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The Impact of Obesity, Smoking, Family History, and Hirsutism on Polycystic Ovarian Syndrome (PCOS) in Women of Reproductive Age: A Meta-Analysis

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Abstract

Polycystic ovarian syndrome (PCOS) is one of the most prevalent endocrine disorders among women of reproductive age. According to WHO (2023), PCOS affects approximately 8–13% of women of reproductive age. Several studies have reported that lifestyle, hormonal, and genetic factors are among the risk factors for PCOS. This study aimed to analyze and estimate the impact of obesity, smoking, family history, and hirsutism on the incidence of PCOS among women of reproductive age. This meta-analysis was conducted based on the PICO model. The population was women of reproductive age. The exposures included obesity, smoking, family history, and hirsutism, with comparison groups of normal weight, non-smoking, no family history, and no hirsutism. The outcome was PCOS. The databases used were Google Scholar, PubMed, BMC, ScienceDirect, and Springer Link. The keywords used were ("determinant" OR "risk factor") AND "obesity" AND "smoking" AND "family history" AND "hirsutism" AND ("PCOS" OR "polycystic ovarian syndrome") AND "cross-sectional" AND ("multivariate" OR "odds ratio"). The inclusion criteria were full-text articles with an observational study design, reported adjusted odds ratios (aORs), and were published between 2017 and 2025. Data analysis was performed using Review Manager 5.3. This meta-analysis included 14 cross-sectional studies conducted in China, Australia, Pakistan, Saudi Arabia, India, Indonesia, the United States, Kuwait, Bangladesh, and Jordan, with a total sample size of 17,136 women of reproductive age. Obesity (aOR=2.01; 95% CI: 1.22–3.33; p<0.001), family history (aOR=3.05; 95% CI: 2.09–4.44; p<0.001), and hirsutism (aOR=2.19; 95% CI: 1.54–3.11; p<0.001) were significantly associated with an increased risk of PCOS. The association between smoking and PCOS was not statistically significant (aOR=1.10; 95% CI: 0.91–1.73; p=0.31). In conclusion, obesity, family history, and hirsutism were significantly associated with an increased risk of PCOS among women of reproductive age.

Keywords: Obesity; Smoking; Family history; Hirsutism; Polycystic ovary syndrome (PCOS)

Introduction

Polycystic Ovary Syndrome (PCOS) is one of the most common endocrine disorders among women of reproductive age, characterized by hormonal imbalance leading to clinical manifestations such as obesity, hirsutism, menstrual irregularities, anovulation, infertility, and increased risk of metabolic and cardiovascular diseases(Rizvi et al., 2023; Tay et al., 2023). Furthermore, PCOS is strongly associated with psychological comorbidities including depression and anxiety, making it a complex and multidimensional health problem (Alshdaifat et al., 2021).

According to the World Health Organization (WHO), PCOS affects approximately 6–13% of women of

reproductive age, with up to 70% of cases remaining undiagnosed (Khatun et al., 2025). A global meta-analysis reported an overall prevalence of 9.2% (95% CI: 6.8–12.5%), varying by diagnostic criteria: 5.5% (NIH), 11.5% (Rotterdam), and 7.1% (AES) (Yang et al., 2022). Other reports estimate prevalence ranging between 4–20%, depending on population and diagnostic methods (Alraddadi et al., 2018). From 1990 to 2021, global trends demonstrated sharp increases, with prevalence rising by 154%, incidence by 114%, and disability-adjusted life years (DALYs) by 154% (Alenzi et al., 2024). In 2021, the age-standardized incidence, prevalence, and DALYs were 30.7 per 100,000, 867.7 per 100,000, and 7.6 per 100,000, respectively representing 27–28% increases compared to 1990.

The clinical consequences of PCOS are profound. It is a leading cause of anovulation and infertility, with long-term sequelae including type 2 diabetes, hypertension, dyslipidemia, cardiovascular disease, sleep apnea, and increased risk of endometrial cancer (Alkhezi et al., 2024). The Centers for Disease Control and Prevention (CDC) highlights that PCOS is strongly linked to both metabolic and mental health conditions, significantly impairing women's quality of life.

Regional epidemiology reveals substantial variations. In China, prevalence increased from 5.6% (2010) to 7.8% (2020) (Yang et al., 2022). In Saudi Arabia, one study estimated prevalence at 31.8%, while another in Madinah reported 32.5% (Alraddadi et al., 2018). In South Asia, PCOS accounts for 38.5% of infertility cases in Pakistan (Rizvi et al., 2023), whereas in India, prevalence is higher in urban than in rural populations (Bharathi et al., 2017). A recent Bangladeshi study reported prevalence as high as 61% among reproductive-aged women (Khatun et al., 2025). Across these studies, obesity, family history, smoking, and hirsutism consistently emerge as significant risk factors for PCOS (Alkhezi et al., 2024; Tay et al., 2023).

Despite its high prevalence, PCOS often remains underdiagnosed or diagnosed late, increasing the likelihood of long-term complications (Alshdaifat et al., 2021).Lack of awareness and limited early detection strategies represent major challenges to effective management. Therefore, a comprehensive meta-analysis is urgently needed to estimate the impact of key risk factors on PCOS.

This study aims to analyze the effects of obesity, smoking, family history, and hirsutism on the occurrence of PCOS in women of reproductive age. The findings are expected to provide robust scientific evidence to inform preventive strategies, early detection, and the design of effective public health interventions to address PCOS.

Methods

Study Design

This study is a systematic review and meta-analysis guided by PRISMA flowcharts. The databases used involve Google Scholar, PubMed, BMC, ScienceDirect, and Springer Link. The keywords used are ("determinant" OR "risk factor") AND "obesity" AND "smoking" AND "family history" AND "hirsutism" AND ("PCOS" OR "polycystic ovarian syndrome") AND "cross-sectional" AND ("multivariate" OR "odds ratio").

Steps of Meta-Analysis

Meta analysis was carried out in the following 5 steps:

1) Formulate questions in PICO format (Population, Intervention, Comparison, Outcome).
2) Search for primary articles from databases such as Google Scholar, PubMed, BMC, ScienceDirect, and Springer Link.

3) Carry out screening by determining inclusion and exclusion criteria and conducting quality assessments.
4) Extract and analyze data using RevMan 5.3 Software.
5) Interpret the results and draw conclusions

Inclusion Criteria

The authors developed inclusion criteria, namely English-language articles with cross-sectional studies, published between 2017-2025. The analysis used is a multivariate analysis with an adjusted odds ratio (aOR). The subjects of the study were women of reproductive age aged 15-49 years, and the results analyzed were PCOS.

Exclusion Criteria

The exclusion criteria in this study were case-control studies, cohort studies, RCT (randomized controlled trials) studies, quasi-experiments, research protocols, preliminary studies, non-full text articles.

