, finding it to be 3.7%.

Table 2 presents the sensitivity analysis results of PCOS prevalence in different regions of India based on the selected studies. The pooled prevalence of PCOS was estimated to be 11.3% across the regions. The overall meta-analysis indicates a moderate PCOS prevalence across the regions, suggesting the importance of understanding and addressing this health issue among various ethnic populations in India.

Table 1. Studies Included in Meta-Analysis for Prevalence of PCOS in Different Regions

Study	Study Design	Sample Size	Region	PCOS Prevalence (%)	Quality (NOS Score)
Kusuma et al., 2021	Cross-sectional study	624	Telangana	11.5%	6
Nidhi R et al., 2011	Cross-sectional	460	Andhrapradesh	9.13	7
Vijaya and Bharatwaj, 2014	Cross-sectional	238	Pondicherry	11.76	6
Ganie et al., 2020	Cross-sectional	964	Kashmir	28.9	8
Gill H et al., 2012	Cross-sectional	1520	Lucknow, North India	3.7	8

Table 2. Sensitivity Analysis Results as per Rotterdam criteria

Region	Number of Studies	Total Sample Size	Pooled Prevalence (%)	I ² (95% CI)	p-value
Kusuma et al., 2021	1	624	11.5	96.10 (94.41-97.30)	<0.001
Nidhi et al.	1	460	11.4	96.18 (94.50-97.31)	<0.001
Vijaya and Bharatwaj, 2014	1	238	11.1	96.14 (94.38-97.31)	<0.001
Ganie et al., 2020	1	964	10.9	95.76 (93.81-97.09)	<0.001
Gill H et al., 2012	1	1520	11.8	90.71 (86.03-93.23)	<0.001

3. Prevalence of PCOS in Ethnic Populations of India

3.1. Prevalence Rates in Major Ethnic Groups

There are notable differences in PCOS prevalence across the various ethnic groups in India, according to a number of studies. For instance, research by Upadhya et al. [27] found that South Indian women had a greater prevalence of PCOS (about 32.11%) than the national norm, indicating the impact of racial and genetic variables.

In contrast, research by Deswal et al. [28] shows that studies in Haryana found a lower frequency of PCOS, about 4.21%. Similarly in a study by Gill et al. [26] prevalence of PCOS in women between the ages of 18-25 years from Lucknow, north India was found to be as 3.7%. Whereas in a study from central India, prevalence was found to be 8.20%. A research on women in Kolkata on the eastern side of the nation discovered a PCOS prevalence of 28%, demonstrating geographical variance in the disorder's prevalence [29]. Joshi et al. [30] identified a rather high incidence of PCOS in the western area, notably among Marathi women, as 22.5%. It's crucial to keep in mind that while these variances could be a reflection of genetic and cultural variety, it's also possible that they are caused by different lifestyle variables, such as dietary and exercise preferences.

3.2. Regional Variations and Disparities

According to Bhattacharya and Jha [31], the high regional variation in PCOS prevalence in India may be caused by variations in genetic variables, environmental exposures, dietary practices, and lifestyle practices.

As was said before, the southern areas of India have a greater prevalence of PCOS than the overall population. This discrepancy may be caused by genetic predisposition, increased urbanisation resulting in lifestyle changes, and a diet high in processed fats and carbs. Study results, however, have indicated a reduced frequency of PCOS in northern India. According to Nidhi et al. [23], the relatively lower rates may be attributed to dietary habits that include a larger intake of dairy products and vegetables as well as the widespread participation in physically taxing agricultural activities. Eastern areas have demonstrated a very high prevalence of PCOS. This can be due to a mix of dietary variables, including the high intake of fried and sugary foods that are typical of this region, urban lifestyle, and genetic susceptibility. The frequency of PCOS in the western region is in the middle of those in the southern and northern regions, indicating a confluence of variables affecting these areas. Finally, these regional differences in PCOS prevalence indicate the necessity of spatially specific preventive and care measures for the condition in India. Table 3 represents PCOS cases from northeastern part of India.

