

“PHENOTYPIC VARIATION IN POLYCYSTIC OVARY SYNDROME: A CROSS-SECTIONAL STUDY OF METABOLIC AND REPRODUCTIVE SUBTYPES IN A TERTIARY CARE HOSPITAL OF TRIPURA”.

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ABSTRACT

Background: Polycystic ovary syndrome (PCOS) is a heterogeneous endocrine disorder characterized by distinct reproductive and metabolic phenotypes, each with unique clinical and biochemical profiles. Data on PCOS phenotypes from Tripura, a northeastern Indian state with unique demographic and lifestyle characteristics, remain limited.

Methods: A cross-sectional study was conducted over 21 months at a tertiary care hospital in Tripura, including 75 women with PCOS diagnosed using the Rotterdam criteria (2003) and 60 healthy controls. Participants underwent anthropometric, hematological, and biochemical assessments. PCOS cases were categorized into reproductive, metabolic, and intermediate phenotypes based on hormonal and metabolic parameters. Statistical analysis included ANOVA, chi-square test, and Spearman's correlation, with $p < 0.05$ considered significant.

Results: Among PCOS patients, 48% were metabolic, 38.7% intermediate, and 13.3% reproductive phenotype. The metabolic phenotype showed significantly higher weight, BMI, body fat, visceral fat, triglycerides, cholesterol, and insulin levels ($p < 0.05$), indicating increased metabolic risk. The reproductive phenotype exhibited elevated luteinizing hormone and sex hormone-binding globulin, reduced progesterone, and significantly lower hemoglobin and RBC counts ($p < 0.05$), suggesting possible hematological vulnerability. Estradiol levels were highest in the metabolic group. The reproductive phenotype was more common in younger women (19–21 years), while the metabolic phenotype predominated in slightly older individuals (22–24 years).

Conclusion: PCOS phenotypes demonstrate distinct clinical and biochemical profiles. These findings support phenotype-specific management strategies, emphasizing metabolic risk reduction in metabolic PCOS and targeted reproductive and hematological care in reproductive PCOS.

KEYWORDS: PCOS, metabolic subtype, reproductive subtype, anthropometric, Tripura

BACKGROUND:

Polycystic ovary syndrome (PCOS) is a complex and multifaceted endocrine disorder that affects women of reproductive age and is characterized by hyperandrogenism, chronic anovulation, and polycystic ovarian morphology [1]. It is one of the most common causes of female infertility and is often associated with a range of metabolic disturbances, including insulin resistance, dyslipidemia, and obesity [2]. Given its heterogeneous nature, PCOS is increasingly being classified into distinct phenotypic subtypes—primarily reproductive and metabolic—each with varying clinical presentations and long-term health implications [3]. Subtypes can be differentiated based on clinical-demographic factors and biochemical profiles, which influence treatment strategies. Burns et al. used cluster and principal component analyses to characterize these subtypes, highlighting the importance of tailored management approaches for effective patient care [4].

The reproductive subtype typically presents with menstrual irregularities and hyperandrogenism but may not always display overt metabolic abnormalities [5]. In contrast, the metabolic subtype is often accompanied by features of metabolic syndrome, including central obesity, insulin resistance, and dyslipidemia, even in the absence of pronounced reproductive symptoms [6].

Tripura, a northeastern state of India, presents a unique demographic and genetic pool, where regional variations in lifestyle, dietary habits, and healthcare access may influence the clinical expression of PCOS [7,8]. This cross-sectional study aims to bridge this gap by evaluating the clinicodemographic profile of reproductive and metabolic subtypes of PCOS in women from Tripura. Furthermore, this study sought to explore the associations between these subtypes and various hematological and biochemical markers, thereby contributing to a more nuanced understanding of PCOS pathophysiology in this population and informing region-specific clinical management

strategies. Therefore, this study was initiated with the following objectives: 1. to estimate the proportions of two subtypes of PCOS, namely, the reproductive subtype and metabolic subtype, among female patients attending a tertiary care hospital in Tripura and then 2. to compare the clinicodemographic and biochemical profiles of the two groups.

Methodology:

Study Design and Setting: This observational cross-sectional study was conducted in a tertiary care hospital of Tripura. The duration of the study was two years, with participant recruitment carried out over a period of 21 months.