Operational Definition of Variable

Table 1. Operational Definition of Variable

No	Variables	Operational Definition	Measurement / Data Source	Category
1.	*Polycystic Ovary Syndrome* (PCOS)	A hormonal disorder among women of reproductive age diagnosed based on established clinical criteria (e.g. Rotterdam criteria: oligo/anovulation, clinical or biochemical hyperandrogenism, and/or polycystic ovarian morphology)	Medical record and/or structured questionnaire based on physician diagnosis	PCOS
2.	Obesity	Excess body fat determined by Body Mass Index (BMI) calculated from weight and height measurements	Anthropometric measurement (BMI = kg/m²)	Obese (BMI ≥ 30 kg/m²)
3.	Smoking	Smoking behavior of the respondent at the time of data collection	Self-reported structured questionnaire	Smoker
4.	Family History	Presence of a history of PCOS among first-degree female relatives (mother or sister)	Structured questionnaire	Having Family History
5.	Hisrutism	Excessive terminal hair growth in androgen-dependent areas indicating clinical hyperandrogenism	Clinical assessment or questionnaire (e.g. Ferriman–Gallwey score)	Having Hirsutism

Instrument

Primary studies that have been screened will undergo a critical appraisal or review of studies to determine feasibility. The assessment instrument uses the Critical Appraisal Cross-Sectional Study for Meta-analysis Research published by the Master of Public Health, Sebelas Maret University Surakarta (Murti, 2023).

Data Analysis

Article search results are collected with the help of PRISMA diagrams. Main articles that fit the inclusion criteria were analyzed using the RevMan 5.3 application to calculate effect size and study heterogeneity. The results of data processing are represented as [OR, 95% confidence interval, and p value] using the Mantel-Haenszel method for meta-analysis and presented in the form of forest plots and funnel plots.

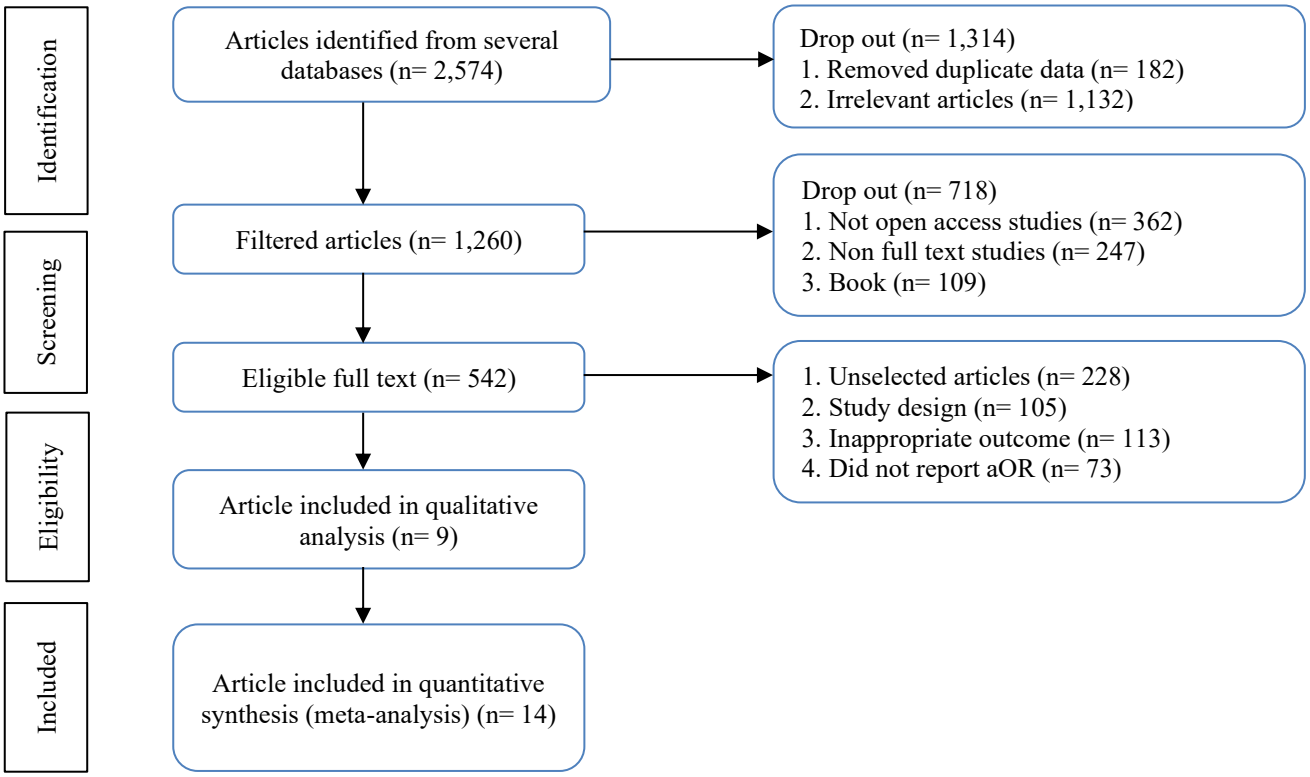

Figure 1. Results of PRISMA flow diagrams

Results

Study Characteristics

The baseline data resulted in 2,574 potentially relevant articles. PRISMA's literature search flowchart and its results are reported in Figure 1 based on selection criteria, a total of 542 articles were identified for further full-text assessment. In the end, 14 full-text articles cross-sectional studies were included for the meta-analysis. Furthermore, in Table 1 researchers assess the quality of study articles. Table 2 is a description of the 14 major studies that have been selected and meet the assessment criteria. The articles come from 10 different country, namely 1 article from China, 2 articles from Australia, 1 article from Pakistan, 3 articles from Saudi Arabia, 2 articles from India, 1 article from Indonesia, 1 article from the United States, 1 article from Kuwait, 1 article from Bangladesh, and 1 article from Jordan. The total sample was 17,136 women of reproductive age.

Table 2. Critical appraisal for cross-sectional study of the effect of obesity, smoking, family history, and hirsutism on PCOS

Author (Year)	Checklist Question													Total
	1a	1b	1c	1d	2a	2b	3a	3b	4	5	6a	6b	7	
Yang et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Tay et al. (2023)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Rizvi et al. (2023)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Alraddadi et al (2018)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Tripathi et al (2021)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Bharathi et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Said et al. (2024)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Mohmed et al (2023)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Alenzi et al. (2024)	2	2	2	2	2	2	2	2	2	2	2	2	2	26

Moran et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Oladipupo et al (2022)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Alkhezi et al. (2024)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Khatun et al. (2025)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
Alshdaifat et al (2021)	2	2	2	2	2	2	2	2	2	2	2	2	2	26

