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Estimation of Atherogenic Index of Plasma, Prolactin, and Some Other Hormones in Polycystic Ovarian Syndrome in Lean Women

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***Abstract*—Polycystic ovary syndrome (PCOS) is a prevalent endocrine disorder with an increase in androgen levels that influences young women during reproductive age, and it is associated with different reproductive health issues and has significant influences on metabolic pathways. This study focused on the estimation of the atherogenic index of plasma (AIP), LDL/HDL ratio, Prolactin, and some other parameters that influenced lean women with PCOS. A total of 120 women from Shahid Doctor Khalid Hospital (Koya health centers) in Koya-Erbil Governorate, aged from 25 to 45 years, were distributed into 90 lean women patients with PCOS and 30 healthy individuals who have no PCOS as control groups. This work revealed that the parameters of serum Prolactin, LH, FSH, TSH, Testo, insulin, FBG and HOMA-IR were significantly elevated in lean women with PCOS groups as compared with normal groups. The lipid profile parameters of serum T-Chol, TG, LDL, and VLDL were significantly higher in the PCOS group when compared with healthy individuals, whereas the serum level of HDL was significantly decreased in the PCOS group compared to healthy persons. No significant difference was found for serum Mg among PCOS and control groups. This study indicates from the calculation of BMI (kg/m2) that women with PCOS have normal body weight. AIP is detected as a useful biomarker to indicate the cardiovascular disease (CVD) risk in the future. The results of this study indicate that those lean women with PCOS have insulin resistance (IR) due to the high levels of HOMA-IR.**

***Index Terms*—Atherogenic index of plasma, Prolactin, Luteinizing hormone, Follicle-stimulating hormone.**

I. Introduction

Polycystic ovary syndrome (PCOS) is one of the endocrinological problems among disorders in hormone-influenced 5–15% of women during reproductive age, characterized by dysfunction in ovulation and an increase in androgen level; also, luteinizing hormone (LH) and follicle-stimulating hormone (FSH) were elevated (Saadia, 2020). The metabolic disorder of dyslipidemia and an elevation of type 2 diabetes mellitus (T2DM) risks, as well as cardiovascular disease (CVD), are related to polycystic ovarian (PCOS) morphology (Uysal, et al., 2024). Irregularities during the menstrual cycle, excess in androgen levels, hirsutism, and infertility seem to be strongly related to PCOS (Anik Ilhan, Yildizhan and Pekin, 2019). Prolactin has been measured routinely to exclude endocrine diseases in PCOS (Glintborg, et al., 2014). An increase in Prolactin level is the most common endocrine disorder and may be indicated in women with PCOS of all ages, depending on the study population. Pathological conditions, physiologic alterations, drugs, and macroprolactin excess could be related to hyperprolactinemia (Davoudi, et al., 2021). PCOS is a major form of ovulatory infertility in women that is related to insulin resistance (IR) and obesity. A recent study illustrated that women with PCOS have a significantly higher risk of progression in T2DM at a young age compared with control cases. Adipose tissue macrophages may produce prolactin in response to hyperglycemia and inflammation, which promotes the growth of adipose tissue and inhibits lipid degradation in the adipose tissue (Yang, et al., 2020; Assani, et al., 2025). According to the Rotterdam Criteria in 2003 (Wang and Mol, 2017), at least two of these three criteria were used to diagnose PCOS, such as anovulation or oligo-ovulation, amenorrhea, and hirsutism with a Ferriman–Gallwey score of more than seven or obvious acne, and also polycystic ovaries on an ultrasound scan are characterized as 12 or more follicles 2–9 mm in size. A recent study clearly observed that women diagnosed with PCOS have a high risk of CVD compared with other women (Hajian-Tilaki, 2014; Hofman, et al., 2007). In a previous study, it has been displayed that women with PCOS have significantly elevated concentrations of triglycerides (TG) to high-density lipoprotein (HDL) cholesterol for detecting significant relationships with IR and cardio-metabolic risk factors (Ulutaş, Cander, and Gül, 2022).