Study population and sampling technique: A total of 75 female participants diagnosed with polycystic ovary syndrome (PCOS) were selected via the Rotterdam criteria (2003) established by the ESHRE/ASRM-sponsored PCOS Consensus Workshop Group. The age group of the participants ranged from 15–45 years. Sampling was performed via the simple random sampling (SRS) method. Participants were recruited from the outpatient department (OPD) of the Department of Obstetrics and Gynecology. Simultaneously, 60 healthy female subjects were included in this study as controls.

Sample Size Estimation: The minimum sample size was calculated via the following formula: $n = [Z\alpha \{p(1-p)\}] \div d^2$, where n is the sample size. $Z\alpha$ is the z statistic for the level of confidence, and in this study, $Z\alpha = 1.96$ at 95% confidence. P is the expected proportion, and here, $p = 3.7\%$, considering that 3.7% of Indian women suffer from PCOS [9], and d is the absolute error; here, d is considered 5%. Hence, the minimum sample size is $n = \{(1.96)^2 \times 3.7(100 - 3.7)\} \div (5)^2 \times 2 = 54.7$. This calculation yielded a minimum sample size of 55 participants. After 10% non-responsiveness was added, approximately 60 study subjects remained.

The inclusion criteria for women were as follows: aged 15–45 years and diagnosed with PCOS as per the Rotterdam criteria [10] and who had not undergone hormonal therapy for at least the last three months. The exclusion criteria for patients were as follows: undergoing immunosuppressive therapy; having a history of endocrine disorders such as late-onset adrenal hyperplasia, 21-hydroxylase deficiency, Cushing's syndrome, or premature ovarian failure; and being diagnosed with thyroid disorders.

Data collection method:

After recruitment, the participants underwent hormonal and anthropometric analysis. On the basis of these findings, they were classified into two groups: 1. Reproductive subtype: This subtype is characterized by higher LH and SHBG levels and lower BMI and insulin levels 2. Metabolic subtype: This subtype is characterized by higher BMI, glucose, and insulin levels and lower LH and SHBG levels.

Clinical and Anthropometric Data Collection: A structured case–record form was used to document demographic and clinical variables. Anthropometric measurements included height and weight. Body mass index (BMI) was calculated via the following formula: $BMI = \text{weight (kg)} / \text{height (m)}^2$. Sample collection and analysis: 5 ml venous blood sample was drawn from each participant after a 12-hour overnight fast. For menstruating women, samples were collected between Day 3 and Day 5 of the menstrual cycle. For participants with amenorrhea, samples were collected on a random day. Blood samples were centrifuged at 2000 rpm for 15 minutes at 4°C. The serum was aliquoted and stored at –80°C until further analysis. Biochemical parameters were measured via a biochemical autoanalyzer (ERBA XL-640) available at the MRU, AGMC. The levels of FSH, LH, testosterone (TH), and prolactin (PRL) were quantified via the Vidas immunoassay analyzer. The technique used was a fluorescent immunoassay-based method. Serum insulin was measured via enzyme-linked immunosorbent assay (ELISA). ELISA kits and protocols were used according to the manufacturer's instructions.

Statistical analysis: All the statistical analyses were performed via IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables, including anthropometric and biochemical parameters, are summarized as the means $\pm$ standard deviations (SDs). Group comparisons for continuous variables were assessed via one-way analysis of variance (ANOVA). For categorical variables, group differences were evaluated via the chi-square (χ^2) test. To assess the strength and direction of association between variables of interest (e.g., hormonal and metabolic markers), Spearman's rank correlation coefficient was applied. A p value of less than 0.05 was considered statistically significant for all tests.

Result: In this study, a total of 135 participants were assessed for age, height, weight, BMI, body fat, and visceral fat. Among the total 135 participants, 75 individuals (55.6%) were diagnosed with polycystic ovary syndrome (PCOS). Sixty individuals (44.4%) were categorized as controls (non-PCOS individuals). Among the participants, PCOS types were classified into three categories: 1. Metabolic phenotype: 36 individuals (48%), 2. Intermediate phenotype: 29 individuals (38.7%), 3. Reproductive phenotype: 10 individuals (13.3%).