Table 3. Description of the question criteria for cross-sectional studies

No	Question	Description of the question criteria
1.	Formulation of study questions in the acronym PICO	a) Is the population in the primary study the same as the population in the PICO meta-analysis?
		b) Is the operational definition of the intervention, i.e. exposure status in the primary study the same as the definition intended in the meta-analysis?
		c) Is the comparator, i.e. non-exposure status used by the primary study the same as the definition intended in the meta-analysis?
		d) Are the outcome variables studied in the primary study the same as the definitions intended in the meta-analysis?
2.	Methods for choosing a subject of study	a) In cross-sectional analytical studies, do researchers randomly select a sample from the population?
		b) Alternatively, if in an analytically cross-sectional study the sample is not randomly selected, do researchers select the sample based on outcome status or based on intervention status?
3.	Methods for measuring exposure and outcome variables	a) Were both exposure and outcome variables measured with the same instruments in all primary studies?
		b) If variables are measured on a categorical scale, are the cutoffs or categories used the same between primary studies?
4.	Design-related bias	If the sample is not randomized, have researchers done anything to prevent bias in choosing research subjects?
5.	Methods for controlling redundancy	Have primary study researchers made efforts to control the influence of confusion?
6.	Statistical analysis methods	a) Did the researchers analyze the data in this primary study with a multivariate analysis model?
		b) Does the primary study report the effect size or relationship of the results of the multivariate analysis?
7.	Conflict of interest	Is there no possibility of a conflict of interest with the sponsor of the study, which causes bias in concluding the results of the study?

Assessment instructions:

1) Total number of questions = 13 questions.
2) A "Yes" answer to each question gives a score of "2". The answer "Undecided" gives a score of "1". The answer "No" gives a score of "0".
3) Maximum total score = 13 questions x 2 = 26.
4) Total number of minium scores= 13 questions x 0 = 0. So the total score ranges for a primary study between 0 and 26.

5) If the total score of a primary study ≥ 22, then the study can be included in the meta-analysis. If the total score of a primary study < 22, then the study was excluded from the meta-analysis.

Tabel 4. Description of the primary studies included in the meta-analysis

Author (Year)	Country (Sample) Study Design	Population	Intervention	Comparison	Outcome
Yang et al. (2022)	China (826) Cross-Sectional	Women of reproductive age	1. Obesity 2. Smoking	1. Normal Weight 2. Not Smoking	PCOS
Tay et al. (2023)	Australia (942) Cross-Sectional	Women aged 24-30 years old	1. Obesity 2. Smoking	1. Normal Weight 2. Not Smoking	PCOS
Rizvi et al. (2023)	Pakistan (646) Cross-Sectional	Female undergraduate students 18 years above	1. Obesity 2. Having Family History	1. Normal Weight 2. Not Having a Family History	PCOS
Alraddadi et al (2018)	Saudi Arabia (234) Cross-Sectional	Women aged 18-45 years old	1. Obesity 2. Having Family History	1. Normal Weight 2. Not Having a Family History	PCOS
Tripathi et al (2021)	India (1200) Cross-Sectional	Women aged 18-30 years old	1. Obesity 2. Having Family History 3. Having Hirsutism	1. Normal Weight 2. Not Having a Family History 3. Not Having a Hirsutism	PCOS
Bharathi et al. (2017)	India (502) Cross-Sectional	Women aged 18-24 years old	1. Obesity 2. Having Family History	1. Normal Weight 2. Not Having a Family History	PCOS
Said et al. (2024)	Indonesia (402) Cross-Sectional	Women aged 15-19 years old	1. Obesity 2. Having Family History 3. Having Hirsutism	1. Normal Weight 2. Not Having a Family History 3. Not Having a Hirsutism	PCOS
Mohmed et al (2023)	Saudi Arabia (1080) Cross-Sectional	Women of reproductive age	1. Obesity 2. Having Family History 3. Having Hirsutism	1. Normal Weight 2. Not Having a Family History 3. Not Having a Hirsutism	PCOS
Alenzi et al. (2024)	Saudi Arabia (1,068) Cross-Sectional	Women of reproductive age	Smoking	Not smoking	PCOS
Moran et al. (2017)	Australia (7767) Cross-Sectional	Women aged 18-23 years old	Smoking	Not smoking	PCOS
Oladipupo et al (2022)	The United States (199) Cross-Sectional	Women aged 21 years old above	Smoking	Not smoking	PCOS
Alkhezi et al. (2024)	Kuwait (588) Cross-Sectional	Women aged 18-25 years old above	1. Having Family History 2. Having Hirsutism	1. Not Having a Family History 2. Not Having a Hirsutism	PCOS
Khatun et al. (2025)	Bangladesh (500) Cross-Sectional	Women aged 21-25 years old	1. Having Family History 2. Having Hirsutism	1. Not Having a Family History 2. Not Having a Hirsutism	PCOS
Alshdaifat et al (2021)	Jordan (1182) Cross-Sectional	Women aged 18 years old above	Having a Hirsutism	Not Having Hirsutism	PCOS

Correlation of Obesity with PCOS

Figure 2 presents a forest plot on the effect of obesity on PCOS risk in women of productive age. Women with obesity had 2.01 times the risk of developing PCOS compared to non-obese (aOR= 2.01; 95% CI: 1.22–3.33; p<0.001). The forest plot also showed high heterogeneity, estimated effect between studies (I^2= 85%). Thus, calculating the average effect estimation using a random effect model approach.

Figure 3 shows a funnel plot on the estimated distribution of the effects of obesity on PCOS risk. The funnel plot demonstrates a relatively symmetrical distribution of studies, suggesting a low risk of publication bias. The observed heterogeneity is likely due to variations in study populations, research designs, and diagnostic criteria for PCOS rather than selective reporting.

Table 5. Adjusted Odds Ratio (aOR) Value of The Effect of Obesity on PCOS

Author (Year)	aOR	95% CI	
		Lower Limit	Upper Limit
Yang et al. (2022)	2.77	2.20	3.48
Tay et al. (2023)	1.01	0.55	1.85
Rizvi et al. (2023)	2.34	1.27	1.27
Alraddadi et al (2018)	0.98	0.51	1.86
Tripathi et al (2021)	6.54	2.14	20.01
Bharathi et al. (2017)	0.60	0.34	1.07
Said et al. (2024)	3.15	2.01	4.93
Mohmed et al (2023)	6.44	2.12	19.53