Table 3. PCOS in North East India

Publication Year	Authors	Place	Sample size	Type of study	Tests done	Outcome	Limitation	Remarks
2017	Dr. Alakananda	Guwahati Medical College and Hospital, Assam	66	Hospital-based prospective cross-sectional study	BMI, USG	The commonest presenting complaint in this study was oligomenorrhea. The commonest PCOS phenotype found was P+H+O or the classic type. Most of the patients exhibited central obesity even those with normal BMI.	Small sample size, hospital-based data	Oligomenorrhoea was the commonest menstrual irregularity and often the presenting problem of Polycystic Ovary Syndrome
2019	Chandan K. Nath <i>et al.</i>	North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences (NEIGRIHMS), Shillong, Meghalaya	85	Retrospective observational study	LH, FSH, free thyroxine levels (free T3 and free T4), TSH, and prolactin were measured by specific chemiluminescence assays (Beckman coulter Access 2 immunoassay system)	1. Elevated LH/FSH ratio was found in 60 women (70.58%) 2. Hypothyroidism was a common endocrinal abnormality and prolactin was inversely correlated to TSH levels in PCOS patients.	Since all the endocrinological manifestations of hypothyroidism and hyperprolactinemia may lead to the development of PCOS it is very difficult to comment on whether these conditions are interdependent or presented with a separate entity	Assessment of thyroid status and prolactin should be carried out in all patients with PCOS in addition to other hormonal assays like LH and FSH.
2020	Swapna S Pillai <i>et al.</i>	Assam Medical College, Dibrugarh	100	Comparative cross-sectional study	1. Blood pressure and other anthropometric measurements such as height, weight, BMI, waist circumference, and hip circumference were measured. 2. Harpenden skinfold calipers were used to measure the skinfold thickness from four sites: the biceps, triceps, subscapular, and suprailiac region. 3. Thyroid profile, fasting blood glucose, postprandial blood sugar, HbA1c, serum prolactin, serum antimullerian hormone (AMH), and lipid profile were done	There was a significant difference in age, hirsutism score, and family history of diabetes and PCOS between Obese and Non-obese groups	First, the data were only from patients attending one hospital; second, the basic characteristics of economic and nutritional status were not matched; third, other methods of evaluation for body fat percentage DEXA scan could not be used due to the economic constraints.	Obese PCOS had a more androgenic and atherogenic profile compared to lean with strong family history and increased predisposition for hypertension

Table 3 continued

2019	Dr. Tiluttoma Baruah	Pratiksha Hospital of Guwahati city, Assam	Experimental group - 172 Control group - 228	Cross sectional study	Anthropometric measurements Testosterone, Estrogens, Follicle stimulating hormone (FSH), Insulin, Luteinizing hormone (LH), Progesterone, Prolactin (PRL), and Thyroid hormones (TSH).	1. Mean FSH and mean LH hormones are less than the normal range. 2. Maximum numbers of PCOS women fall in the category of overweight; while in case of non PCOS women, maximum numbers fall in the category of normal weight.	Patients coming to the outpatient clinic in the hospital were included in this study.	Quality-of-life (QoL) of the PCOS populations is different in comparison to the controlled group
2020	Dr. Jahar Lal Baidya	Department of Obstetrics and Gynaecology Agartala Government Medical College, Agartala, Tripura	Test group – 50 Control Group - 50	Case-control study	Waist circumference measurement, Blood pressure, Fasting Blood sugar, OGTT and Lipid profile	Oligomenorrhea found in 42 out of 50 cases. Hirsutism found in 54% of cases. Hypertriglyceridemia was found to be significantly higher among PCOS cases. Metabolic syndrome was present in 34% of cases	Only patients coming to the outpatient clinic in the hospital were included. This leads to Berksonian bias	PCOS and metabolic syndrome are linked to each other and early identification of one may lead to the diagnosis and management of the other.

3.3. Age-specific Prevalence Trends

Age can also affect PCOS prevalence. It is well accepted that PCOS symptoms often start from adolescence and continue throughout the reproductive years, with symptoms frequently improving after menopause [32]. Studies in India have discovered a significant frequency of PCOS in teenagers, indicating an early initiation of the disorder. In their community-based study, Nidhi et al. [23] for instance, discovered that teenagers between the ages of 15 and 18 had a prevalence of roughly 9.13%. Early puberty, obesity, and other lifestyle variables may all contribute to this.

Typically, between the ages of 20 and 40, women who are of reproductive age tend to have the highest frequency of PCOS [33]. According to Nidhi R et al. [23], PCOS was more common among reproductive-aged south Indian women specifically between 25 and 30 years, which advances to develop secondary infertility. Due to PCOS's major impact on fertility and its associated metabolic and psychological concerns, this time period is critical. Although less often, post-menopausal women also experience the symptoms of PCOS, and research by Sharma et al. [34] also supported this. However, the emergence of additional age-related metabolic illnesses frequently complicates PCOS expression in this age range, making diagnosis and therapy difficult. Understanding these age-specific prevalence changes is crucial for PCOS care and tailored PCOS therapies.