The mean age differed significantly between groups ($p < 0.001$), whereas ethnicity distribution, predominantly nontribal, was not significantly different ($p = 0.780$). Most participants were unmarried, with marital status showing a significant group difference ($p = 0.021$). Food habits were largely nonvegetarian across all groups, with no significant variation ($p = 0.234$) (Table 1).

Table 2 presents the comparison of the anthropometric parameters. Height did not differ significantly between the groups ($p = 0.796$). The metabolic PCOS patients had the highest mean weight and body fat percentage, with both parameters showing significant differences across groups ($p < 0.001$). The waist–hip ratio was also significantly greater in the metabolic PCOS group than in the other groups ($p = 0.046$).

Figure 1 implies that the metabolic subtype of PCOS had a mean age of 21.9 years, with most cases clustered between 18–26 years and a peak at 22–24 years. However, the reproductive subtype had a slightly lower mean age of 20.8 years, with most cases between 18–25 years and a peak at 19–21 years.

Hemoglobin and RBC counts were significantly lower in the reproductive subtype than in the metabolic subtype and controls ($p = 0.049$ and $p = 0.032$, respectively). The TLC was also lower in the PCOS group than in the control group, although the difference was not statistically significant ($p = 0.058$) (Table 3).

Analysis of biochemical parameters revealed that triglyceride and cholesterol levels were significantly greater in the metabolic subtype group than in the reproductive subtype and control groups ($p = 0.019$ and $p = 0.038$, respectively). HDL was not significantly different ($p = 0.732$), whereas LDL was significantly greater in the metabolic subtype ($p = 0.075$) (Table 4).

Table 5 shows that LH and SHBG were significantly greater in the reproductive subtype, whereas insulin was markedly greater in the metabolic subtype ($p < 0.001$ each). FSH was modestly increased in both subtypes compared with the controls ($p = 0.018$). AMH levels were higher in the PCOS groups, but the difference was not significant. Progesterone was significantly reduced, especially in the reproductive subtype ($p = 0.007$). Testosterone was not significantly different among the groups.

According to Figure 2, the mean estradiol level was greater in the metabolic subgroup (204.0) than in the control subgroup (112.8). The intermediate subtype presented the lowest value (82.9), whereas the reproductive subtype (105.3) presented the greatest difference from the control group. Overall, estradiol levels varied considerably among PCOS subtypes, with a marked elevation in the metabolic subtype.

DISCUSSION:

This study presents persuasive evidence of unique anthropometric, metabolic, and hormonal profiles among PCOS phenotypes, particularly highlighting the increased metabolic risk linked to the metabolic subtype. The ages of both the metabolic and reproductive subtypes exhibited a nearly typical distribution concentrated around early adulthood. The metabolic subtype predominantly stretched into the late twenties and early thirties, whereas the reproductive subtype was primarily concentrated in the late teens and early twenties. Both subtypes primarily impacted women in early adulthood, whereas the reproductive subtype exhibited a marginally younger age distribution than did the metabolic subtype. A significant disparity in visceral fat levels was noted among the groups, with the metabolic subtype exhibiting the greatest mean visceral fat and the intermediate subtype the lowest. Statistically significant differences were observed in age, weight, BMI, body fat percentage, and visceral fat, underscoring the increasing acknowledgment of visceral adiposity as a primary contributor to metabolic dysfunction in patients with PCOS [11]. Recent research has indicated that women with PCOS accumulate visceral fat regardless of body weight, underscoring the efficacy of composite indices compared with traditional metrics such as BMI and waist circumference [12,13]. Conversely, height exhibited no significant variation, suggesting that disparities in body composition are not linked to stature. The metabolic phenotype consistently demonstrated elevated levels of weight, BMI, body fat, and visceral fat, corresponding with established metabolic risk profiles. Concurrently, the intermediate and reproductive subtypes presented the lowest averages across most metrics, indicating comparatively healthier or leaner profiles. The metabolic phenotype, defined by elevated weight, BMI, and adiposity metrics, constitutes a high-risk cohort for enduring metabolic problems [14]. The significant percentage of unmarried and nontribal individuals may indicate sociocultural factors affecting health-seeking behavior and access to healthcare. Cultural norms and marital expectations in India have been demonstrated to postpone medical consultation for reproductive-related diseases, with approximately 60% of women initially pursuing nonmedical therapies [15,16].