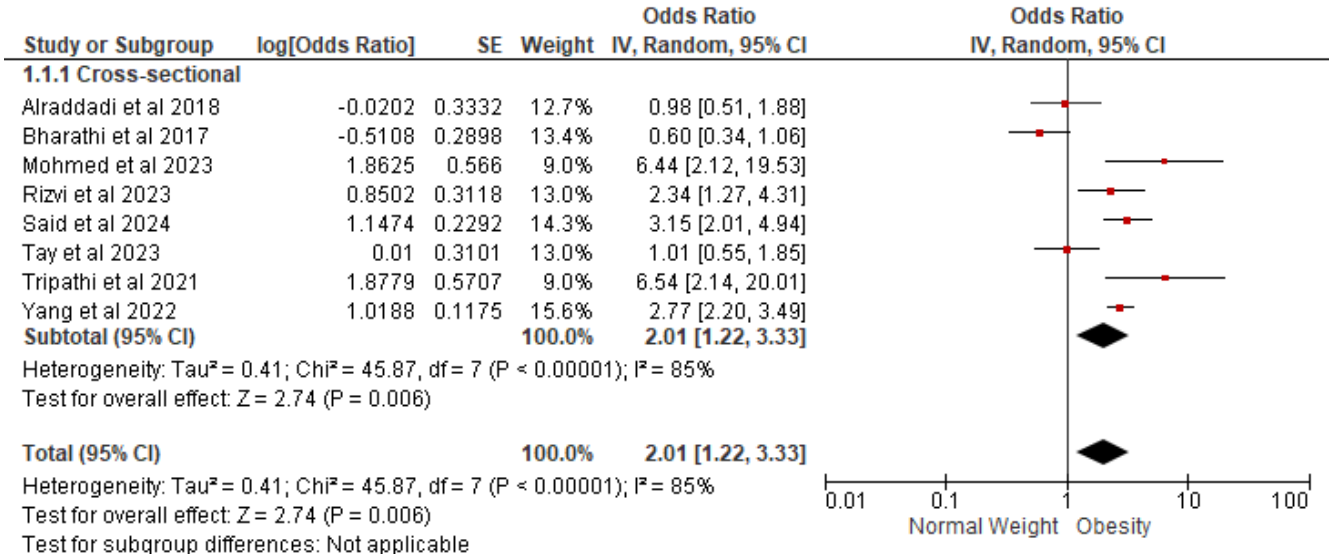

Figure 2. Forest Plot Value of The Effect of Obesity on PCOS

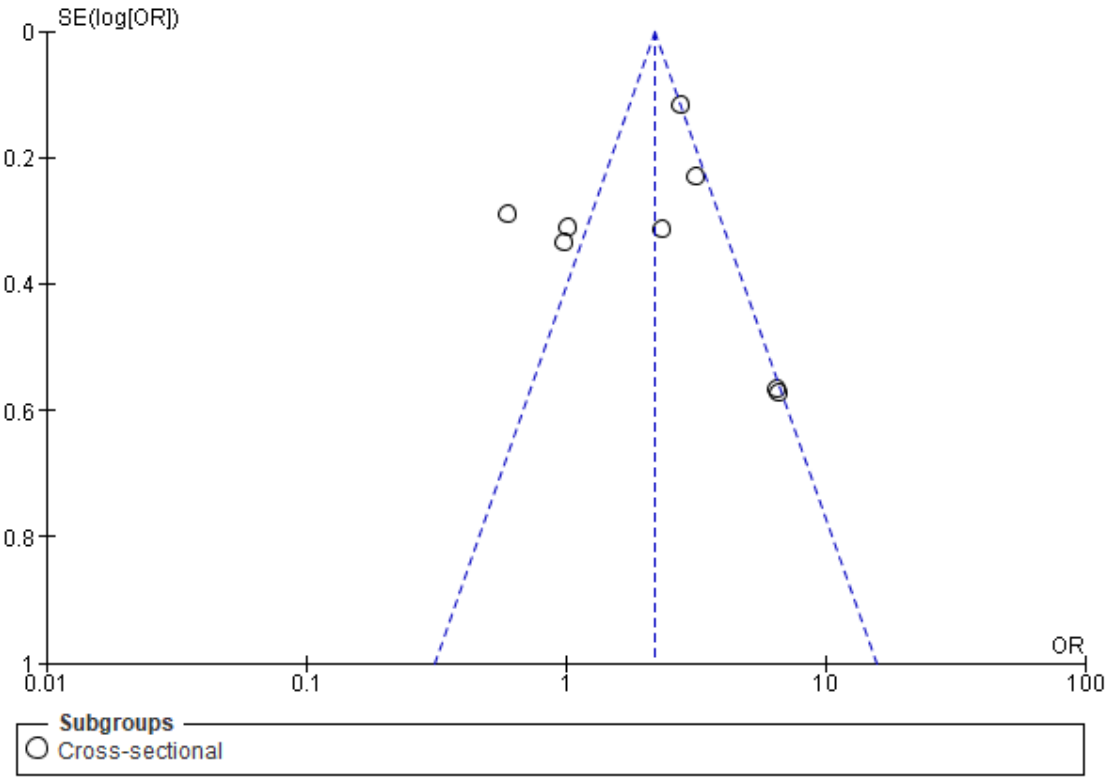

Figure 3. Funnel Plot Value of The Effect of Obesity on PCOS

Correlation of Smoking with PCOS

Figure 4 presents a forest plot on the effect of smoking on PCOS risk in women of productive age. Women with smoking habits have a risk of developing PCOS 1.10 times compared to nonsmokers (aOR=1.10; 95% CI: 0.91–1.73; p=0.31), but this finding was not statistically significant (p = 0.31). The forest plot showed low heterogeneity, estimated effect between studies ($I^2 = 21\%$). Thus, calculating the average effect estimation using a random effect model approach.

Figure 5 shows a funnel plot on the estimated distribution of the effects of smoking on PCOS risk. The funnel plot shows that the distribution of effect estimates is balanced to the right and left of the average vertical line. Thus, the funnel plot indicating a low risk of publication bias.

Table 6. Adjusted Odds Ratio (aOR) Value of The Effect of Smoking on PCOS

Author (Year)	aOR	95% CI	
		Lower Limit	Upper Limit
Yang et al. (2022)	1.11	0.78	1.55
Tay et al. (2023)	0.90	0.61	1.33
Alenzi et al. (2024)	1.64	0.71	3.79
Moran et al. (2017)	1.60	1.02	2.52
Oladipupo et al (2022)	0.62	0.24	1.56