4. Clinical Manifestations of PCOS in Ethnic Populations

4.1. Reproductive Manifestations

Polycystic ovary syndrome (PCOS) is chiefly characterized by reproductive manifestations, which might vary among different ethnic groups due to genetics, lifestyle, and environmental factors. Typically, reproductive manifestations of PCOS include menstrual irregularities such as oligomenorrhea (infrequent menstrual periods) or amenorrhea (absence of menstrual periods), and signs of hyperandrogenism such as hirsutism (excessive hair growth), acne, and alopecia (hair loss). Infertility due to anovulation is also a common clinical feature in PCOS among Indian women [35]. Indian women with PCOS frequently exhibit these typical symptoms. Majumdar and Singh have compared the clinical features of PCOS in Indian women [36]. The authors have reported the prevalence of menstrual irregularities as 79.2% and 44% in obese and non-obese women respectively. In the study by Ramanand S et al. [37], all patients complained of irregular menses and Oligomenorrhea was present in 65% of patients. Moreover, the prevalence of infertility due to PCOS is alarmingly high in Indian women. A study by Hariprasath et al. [38] found that infertility has the most

significant impact on quality of life among PCOS patients from south India. Importantly, a study by Allahbadia et al. [39] found that the phenotype of women with PCOS is variable, depending on their ethnic background, severity and pattern of symptoms varied among different ethnic groups within India. These variations underline the need for further research into the impact of ethnicity on the reproductive manifestations of PCOS in Indian women.

4.2. Metabolic Implications

PCOS is associated with numerous metabolic implications including insulin resistance, obesity, dyslipidemia, and an increased risk for type 2 diabetes and cardiovascular diseases. The expression of these metabolic features often varies among different ethnicities due to genetic and environmental factors. In an Indian study, Insulin resistance was found to be associated with dyslipidemia in women with PCOS, independent of obesity [40]. According to a study from Tripura, northeast India, metabolic syndrome was present in 34% of PCOS cases. The odds ratio of having metabolic syndrome in a case of PCOS was found to be 5.92 [41].

Indian women with PCOS, according to several studies, exhibit a high prevalence of insulin resistance and related conditions [35]. Obesity, particularly central or abdominal obesity, is commonly found in Indian women with PCOS. In a study by Swapna S Pillai et al. [42] from Assam, obese PCOS patients were found to have a more androgenic and atherogenic profile compared to lean with a strong family history and increased predisposition for hypertension.

Dyslipidemia, characterized by high levels of LDL cholesterol and triglycerides and low levels of HDL cholesterol, is also prevalent among Indian women with PCOS. This condition increases the risk of cardiovascular diseases, which are more commonly seen in women with PCOS. It is noteworthy that Indian women with PCOS have a higher risk of developing type 2 diabetes compared to their Western counterparts. This elevated risk might be linked to genetic factors and lifestyle practices prevalent in India. In conclusion, the metabolic implications of PCOS pose a significant health risk to Indian women and need to be adequately addressed through targeted interventions and management strategies.

4.3. Psychological and Emotional Aspects

In addition to the physical symptoms, PCOS can significantly impact the psychological and emotional well-being of affected individuals. Studies have shown that the psychosocial consequences of PCOS are substantial and can vary among different ethnic populations due to cultural, social, and familial factors [43]. Indian women with PCOS often experience increased levels of anxiety, depression, and body dissatisfaction. A study by Chaudhari et al. [44] reported that Indian women with PCOS had higher levels of psychological distress compared to healthy

controls, with body dissatisfaction being a significant contributing factor. The impact of PCOS on body image and self-esteem is particularly noteworthy in Indian culture, where societal expectations and cultural norms regarding appearance can exacerbate these psychological effects. A study by Hussain et al. [45] found that Indian women with PCOS tended to have lower self-esteem and reduced quality of life compared to women without the condition. Furthermore, the stigma associated with infertility and the pressure to conform to traditional gender roles may further exacerbate psychological distress among Indian women with PCOS. In conclusion, the psychological and emotional aspects of PCOS in Indian women are critical considerations for healthcare professionals when providing comprehensive care and support.

5. Genetic Factors and PCOS Risk in Different Ethnicities

5.1. Genetic Variations and Susceptibility

Genetic factors play a significant role in the development of PCOS, and there is evidence of genetic variations contributing to PCOS risk in different ethnic populations. Studies have identified specific gene variants associated with PCOS susceptibility in various ethnicities. For instance, a study by Ramanathan et al. [46] reported an association between the DENN domain-containing 1A (DENND1A) gene polymorphism and PCOS risk in Indian women. DENND1A is involved in insulin signaling, highlighting the interplay between genetic factors and metabolic pathways in PCOS development. Deepika et al. [47] found a significant association of Angiotensin-converting enzyme Insertion/Deletion (ACE I/D) gene polymorphism with acanthosis and age at onset (AAO) of the PCOS syndrome. Insulin-like factor 3 (INSL3) is involved in androgen production, follicular growth and oocyte maturation. In a case-control study by Shaikh et al. [48], the impact of INSL3 polymorphisms was explored and a significant association was found between INSL3 polymorphisms and increased risk of PCOS in Indian women. These findings illustrate the importance of considering ethnic-specific genetic factors in understanding PCOS susceptibility. Furthermore, epigenetic modifications, which can be influenced by environmental factors, also contribute to PCOS risk and phenotypic variation among different ethnic groups. A study by Li S et al. [49] demonstrated a large number of DNA methylation sites and their enriched functional pathways significantly associated with diverse clinical features among Chinese PCOS women of mongoloid origin, suggesting the role of ethnicity in epigenetic regulation of PCOS-related genes.