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A few of the studies correspond with the parameters of metabolic syndrome (abnormal blood glucose concentration, hypertension, decreased HDL cholesterol, and hypertriglyceridemia) (Kulik-Kupka, et al., 2022, Kaune, et al., 2022, Al-Moayad, Alezzi, and Mohammed, 2024). Metabolic disorders of dyslipidemia are the most common features of PCOS, which detects the risk of CVD. A recent study clearly demonstrated that an increase in the levels of the lipid accumulation product (LAP) accuracy index is an additional risk indicator for CVD in patients with PCOS. Most of the recent studies displayed that obesity and being overweight influenced a large number of women with PCOS (Shah, et al., 2023). To date, the estimation of high levels of atherogenic index of plasma (AIP), LH, and Prolactin for patients with IR who have hirsutism, amenorrhea, and severe acne in lean women with PCOS has not been studied. This study aims to estimate the AIP, Prolactin, homeostasis model assessment for IR (HOMA-IR), and some other hormones to compare between lean women who were diagnosed with PCOS and healthy individuals without PCOS in Koya City.

II. Materials and Methods

A. Study Design

This work consecutively enrolled a total of 120 females who were aged from 25 to 45 years. This study was conducted at Shahid Doctor Khalid Hospital (Koya health centers) in Koya-Erbil Governorate and approved by the Faculty of Science and Health, Koya University Ethics Committee, with (Approval No. KOUFSDCHM2025-001) on February 3, 2025. Written informed consent was obtained from all individual participants. The blood samples were collected between August 2024 and February 2025. A total of 90 lean women with PCOS based on the Rotterdam criteria in 2003 (Hajian-Tilaki, 2014; Wang and Mol, 2017) were featured in this work, and 30 persons were in the healthy groups.

B. Blood Specimens and Procedures

In this study, about 7 ml of blood samples were drawn from each participant after 12 h of fasting, which was placed in a collecting tube with gel (clot activator). Serum samples of venous blood were allowed to clot for around 20 min, and blood samples were centrifuged for approximately 10 min at 4000 rpm to create serum samples, which were then frozen at −80°C in a refrigerator in the Science and Health Research Center at Koya University. The biochemical parameters of serum total cholesterol (T-Chol), TG, HDL, low density lipoprotein (LDL), and magnesium (Mg) were measured by a Cobas c 111 fully automated chemical analyzer with diagnostic kits (Roche/Hitachi Cobas), model Germany. The measuring concentrations of very LDL (VLDL) were calculated by using the formula (TG/5) in mg/dL. In addition, the biochemical parameters of serum Prolactin, FSH, LH, thyroid-stimulating hormone (TSH), testosterone (Testo), and fasting serum insulin were measured via Cobas e 411, a fully automated chemical analyzer with diagnostic kits (Roche/Hitachi Cobas), model Germany. The parameter of fasting blood glucose (FBG) was measured by a fully automated chemical analyzer of Cobas c 311 with diagnostic kits (Roche/Hitachi Cobas), model Germany. The HOMA-IR has been calculated from multiplying FBG (mg/dL) and insulin concentrations (uU/ml), dividing by 405 (Kheirollahi, et al., 2020).

C. Statistical Analysis

GraphPad Prism version 9 (GraphPad Software, Inc.) was used to perform the statistical analysis. Furthermore, the Student's t-test has been carried out to investigate the differences between the two groups. The p-value ($p < 0.05$) was represented as statistically significant (S), and the data results were displayed as the mean and standard error of the mean (mean ± SEM). The interquartile range (IQR) and the median are considered for non-significant results (N.S.) if the p-value ($p > 0.05$). The Chi-square (χ^2) was used to measure the characteristics of acne, hirsutism, and amenorrhea.