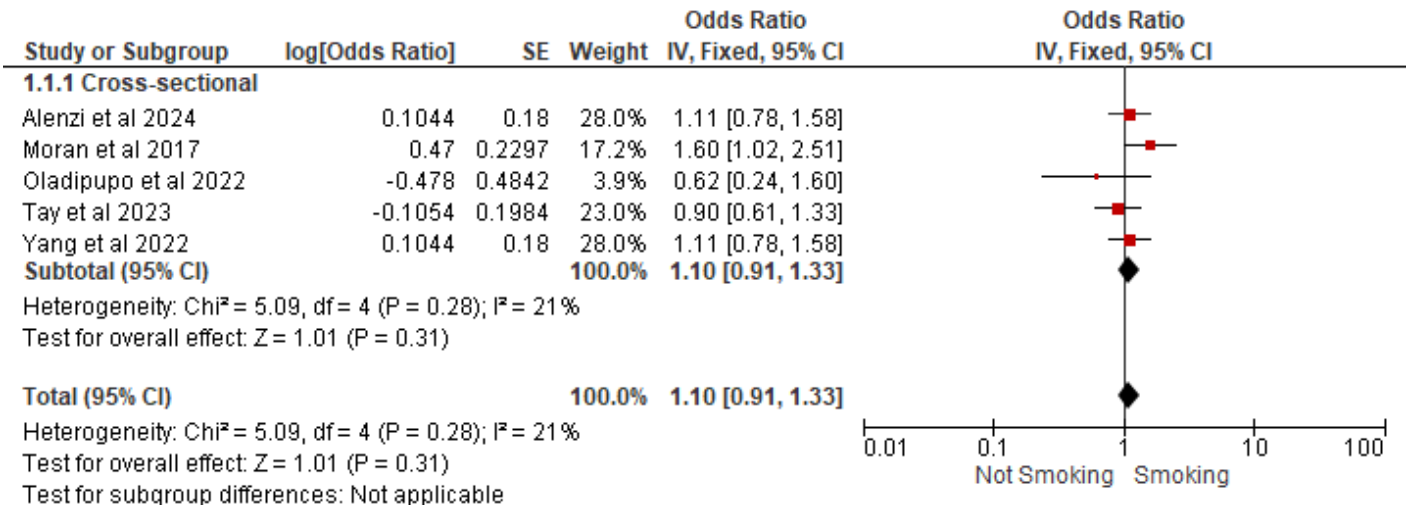

Figure 4. Forest Plot Value of The Effect of Smoking on PCOS

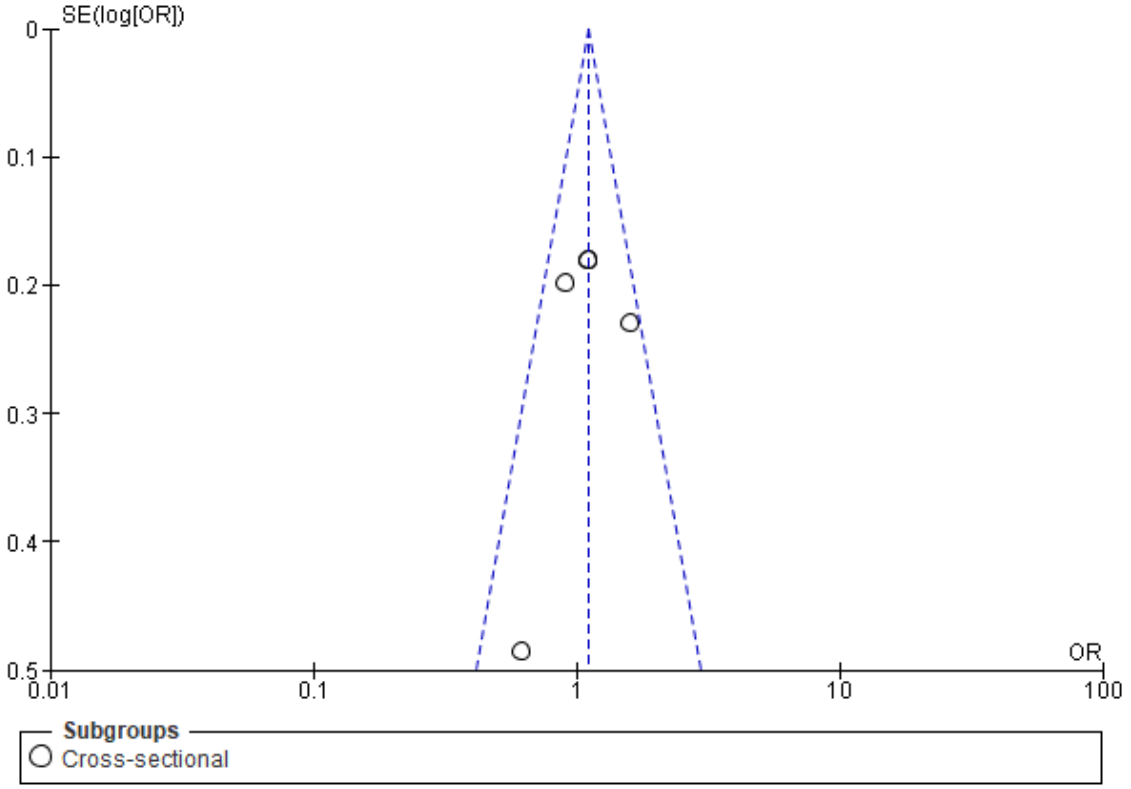

Figure 5. Funnel Plot Value of The Effect of Smoking on PCOS

Correlation of Family History with PCOS

Figure 6 presents a forest plot on the effect of family history of PCOS-on-PCOS risk in women of productive age. Women with a family history of PCOS had a 3.05 times higher risk of having PCOS than no family history of PCOS (aOR=3.05; 95% CI: 2.09–4.44; p<0.001).

The forest plot also showed a large heterogeneity of the effect of the study (I^2= 65%). Thus, the calculation of the average effect estimation is done with a random effect model. Figure 7 shows a funnel plot on the estimated distribution of the effects of family history on PCOS risk. The funnel plot shows that the distribution of effect estimates between studies is more or less balanced to the right and left of the mean vertical line. Thus, the funnel plot does not show any publication bias.

Table 7. Adjusted Odds Ratio (aOR) Value of The Effect of Family History on PCOS

Author (Year)	aOR	95% CI	
		Lower Limit	Upper Limit
Rizvi et al. (2023)	2.01	1.19	4.18
Alkhezi et al. (2024)	3.49	1.93	6.29
Alraddadi et al (2018)	1.30	0.80	1.90
Bharathi et al. (2017)	5.08	2.79	9.27
Said et al. (2024)	2.48	1.55	3.96
Khatun et al. (2025)	5.11	2.32	11.31
Tripathi et al (2021)	4.72	1.87	11.90
Mohmed et al (2023)	4.62	1.86	11.50