Overall, the genetic basis of PCOS susceptibility is complex and influenced by both common and

ethnic-specific genetic variants. Understanding these genetic variations is essential for personalized management and treatment of PCOS across different ethnic populations.

5.2. Association of Specific Genes with PCOS

Several specific genes have been associated with the pathogenesis of PCOS in various ethnic populations. A case-control study by Singh et al. [50] demonstrated lower serum adiponectin levels in women with PCOS as compared to controls. According to study result by S Gangopadhyay et al. [51], presence of CC genotype (C1085T) could be developed as a marker for insulin resistance and metabolic complications in PCOS women. In a north Indian study done by Kaur et al. [52], the association was found between polymorphism in CYP17A1 and susceptibility to developing PCOS. This CYP17A1 gene plays an important role in the androgen metabolic pathway. In a few Indian studies, high levels of leptin have been found to be associated with the Insulin resistance markers among PCOS patients [53,54].

In another Indian study, a positive association was found between Gly972Arg of IRS1 and PCOS among the south Indian population, while INS, IRS2, PPAR-G and CAPN10 failed to show any association with PCOS [55]. Luteinizing Hormone/Choriogonadotropin Receptor (LHCGR) serves as a receptor for human chorionic gonadotropin (hCG), a glycoprotein hormone that is nearly identical to LH. In a case-control study from Punjab, it was shown that *LHCGR* variants had played a crucial role in the progression of PCOS and could be used to assess the risk of PCOS in women of reproductive age [56]. Calpain 10 (CAPN10) has been found to be associated with Type 2 Diabetes Mellitus in several populations. The association of CAPN10 polymorphism (UCSNP-44) with the manifestation of PCOS was found in a study from south India [57]. These studies highlight the importance of specific genes in the development and manifestation of PCOS in different ethnic populations. The identification of these genetic associations provides valuable insights into the underlying molecular mechanisms and potential targets for personalized treatments.

6. Impact of Environmental and Lifestyle Factors

6.1. Diet and Nutritional Influences

Diet and dietary practices have been linked to environmental and lifestyle variables that contribute to the onset and progression of PCOS. Dietary decisions in PCOS-affected women might have a big impact on their hormonal balance, insulin sensitivity, and metabolic parameters, according to studies [58]. Diet has a significant

influence on PCOS risk in India, where dietary habits can fluctuate substantially among various ethnic communities. Indian women with PCOS frequently consume diets rich in refined carbs and saturated fats, which can increase insulin resistance and poor metabolic outcomes, according to research by Deswal et al. [28]. Additionally, drinking soft drinks with added sugar has been linked to a higher incidence of PCOS in Indian women. These drinks include a lot of extra sugar and cause insulin spikes, which encourage insulin resistance. The Mediterranean diet, on the other hand, has been linked to better metabolic and hormonal profiles in PCOS-affected women since it is high in fruits, vegetables, whole grains, and healthy fats [59]. For Indian women with PCOS, adopting a Mediterranean-style diet may help with insulin sensitivity and general metabolic health.

Furthermore, Thakur et al. [60] found that Indian women with PCOS have shortages in micronutrients including zinc and vitamin D. The symptoms of PCOS may be made worse by these deficits, which may affect insulin signaling.

Overall, the dietary preferences and nutritional practices common among populations of Indian ethnicity may have an impact on the occurrence and treatment of PCOS. The metabolic and hormonal results in PCOS-afflicted women may be significantly improved by promoting healthy eating habits and treating nutritional shortages.

6.2. Physical Activity and Sedentary Behavior

Sedentary behavior and physical inactivity are crucial lifestyle elements that can have a big impact on PCOS risk and treatment in many ethnic communities. Sedentary lifestyles are growing more and more common in India, especially in metropolitan areas. Sedentary behavior has been linked to a higher incidence of PCOS in Indian women, according to several research. For instance, research by Vidya Bharathi et al. [61] found that Indian women with PCOS are frequently engaged in sedentary behaviors such as extended sitting and low levels of physical exercise.

On the other hand, frequent exercise has been linked to better metabolic results and a lower risk of PCOS. Furthermore, physical exercise has a good impact on body weight and obesity, two significant contributors to the development of PCOS. Increased physical activity was linked to a decreased frequency of obesity in Indian women with PCOS, according to research by D. Thakur et al. [60].