III. Results and Discussion

The findings of this work provide valuable estimates of AIP, prolactin, and some other hormones among lean women with PCOS as compared with healthy individuals. The median and interquartile range (IQR: 25% and 75%) levels of serum Mg for women with PCOS groups are 2.190 and (25% = 2.075), (75% = 2.400) respectively, while in control groups are 2.160, and (25% = 2.100), (75% = 2.240), respectively. The median and IQR levels of serum Mg exhibit no significant difference among lean women with PCOS and healthy individuals, as shown in Table I and Fig. 1. This study displayed that the median and (IQR: 25% and 75%) levels of body mass index (BMI) (Kg/m^2), for women with PCOS groups are 21.21 and (25% = 19.90), (75% = 22.32) respectively, whereas in control groups are 21.12, and (25% = 19.90), (75% = 22.00) respectively. The results of this study display that no significant difference was found between the two groups, hence exhibiting that women who have PCOS have normal body weight, as shown in Table I and Fig. 1. The Chi-square (χ^2) results display that the values are extremely high. A higher χ^2 indicates a greater difference between observed and expected values. The prevalence of clinical symptoms was dramatically higher in the PCOS group compared to the healthy controls. Acne was present in 75%, in PCOS patients with $\chi^2 = 52.31$ but absent in all controls ($p < 0.0001$). Similarly, hirsutism and amenorrhea were observed in 83% and 92% in PCOS patients, with $\chi^2 = 66.67$ and 89.74, respectively, with no cases reported in the control group (both $p < 0.0001$). These differences were statistically absolute, indicating a powerful association between PCOS and these clinical features, as shown in Table I. Our study has displayed that the serum concentrations of Prolactin, LH, FSH, TSH, and Testo are indicated as significantly elevated in patients with PCOS groups when compared with control cases; the p-values are ($p < 0.0001$) except for TSH ($p = 0.0004$). The mean levels of Prolactin, LH, FSH, TSH, and Testo

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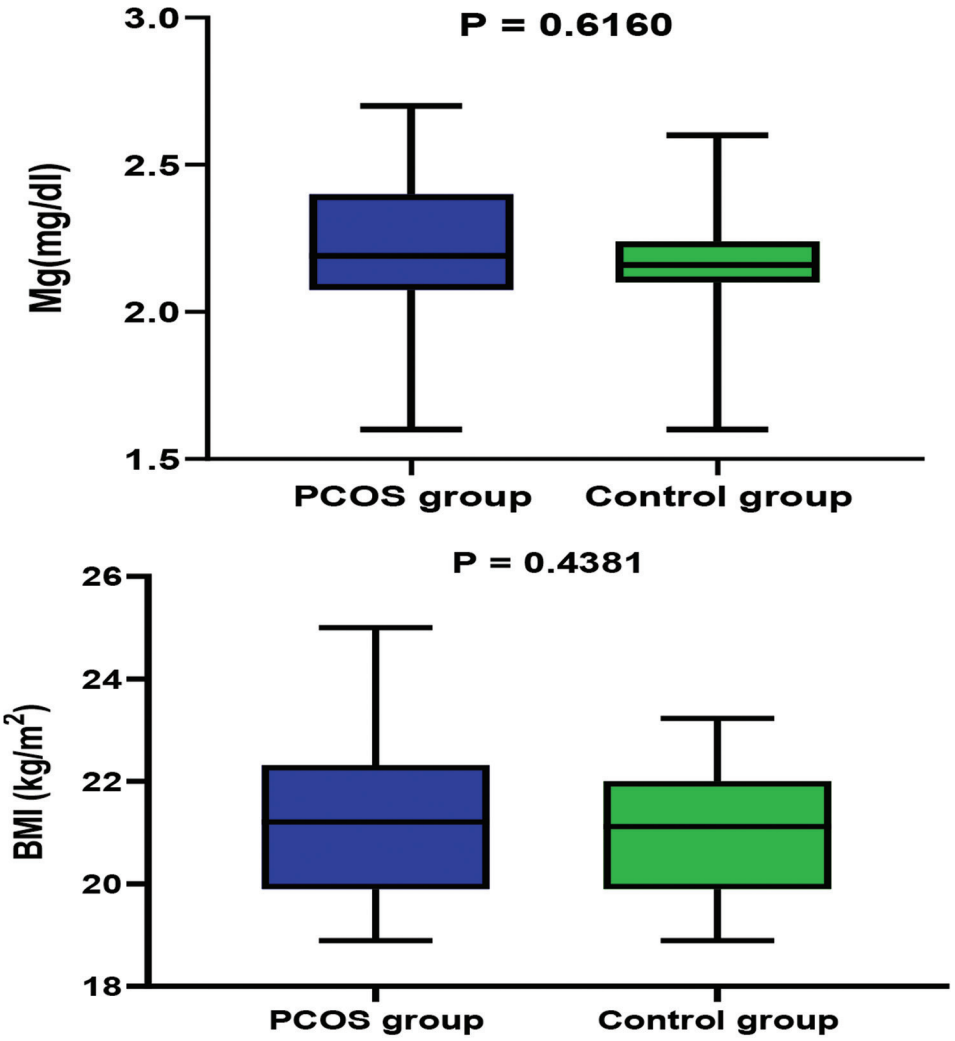