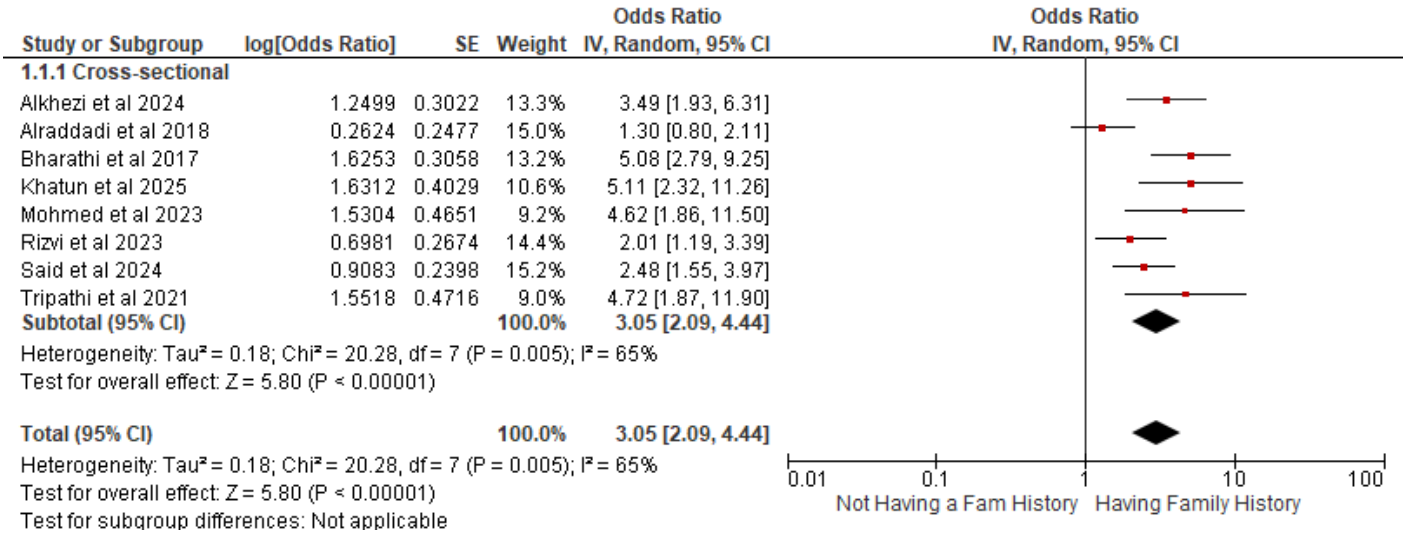

Figure 6. Forest Plot Value of The Effect of Having Family History on PCOS

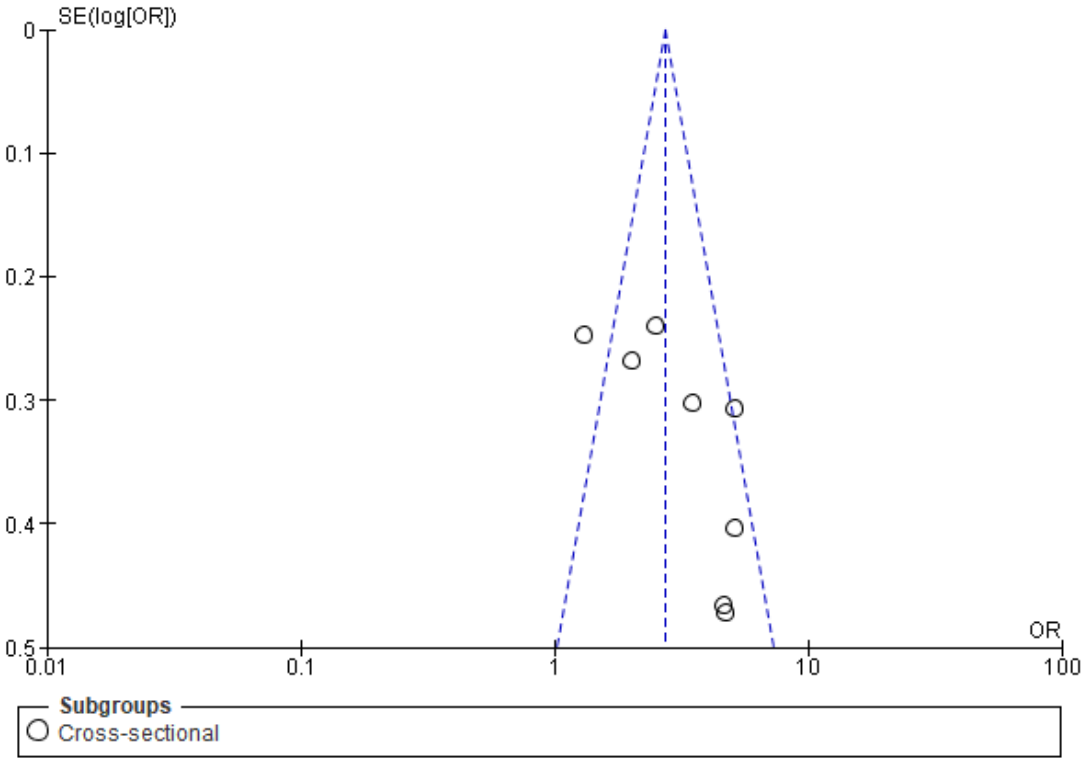

Figure 7. Funnel Plot Value of The Effect of Having Family History on PCOS

Correlation of Hirsutism with PCOS

Figure 8 presents a forest plot on the effect of hirsutism on PCOS risk in women of productive age. Women with hirsutism have a risk of developing PCOS 2.19 times compared to no hirsutism (aOR= 2.19; 95% CI: 1.54-3.11; p<0.001). The forest plot also showed a large heterogeneity of the effect of the study (I^2= 67%). Thus, the calculation of the average effect estimation is done with a random effect model.

Table 8. Adjusted Odds Ratio (aOR) Value of The Effect of Hirsutism on PCOS

Author (Year)	aOR	95% CI	
		Lower Limit	Upper Limit
Alkhezi et al. (2024)	3.58	2.06	2.06
Alshdaifat et al (2021)	1.36	0.73	0.73
Khatun et al. (2025)	3.55	6.21	2.06
Mohmed et al (2023)	1.48	1.48	2.26
Said et al. (2024)	2.79	2.79	4.21
Tripathi et al (2021)	1.54	1.54	2.50

Figure 9 shows a funnel plot on the estimated distribution of the effects of hirsutism on PCOS risk. the funnel plot indicated that the studies were relatively symmetrically distributed around the central line, suggesting a low risk of publication bias. These findings strengthen the evidence that hirsutism is an important clinical factor closely associated with the occurrence of PCOS.