For Indian women with PCOS, lifestyle therapies should emphasize promoting physical exercise and minimizing sedentary behavior. This may be done by employing practical, culturally aware tactics that take into account the unique lives and tastes of India's many ethnic groups.

6.3. Socioeconomic and Cultural Influences

In India, socioeconomic and cultural variables might have a big influence on PCOS risk, diagnosis, and

treatment in various ethnic groupings. In India, women's access to healthcare and health-seeking behaviors are strongly influenced by socioeconomic position. Women from lower socioeconomic backgrounds were less likely to seek medical treatment for PCOS symptoms, according to a study by Bhattacharya and Jha [31]. This resulted in an underdiagnosis and delayed therapy.

The identification and acceptability of PCOS as a medical illness may also be influenced by cultural attitudes and views about women's health and fertility. Menstrual abnormalities and infertility are stigmatized in some traditional Indian societies, which causes social and psychological stress for women with PCOS [62]. Cultural dietary customs can also affect the risk for and treatment of PCOS. For instance, dietary preferences or limits may affect nutrient intake in some Indian ethnic groups, thereby aggravating metabolic abnormalities in PCOS. Treatment compliance and adherence may be impacted by cultural norms and beliefs. According to S. M. Vijayan [63], some women chose self-medication or traditional treatments for PCOS symptoms rather than seeking medical attention. Furthermore, differences in cultural practices might affect lifestyle elements like physical exercise. For instance, cultural prohibitions or customs may place limitations on physical exercise in some societies. In order to create effective treatments and management techniques that are sensitive to cultural differences and accessible to all Indian women, regardless of their ethnic backgrounds, it is imperative to address the impact of socioeconomic and cultural variables.

7. Challenges and Gaps in PCOS Research among Ethnic Populations

7.1. Lack of Representation in Research

One of the significant challenges in PCOS research among ethnic populations is the lack of representation of diverse ethnic groups in scientific studies. Historically, many research studies on PCOS have predominantly focused on populations of European descent, leading to a lack of comprehensive data on other ethnic groups, including those in India. This underrepresentation can result in biased conclusions and hinder the understanding of the unique genetic, environmental, and lifestyle factors that may influence PCOS in different ethnicities. A study by M Dapas et al. [64] highlighted the disparity in genetic studies, with a majority of the participants being of European ancestry, limiting the generalizability of findings to other ethnic populations. Moreover, the lack of diverse representation in research can contribute to disparities in healthcare access and treatment outcomes. Healthcare providers may not be adequately aware of the specific challenges and risk factors faced by different ethnic groups, leading to misdiagnosis or delayed diagnosis of PCOS in

non-represented populations.

To address this gap, there is a need for more inclusive and ethnically diverse research studies on PCOS. Collaborative efforts between researchers and healthcare institutions can help recruit and involve individuals from diverse ethnic backgrounds to ensure comprehensive and accurate findings that can inform targeted interventions and treatments for PCOS.

7.2. Misdiagnosis and Underdiagnosis

Misdiagnosis and underdiagnosis of PCOS are common challenges, particularly in ethnic populations where awareness and understanding of the condition may be limited. Studies have shown that PCOS is often underdiagnosed in women from certain ethnic backgrounds. A study by Hannah Wickham [65] reported that PCOS was frequently missed or misdiagnosed in Indian ethnic women, leading to delayed or inadequate management of the condition. The diagnostic criteria for PCOS, such as the Rotterdam criteria, may not always be applicable to all ethnic populations due to variations in symptom presentation and hormonal profiles [66]. This can result in discrepancies in the prevalence rates and hinder accurate assessments of PCOS prevalence among different ethnicities. Moreover, cultural norms and perceptions about women's health may impact the willingness of women to seek medical help for PCOS symptoms, leading to a lack of awareness and delayed diagnosis. A study by Bhattacharya and Jha [31] reported that cultural stigmatization surrounding menstrual irregularities and infertility affected women's health-seeking behaviors and hindered timely diagnosis and management. To address misdiagnosis and underdiagnosis, healthcare providers need to be better educated about the diverse clinical presentations of PCOS in different ethnic populations. Increasing awareness about PCOS and its symptoms in culturally sensitive ways can encourage women to seek timely medical help, leading to earlier diagnosis and appropriate management.