The significant prevalence of overweight/obesity in the metabolic PCOS cohort highlights the necessity for focused lifestyle modifications. Recent studies and evaluations have demonstrated that dietary changes, physical exercise, and behavioral assistance markedly increase weight, insulin sensitivity, and reproductive outcomes in individuals with PCOS [17,18].

The metabolic phenotype in this cohort exhibited significantly increased triglycerides and cholesterol, aligning with established dyslipidemia patterns in PCOS populations. Insulin levels are markedly elevated in the metabolic subtype, further substantiating the phenotype's correlation with insulin resistance—a defining metabolic aberration in PCOS [19].

In contrast, the reproductive subtype exhibited distinct problems, characterized by markedly reduced hemoglobin and RBC counts—indicating a possible hematologic susceptibility that is often overlooked in PCOS studies. This subtype demonstrated increased LH and SHBG levels and decreased progesterone, suggesting a unique endocrine environment and potential reproductive consequences. Although the literature frequently emphasizes metabolic inequalities, hematologic variations among phenotypes are less well documented; however, a recent Iranian study revealed reduced RBC and hemoglobin levels in individuals with a specific PCOS phenotype, suggesting a phenotype-specific hematological profile [17].

The age distribution patterns reveal distinct phenotypic differences: the reproductive subtype is concentrated in younger individuals (peak ages 19–21 years), whereas the metabolic subtype extends into somewhat older individuals, reaching the late twenties. These findings align with larger narratives highlighting the beginning of

PCOS during adolescence and early adulthood, with metabolic risks potentially exacerbated in later reproductive years[20,21].

From a pathophysiological standpoint, obesity—particularly the accumulation of visceral fat—exacerbates insulin resistance through disrupted PI3-K signaling and hyperinsulinemia. Obesity diminishes SHBG levels and intensifies hyperandrogenism, leading to menstrual abnormalities and exacerbated metabolic decline[22]. This mechanistic interaction provides a solid foundation for understanding the anthropometric and endocrine differences noted in the present study.

These findings highlight the necessity for therapies tailored to certain phenotypes: For the metabolic subtype, implementing interventions aimed at reducing visceral fat—such as tailored dietary adjustments, exercise programs, and insulin-sensitizing treatments—may produce significant metabolic advantages. Previous studies have validated the effectiveness of lifestyle modifications for metabolic enhancement in patients with PCOS. The reproductive subtype, characterized by its hematological and hormonal complexities, may benefit from thorough endocrine assessments and customized reproductive health strategies, especially considering its younger demographic characteristics.

Conclusion:

The findings demonstrate clear phenotypic variability in PCOS presentation, with significant differences in anthropometric indices across groups. Identifying and classifying PCOS by phenotype can aid in more tailored treatment approaches and improve long-term outcomes, especially in populations vulnerable to metabolic risks.

Limitations and Future Directions:

The present study's cross-sectional design limits causal inference. Moreover, the sample is regionally specific; broader multiethnic studies could better capture PCOS heterogeneity. Future research might explore long-term metabolic trajectories across phenotypes, track transition patterns, and assess intervention responsiveness. Therefore, in the future, large-scale, phenotype-specific studies are critical for advancing precision diagnostics and equitable, individualized care in patients with PCOS.

Recommendations:

- Screening for metabolic risk factors in all PCOS patients, particularly those with the metabolic subtype.
- Incorporation of lifestyle management and early intervention strategies in reproductive health programs.
- Further longitudinal studies to evaluate outcomes on the basis of phenotype classification are needed.

Declarations:

List of abbreviations:

PCOS - Polycystic Ovarian Syndrome
LH - Luteinizing hormone
SHBG - Sex Hormone Binding Globulin
HDL- High-density lipoprotein
LDL - Low-density lipoprotein

Ethical Approval:

This study was conducted in accordance with the ethical standards of the Institutional Ethics Committee (IEC) of Agartala Government Medical College, after obtaining approval vide letter No. F.4(6-13)/AGMC/MedicalEducation/IECApapproval/2022/22310, dated, 14.07.2023 and in compliance with the principles outlined in the Declaration of Helsinki and its subsequent revisions. Informed written consent document for participation in this study was collected from all the study participants.