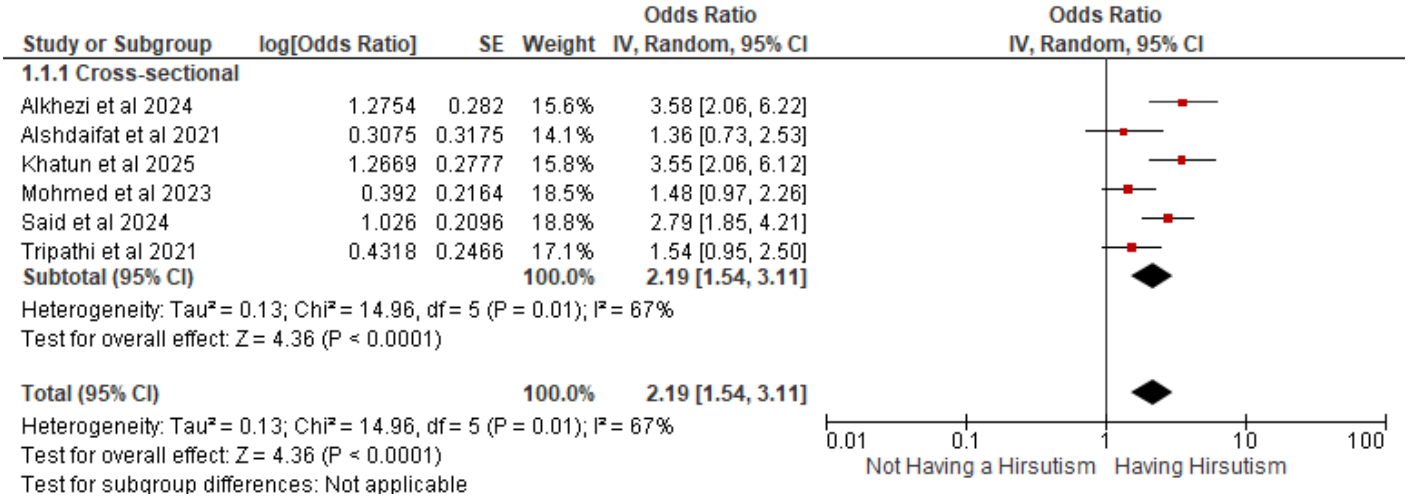

Figure 8. Forest Plot Value of The Effect of Having Hirsutism on PCOS

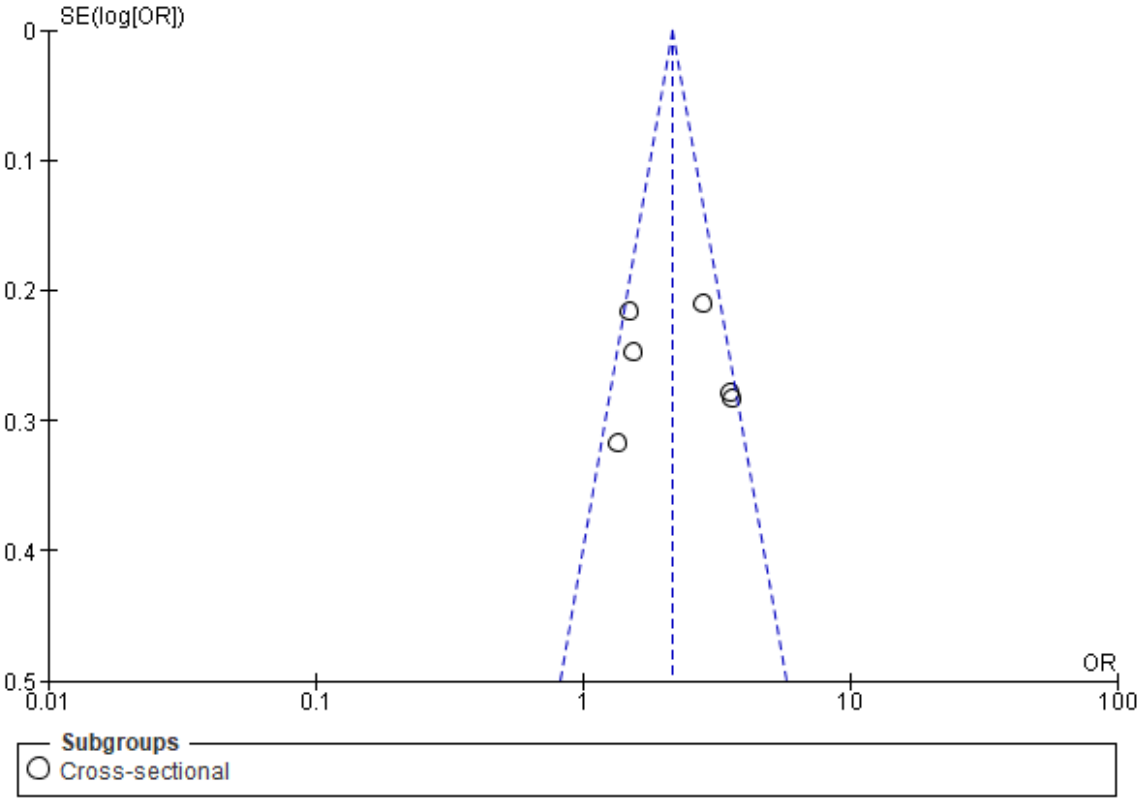

Figure 9. Funnel Plot Value of The Effect of Having Hirsutism on PCOS

Discussion

Obesity with PCOS

A total of eight articles from different countries were included to estimate the effect size of obesity on PCOS. The findings consistently indicate a strong association between obesity and the development of PCOS. Evidence demonstrates that women with obesity have a markedly higher likelihood of experiencing PCOS compared with women of normal weight. For instance, (Sirmans et al., 2013) reported that over 50% of women diagnosed with PCOS were obese, underscoring the strong correlation between these two conditions. Beyond increasing the risk of PCOS onset, obesity also influences its clinical manifestations by altering hormonal balance and aggravating insulin resistance, which are central mechanisms in PCOS pathophysiology (Kaur et al., 2022; Makhija et al., 2023). Insulin resistance leads to compensatory hyperinsulinemia that enhances ovarian androgen production, reduces hepatic sex hormone-binding globulin (SHBG), and consequently increases bioavailable androgens, thereby exacerbating PCOS symptoms such as menstrual irregularities, infertility, and polycystic ovarian morphology (Hanedan et al., 2022; (Peeva et al., 2022); West et al., 2014).

Furthermore, obesity-related low-grade chronic inflammation is thought to contribute significantly to the progression of PCOS by amplifying oxidative stress and metabolic dysfunction (Stokkeland et al., 2022; Escobar-Morreale, 2018). Conversely, PCOS itself may predispose women to weight gain and obesity, creating a bidirectional relationship. Hormonal disturbances, particularly hyperandrogenism and impaired metabolic regulation, make weight management challenging for women with PCOS, further complicating their clinical outcomes (Witchel et al., 2019; Lim et al., 2019). In addition, lifestyle factors such as smoking and dietary habits are also associated with increased ovulatory dysfunction and may exacerbate reproductive and metabolic disturbances in PCOS (Yang et al., 2022; Barrea et al., 2019)

Smoking with PCOS

There are five articles from several countries that were included to measure the magnitude of the effect of smoking on PCOS. Although the pooled results from this meta-analysis indicated no statistically significant association, individual studies have consistently shown that smoking may negatively affect ovarian function and endocrine balance. Previous evidence has suggested that smoking is linked to impaired ovarian reserve and altered reproductive hormones, which could exacerbate the risk of PCOS (Özay & Özay, 2020); Tao et al., 2021). The study of Özay & Özay (2020) demonstrated that smoking reduces ovarian stromal blood flow, with markedly higher pulsation and resistance indices observed in both ovaries of smokers compared to non-smokers, suggesting vascular stiffness and endothelial dysfunction as underlying mechanisms. In addition, Tao et al. (2021) reported that smoking was positively correlated with circulating androgen levels, indicating its impact on androgen metabolism and PCOS symptoms such as menstrual irregularity and hyperandrogenism.