7.3. Cultural Stigmatization and Access to Healthcare

Cultural stigmatization surrounding women's health issues, including menstrual irregularities and infertility, can significantly impact access to healthcare for women with PCOS in different ethnic populations. In some Indian cultural settings, discussing reproductive health problems openly may be considered taboo or inappropriate, leading to a reluctance to seek medical help for PCOS symptoms. This cultural stigma can result in delayed diagnosis and limited access to appropriate healthcare services. Furthermore, cultural norms and gender roles may influence decision-making within families regarding seeking medical care for PCOS. Women may have limited autonomy in healthcare decisions, and their health concerns may not receive adequate attention or priority

[20]. A study from Assam, North East India revealed that a long-term personalized management program is required for effectively treating individuals with PCOS [67].

Cultural beliefs and traditional remedies may be preferred over modern medical treatments for PCOS, especially in regions where access to healthcare is limited or costly. This reliance on traditional practices can delay diagnosis and appropriate management of PCOS. To address cultural stigmatization and improve access to healthcare for women with PCOS, community-based educational programs that promote awareness and understanding of the condition are essential. Encouraging open discussions about reproductive health and breaking the silence around PCOS can help reduce stigma and improve healthcare-seeking behaviours among affected individuals. Healthcare providers should also be trained to provide culturally competent care, acknowledging and respecting the cultural beliefs and practices of patients while offering evidence-based treatments for PCOS.

8. Interventions and Management Strategies

8.1. Tailored Approaches for Different Ethnicities

Given the diversity among ethnic populations in India, it is crucial to adopt tailored approaches in the management and treatment of PCOS to address specific challenges and risk factors faced by different ethnic groups. Cultural beliefs, dietary practices, and lifestyle preferences vary among Indian ethnicities, and these factors can impact the effectiveness of interventions for PCOS. For instance, the study by Nidhi R et al. [23] emphasized the importance of cultural sensitivity in healthcare delivery to improve treatment adherence and outcomes in South Indian women with PCOS. Tailored dietary interventions that align with the traditional dietary patterns of specific ethnic groups may be more effective in improving metabolic parameters and insulin sensitivity [68]. Many Indian studies suggested the development of culturally adapted dietary counselling strategies to address the dietary habits of Indian women with PCOS [2, 69]. Additionally, physical activity programs should be tailored to suit the cultural preferences and lifestyle constraints of different ethnic populations. Promoting physical activities that are culturally accepted and enjoyable may enhance adherence to exercise regimens among women with PCOS [70]. Furthermore, raising awareness about PCOS within different ethnic communities through culturally appropriate educational programs and materials can help reduce the stigma surrounding the condition and encourage women to seek timely medical care [3]. Collaborative efforts between healthcare providers, researchers, and community leaders are essential in designing and implementing tailored interventions that can effectively address the unique needs and challenges faced by different ethnicities in India.

8.2. Lifestyle Modifications and Holistic Management

Lifestyle modifications and holistic management approaches are key components in the management of PCOS in different ethnic populations. Lifestyle interventions that focus on dietary changes and increased physical activities have been shown to improve metabolic parameters and hormonal imbalances in women with PCOS. Studies have demonstrated the effectiveness of lifestyle modifications in improving insulin sensitivity, reducing androgen levels, and promoting weight loss in Indian women with PCOS [71]. Holistic management of PCOS involves addressing not only the physical symptoms but also the psychological and emotional aspects of the condition [72]. Psychological support and counselling can help women cope with the emotional distress and body image issues associated with PCOS. Integrating mental health services into PCOS management can lead to improved quality of life and overall well-being. Moreover, holistic management may include complementary and alternative therapies, such as yoga and meditation, which have been shown to reduce stress and improve hormonal balance in women with PCOS.

A multidisciplinary approach that involves healthcare providers, dietitians, mental health professionals, and fitness experts is crucial in providing comprehensive care for women with PCOS. Individualized treatment plans that consider the cultural and lifestyle preferences of different ethnic groups can enhance treatment adherence and long-term outcomes.

Promoting a holistic approach to PCOS management can empower women to take charge of their health and make informed decisions about their well-being, ultimately improving the overall management of PCOS in diverse ethnic populations in India.

8.3. Pharmacological Interventions and their Effectiveness

Pharmacological interventions play a significant role in the management of PCOS, and their effectiveness has been studied in various ethnic populations.

1. **Oral Contraceptives:** Combined oral contraceptive pills (COCs) are commonly prescribed to regulate menstrual cycles and reduce androgen levels in women with PCOS. COCs have been shown to improve hormonal imbalances and reduce symptoms like hirsutism and acne in Indian women with PCOS [73].
2. **Metformin:** Metformin is an insulin-sensitizing drug that is frequently used to improve insulin resistance in women with PCOS. Studies have demonstrated the beneficial effects of metformin in Indian women with PCOS, including improved menstrual regularity and ovulation [74].
3. **Anti-androgens:** Anti-androgen medications, such as spironolactone, can help reduce excessive hair growth (hirsutism) and acne associated with PCOS. These medications have been found to be effective in improving cosmetic concerns in Indian women with PCOS [75].
4. **Letrozole:** Letrozole is an aromatase inhibitor that has been used as an alternative to clomiphene citrate for ovulation induction in women with PCOS. Studies have shown that letrozole may be more effective in achieving ovulation and pregnancy in Indian women with PCOS [32].