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Availability of data and materials: All the Data is available with the Corresponding author which can be shared on acceptance of the manuscript.

Competing Interests: None

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Table 1: Descriptive statistics of study participants.

Variables	PCOS subtypes (n=75)			Control group (n= 60)	Significance (P value)
	Reproductive (n=29)	Metabolic (n=36)	Intermediate (n=10)		
Age (mean ± SD)	20.8 ± 4.2	21.8 ± 4.5	21.4 ± 2.1	21.8 ± 5.6	<0.001
Ethnicity	Tribal – 1 Non-Tribal - 28	Tribal – 4 Non-Tribal - 32	Tribal – 1 Non-Tribal - 9	Tribal – 7 Non-Tribal - 53	0.780
Marital Status Married(M) Un-married (UM)	M - 1 UM - 28	M- 6 UM - 30	M- 2 UM - 8	M- 52 UM - 8	0.021
Food Habit Non-vegetarian (NV) Vegetarian(V)	NV – 24 V - 5	NV – 32 V - 4	NV – 8 V - 2	NV – 54 V - 6	0.234

Table 2: Comparison of anthropometric parameters among the three study groups

Parameters	Reproductive PCOS subtype (n=29)	Metabolic PCOS subtype (n=36)	Control group (n= 60)	Significance (P value)
Height in centimeter	153.0± 4.2	153.3± 5.6	152.5 ± 5.0	0.796
Weight in Kg	51.4 ± 6.0	66.6 ± 10.8	54.9 ± 8.9	<0.001
BMI	21.7±2.5	28.08 ± 3.2	23.6 ± 3.3	<0.001
Body Fat percentage	29.6 ± 6.3	35.2 ± 4.4	31.4 ± 6.0	<0.001
Waist Hip Circumference	0.88 ± 0.12	0.96 ± 0.05	0.87 ± 0.02	0.046

Table 3: Distribution of Haematological parameters among the three groups.

Name of the Tests	Reproductive Subtype (mean ± SD)	Metabolic Subtype	Control Subjects	Normal Range	Significance (P value)
Haemoglobin	11.7±1.1	12.6±1.2	13.9±1.8	11-15 gm/dl	0.049
TLC	7548±12.9	8310±18.7	9820±15.2	4500-11000 /cumm	0.058
Red Blood Cell Count	4.6±2.2	5.4±1.9	5.3±1.3	4.5-5.5 million/cumm	0.032

Table 4: Comparison of Biochemical parameters among the three groups.

Name of the Tests	Reproductive Subtype (mean±SD)	Metabolic Subtype	Control Subjects	Normal Range	Significance (P value)
Triglyceride	142.7 ± 4.2	173.5 ± 7.8	106.3 ± 7.2	40-160 mg/dl	0.019
Cholesterol	156.9 ± 5.2	190.1 ± 6.8	158.8 ± 8.9	46-171 mg/dl	0.038
HDL	47.6 ± 3.1	43.7 ± 10.7	49.0 ± 3.9	42.0-88.0 mg/dl	0.732
LDL	73.8 ± 8.6	110.7 ± 9.1	83.9 ± 15.7	0.0-130 mg/dl	0.075

Table 5: Comparison of reproductive hormonal profile among the groups.

Name of the parameters	Control Subjects (mean ± SD)	Reproductive Subtype (mean ± SD)	Metabolic Subtype (mean ± SD)	Normal range	P value
LH	7.7 ± 3.5	18.8 ± 6.9	7.2 ± 4.7	1-15 mIU/ml	<0.001
SHBG	22.7 ± 6.3	42.0 ± 17.9	22.9 ± 9.6	18-144 nmol/L	<0.001
Insulin	8.04 ± 4.0	5.7 ± 2.5	45.4 ± 17.7	1.9-23 uIU/ml	<0.001
FSH (mIU/ml)	4.3±2.3	5.6±1.9	6.77 ± 3.1	3-9 mIU/ml	0.018
AMH (ng/ml)	2.9±1.4	5.5 ± 3.0	5.8±3.9	0.7-3.5 ng/ml	0.174
Progesterone (ng/ml)	12.9±1.8	4.2 ± 0.4	8.9±1.2	5-20 ng/ml	0.007
Testosterone (ng/ml)	0.85±0.9	0.6±0.19	0.72±0.3	0.5 to 2.4 nmol/L	0.085

Figure1: Age distribution among metabolic and reproductive subtypes of PCOS.