Furthermore, Oladipupo et al. (2022) highlighted that smoking contributes to vascular dysfunction through hemodynamic changes, increased stiffness, and endothelial damage, all of which may impair ovarian perfusion. This is consistent with the meta-analysis findings where smoking was associated with an elevated but non-significant risk, indicating that while smoking may not independently increase PCOS risk, it can act as an exacerbating factor in the presence of other risks such as obesity or family history. Supporting this, Coffin et al. (2023) found that PCOS often coexisted with family history, reinforcing the multifactorial nature of the syndrome. Similarly, Tahir et al. (2020) reported familial clustering of PCOS symptoms among medical students, where 12.6% had mothers or sisters with PCOS, indicating shared genetic and environmental influences such as lifestyle factors, including smoking.

Additional research has also shown that smoking accelerates oxidative stress and increases inflammatory cytokines (Jandíková et al., 2017), which are mechanisms already implicated in the pathophysiology of PCOS (Stokkeland et al., 2022). Therefore, even though the present analysis did not confirm a significant independent effect of smoking, the biological plausibility supported by prior studies suggests that smoking remains a critical modifiable risk factor that can worsen the clinical course of PCOS.

Family History with PCOS

There are eight articles from different countries included to measure the magnitude of the influence of family history of PCOS on the risk of PCOS. The findings consistently demonstrate that women with a family history of PCOS have a significantly higher likelihood of developing the condition compared to those without such history. This highlights the strong hereditary and genetic contribution to the pathogenesis of PCOS.

The significant role of genetic predisposition in PCOS development is widely acknowledged. Family history has been identified as a strong predictor of PCOS, supporting the notion that hereditary factors contribute to both the onset and severity of the syndrome (Li et al., 2013; Barber & Franks, 2012). For instance, Bogari (2020) showed that a family history of type 2 diabetes (T2D) correlates with an increased risk of T2D in women with PCOS, reinforcing the link between genetic and metabolic disorders in this population. Additionally, evidence suggests that genetic polymorphisms can serve as potential predictors of PCOS. (Kaur et al., 2022a) demonstrated that variants such as CYP11B2 and CYP1A1 play critical roles in steroidogenesis, where disruptions in these pathways lead to hyperandrogenism, a hallmark of PCOS.

Furthermore, genetic studies emphasize that PCOS is not only influenced by isolated genetic variants but also by a

complex interaction involving hormonal dysregulation, chronic low-grade inflammation, oxidative stress, and metabolic dysfunction (Rakic et al., 2023Recent findings also suggest that first-degree relatives of women with PCOS show higher risks of metabolic abnormalities, insulin resistance, and reproductive dysfunction, confirming the familial clustering of PCOS traits (Dapas et al., 2020).

Overall, the strong association between family history and PCOS underscores the need for early screening and genetic counseling in women with a positive family history, as well as the importance of considering both hereditary and environmental factors in the prevention and management of PCOS.

Hirsutism with PCOS

There are six articles from several countries used to measure the magnitude of the effect of hirsutism on PCOS. This finding indicates that women with hirsutism are more than twice as likely to develop PCOS compared to those without hirsutism. These results are consistent with the pathophysiological understanding of PCOS, where hyperandrogenism is a key feature that drives clinical manifestations, including hirsutism (Alkhezi et al., 2024; Khatun et al., 2025)

Biologically, hirsutism in PCOS is primarily caused by increased androgen production from both the ovaries and adrenal glands. Elevated androgen levels promote the accelerated and thickened growth of terminal hair in androgen-sensitive areas of the body, resulting in the clinical manifestation of hirsutism (Said et al., 2023; Mohmed et al., 2023) Previous studies have also confirmed that hyperandrogenism not only exacerbates hirsutism but also contributes to insulin resistance and metabolic disturbances commonly observed in women with PCOS (Tripathi et al., 2021; Rizvi et al., 2023)

Genetic factors also play an important role in the association between hirsutism and PCOS. Research has shown that specific gene polymorphisms, such as CYP11A1 and CYP17, which are involved in the steroidogenesis pathway, can increase androgen production and worsen hirsutism (Kaur et al., 2022; Rakic et al., 2023). This highlights the complex interplay between genetic predisposition, hyperandrogenism, and the clinical expression of PCOS.

Furthermore, hirsutism is often associated with psychosocial factors that negatively impact the quality of life in women with PCOS. Patients with hirsutism have been reported to experience higher levels of stress and body image dissatisfaction, which may contribute to mental health problems, including depression and anxiety (Witchel et al., 2019; Stokkeland et al., 2022). Thus, the presence of hirsutism is significant not only in clinical terms but also in relation to the psychosocial well-being of PCOS patients.

These findings are consistent with previous studies emphasizing that hirsutism is an important clinical indicator in the diagnosis of PCOS, as outlined by the Rotterdam and NIH criteria (Hanedan et al., 2022; Peeva et al., 2022). Therefore, early recognition of hirsutism as a hallmark feature of PCOS can support timely diagnosis and management, ultimately preventing long-term complications such as infertility, metabolic disorders, and cardiovascular disease.

Conclusion

This meta-analysis provides strong evidence that obesity, family history, and hirsutism are significantly associated with an increased risk of polycystic ovary syndrome (PCOS) among women of reproductive age. Obesity was found to double the risk of PCOS, while family history and hirsutism also demonstrated a strong positive association. In contrast, smoking did not show a statistically significant relationship with PCOS. These findings highlight the importance of

metabolic, genetic, and clinical manifestations in the development of PCOS, supporting the multifactorial nature of this syndrome. This study advances the scientific understanding of PCOS by providing quantitative evidence from multiple countries and populations, strengthening the epidemiological basis for prevention and early detection strategies. However, limitations of this meta-analysis include the reliance on cross-sectional studies, potential publication bias, and heterogeneity across populations and diagnostic criteria. Therefore, caution is needed in generalizing the findings to all populations.

Future studies should prioritize longitudinal and experimental designs to establish causal relationships between lifestyle, genetic, and clinical risk factors and the development of PCOS. More research is also needed to explore the biological mechanisms underlying the associations, especially the role of hormonal regulation, metabolic pathways, and environmental exposures. Additionally, public health interventions should focus on obesity prevention, screening women with a family history of PCOS, and early management of hirsutism as part of comprehensive reproductive health programs. Integrating lifestyle modifications, genetic counseling, and awareness campaigns could reduce the burden of PCOS and improve the reproductive and metabolic health outcomes of women of reproductive age.

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Author Contribution and Competing Interest

Alfida Aulia Rahma Firdausy Nurhaliza was responsible for determining the research topic, identifying and reviewing relevant articles, analyzing the data, and preparing the manuscript. Bhisma Murti contributed by assisting in data processing and compiling the manuscript. The authors declare that there are no competing interests.

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