It is important to note that the response to pharmacological interventions can vary among different ethnic populations, and individualized treatment plans should be developed based on the patient's specific needs and medical history.

Long-term safety and efficacy of these medications in different ethnicities should also be considered. Healthcare providers need to closely monitor patients and adjust treatment regimens as needed to achieve optimal outcomes.

9. Future Perspectives

9.1. The Need for Ethnically Diverse Studies

As we move forward in PCOS research, there is a critical need for more ethnically diverse studies to gain a comprehensive understanding of the condition's impact on different populations, including those in India.

Currently, a significant proportion of PCOS research has been conducted on populations of European descent, leading to a lack of representation of other ethnic groups. This lack of diversity limits the generalizability of research findings and may result in biased conclusions about PCOS prevalence, risk factors, and treatment outcomes in different ethnicities.

Ethnically diverse studies are essential for several reasons:

1. **Accurate prevalence estimates:** Ethnically diverse studies can provide more accurate prevalence rates of PCOS within specific ethnic populations. Understanding the true burden of PCOS in different ethnicities is crucial for effective healthcare planning and resource allocation.
2. **Identifying genetic factors:** PCOS has a strong genetic component, and specific genetic variations may differ among ethnic groups. Ethnically diverse studies can help identify unique genetic risk factors for PCOS in different populations, leading to personalized treatments and interventions.
3. **Lifestyle and environmental factors:** Lifestyle and environmental factors, such as diet and physical activity, can impact PCOS risk and outcomes. Ethnically diverse studies can shed light on how these

factors influence PCOS within specific cultural contexts.

4. **Tailored interventions:** By including diverse ethnic populations, researchers can develop tailored interventions that address the unique challenges and risk factors faced by different communities. Culturally sensitive approaches to PCOS management can lead to improved treatment adherence and outcomes.
5. **Healthcare disparities:** Ethnically diverse studies can help identify healthcare disparities related to PCOS diagnosis, access to treatment, and healthcare utilization. Addressing these disparities is crucial for promoting equitable healthcare for all women with PCOS.

In conclusion, conducting ethnically diverse studies is essential for advancing our understanding of PCOS and tailoring effective interventions for different ethnic populations, including those in India. Collaborative efforts among researchers, healthcare providers, and community stakeholders are needed to ensure inclusive and representative research that benefits all women affected by PCOS.

9.2. Potential Areas of Research and Collaboration

In the field of PCOS research, several potential areas of investigation and opportunities for collaboration can enhance our understanding of the condition and improve its management, especially in the context of diverse ethnic populations in India.

1. **Genetic Studies:** Collaborative efforts to conduct large-scale genetic studies that include diverse ethnic groups can help identify specific genetic variations associated with PCOS risk and presentation in different populations. Understanding the genetic basis of PCOS in various ethnicities can pave the way for personalized treatments and precision medicine approaches.
2. **Epigenetics and Environment:** Investigating the role of epigenetics and environmental factors in PCOS development can provide valuable insights into how lifestyle, diet, and cultural practices contribute to the condition's prevalence and severity among different ethnic groups. Such research can inform targeted interventions to mitigate environmental risk factors.
3. **Longitudinal Studies:** Long-term follow-up studies tracking the progression and outcomes of PCOS in ethnically diverse populations can help identify unique patterns of disease manifestation and treatment responses. Longitudinal research can provide valuable data on the natural history of PCOS and the effectiveness of various management strategies over time.

4. **Access to Healthcare:** Collaborative studies that examine healthcare access and utilization among different ethnic populations with PCOS can shed light on disparities in diagnosis, treatment, and healthcare outcomes. Identifying barriers to healthcare and developing strategies to improve access to quality care are essential for reducing healthcare disparities.
5. **Lifestyle Interventions:** Comparative studies evaluating the effectiveness of lifestyle interventions (e.g., dietary modifications, physical activity programs) in diverse ethnic groups can guide the development of culturally sensitive lifestyle management strategies for PCOS.
6. **Mental Health and Quality of Life:** Research on the psychological and emotional aspects of PCOS in ethnically diverse populations can help design comprehensive care models that address mental health issues and improve the overall quality of life for women with PCOS.
7. **Health Economics:** Collaborative studies examining the economic burden of PCOS and the cost-effectiveness of various interventions can inform health policy decisions and resource allocation.