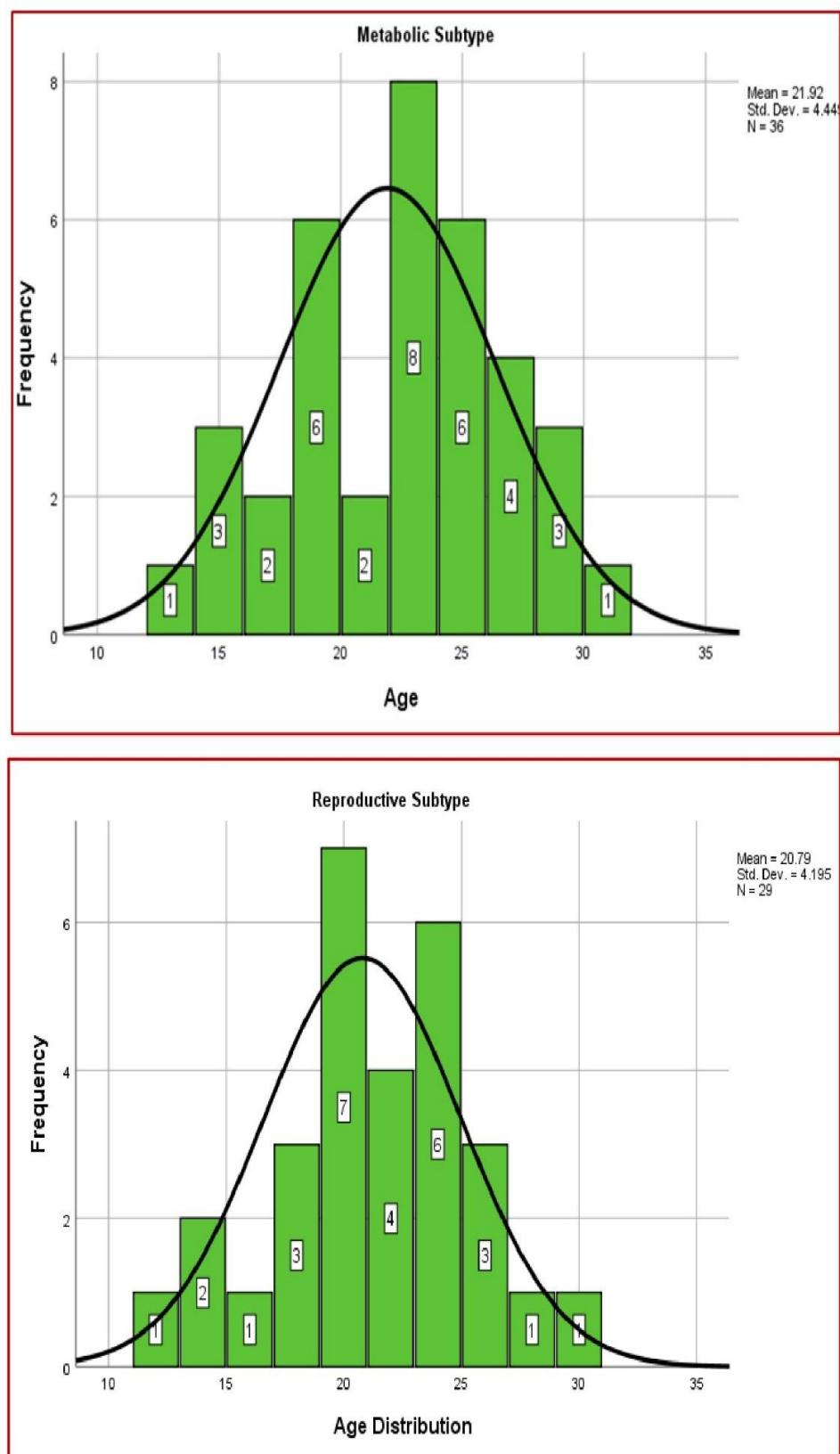


Figure 2: Comparison of Mean values of Estradiol between PCOS patients and Control groups.