To achieve progress in these areas, collaborations between researchers, healthcare institutions, community organizations, and policymakers are crucial. Multidisciplinary research teams that include experts from diverse fields can bring varied perspectives and skills to address the complex challenges of PCOS in different ethnic populations.

Furthermore, engaging with patient advocacy groups and involving affected individuals in research design and implementation can ensure that research priorities align with the needs and concerns of women with PCOS.

By prioritizing these potential areas of research and fostering collaboration, we can advance knowledge, promote equitable healthcare, and improve the quality of life for women affected by PCOS, irrespective of their ethnic backgrounds.

9.3. Implications for Policy and Healthcare

The research findings and collaborations in PCOS can have significant implications for policy and healthcare in India, particularly concerning the management and support for women with PCOS from diverse ethnic backgrounds. Some key implications include:

1. **Inclusive Healthcare Policies:** The evidence from ethnically diverse studies can inform policymakers about the diverse needs and challenges faced by women with PCOS in different ethnic populations. Policymakers can use this information to develop inclusive healthcare policies that address disparities in access to diagnosis, treatment, and support services.

2. **Culturally Sensitive Interventions:** Research on tailored interventions for different ethnic groups can guide the development of culturally sensitive healthcare practices. Healthcare providers can be trained to understand and respect cultural beliefs and preferences, leading to improved patient-provider communication and treatment adherence.
3. **Early Diagnosis and Awareness:** Research outcomes can influence public health campaigns and educational initiatives to raise awareness about PCOS, its symptoms, and its impact on women's health. Early diagnosis and intervention can be promoted through targeted awareness campaigns in diverse communities.
4. **Integration of Mental Health Services:** Understanding the psychological and emotional aspects of PCOS can underscore the importance of integrating mental health services into PCOS management. Policy support can be provided to facilitate the availability of mental health support for women with PCOS.
5. **Insurance Coverage and Accessibility:** Policymakers can consider revising health insurance coverage to include essential services related to PCOS diagnosis and treatment. Additionally, measures can be taken to ensure accessibility to affordable medications and treatments for PCOS, especially for disadvantaged communities.
6. **Research Funding:** Policymakers can allocate research funding to support ethnically diverse studies on PCOS, recognizing the importance of inclusive research in addressing health disparities and improving healthcare outcomes.
7. **Health Professional Training:** The implications of research can drive changes in medical and allied health professional training. Medical schools and healthcare training programs can incorporate culturally competent education to enhance the understanding and care of women with PCOS from diverse backgrounds.
8. **Health Equity and Advocacy:** The evidence from research can empower advocacy groups to champion the cause of women with PCOS and promote health equity. Collaboration between researchers and advocacy organizations can amplify the voices of affected individuals in shaping policy decisions.

Overall, the implications of research on PCOS for policy and healthcare can create an enabling environment for providing comprehensive and equitable care to women with PCOS from diverse ethnic populations in India. By addressing the unique challenges faced by different communities, these initiatives can improve the overall health and well-being of women affected by PCOS in the country.

10. Conclusions

In conclusion, Polycystic Ovary Syndrome (PCOS) is a complex endocrine disorder that affects a substantial number of women worldwide, with significant implications for reproductive, metabolic, and psychological health. In recent years, the prevalence and impact of PCOS in different ethnic populations have garnered increasing attention. India is a country known for its diverse ethnic groups. According to this meta-analysis, PCOS is highly prevalent in women of Indian ethnicity. It has been observed that there is a significant difference in the symptoms presented across geographical locations and between different ethnic groups.

This comprehensive meta-analysis and review have highlighted the importance of considering ethnicity in understanding the prevalence, clinical manifestations, genetic factors, and impact of environmental and lifestyle factors on PCOS in India. The research findings underscore the need for ethnically diverse studies to provide accurate prevalence rates, identify unique genetic variations, and tailor interventions for different ethnic groups.

The review has also shed light on the challenges faced by women with PCOS from diverse backgrounds, including misdiagnosis, cultural stigmatization, and limited access to healthcare. Tailored approaches, including lifestyle modifications, holistic management, and pharmacological interventions, have been discussed as key components of effective PCOS management.

The implications of this research for policy and healthcare are far-reaching. Policymakers can use the evidence to develop inclusive healthcare policies, improve awareness, and promote equitable access to healthcare for women with PCOS. Culturally sensitive interventions can enhance the patient-provider relationship and support women in managing their condition effectively.

Looking ahead, collaborative efforts among researchers, healthcare institutions, community organizations, and policymakers are crucial to advancing knowledge, addressing healthcare disparities, and improving the quality of life for women affected by PCOS in India. By working together, we can pave the way for a brighter future, where all women with PCOS receive the support and care they need to lead healthier lives, regardless of their ethnic backgrounds.

Conflict of Interest

There is no conflict of interest among the authors.

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