Fig. 1. Box plot for the characteristic of body mass index (kg/m^2) and parameter of serum of Mg (mg/dL) between patients with polycystic ovary syndrome and control groups. Box plot used if the data are non-significant (N.S) parametric and the p-value ($p > 0.05$). We consider the median and interquartile range [(IQR) 25% and 75%] as mentioned in the Table I.

TABLE I
The Parameter of mg, and Characteristics of BMI, Acne, Hirsutism and Amenorrhea between Patients with PCOS and Control Groups

Parameter and characteristics	PCOS group n=(90)	Control group n=(30)	Chi-square (χ^2)	p-value
Mg (mg/dL)	(Median): 2.190 IQR (25%): 2.075 (75%): 2.400	(Median): 2.160 IQR (25%): 2.100 (75%): 2.240	---------	N.S
BMI (kg/m^2)	(Median): 21.21 IQR (25%) 19.90 (75%): 22.32	(Median): 21.12 IQR (25%): 19.90 (75%): 22.00	---------	N.S
Acne%	75%	0.0%	52.31	<0.0001 (****) S
Hirsutism%	83%	0.0%	66.67	<0.0001 (****) S
Amenorrhea%	92%	0.0%	89.74	<0.0001 (****) S

The values are expressed as median and interquartile range (IQR) (25% and 75%), for non-significant (N.S) parameters if ($p > 0.05$). Whereas, the values are expressed as (mean±SEM), if the p value ($p < 0.05$) is considered statistically significant (S), ****Extremely significant; level of significance 0.01% (0.0001). BMI: Body mass index, PCOS: Polycystic ovary syndrome

in patients with PCOS group are (45.73 ± 1.514 ng/mL, 19.21 ± 1.009 mIU/mL, 7.521 ± 0.3128 mIU/mL, 4.090 ± 0.2603 uIU/mL and 0.6967 ± 0.04111 ng/mL), respectively, while the mean levels of Prolactin, LH, FSH, TSH, and Testo in control groups are (15.03 ± 0.8007 ng/mL, 4.855 ± 0.2897 mIU/mL, 4.706 ± 0.3183 mIU/mL, 2.766 ± 0.1592 uIU/mL and 0.2427 ± 0.03530 ng/mL) respectively, as shown in Table II and Fig. 2. These findings agree with a recent study that showed increased TSH, LH, and FSH levels in groups of PCOS patients (Deli, Almammory, and Obaid, 2024). Furthermore, recent studies have shown that hyperprolactinemia, or elevated prolactin levels, is a relatively rare cause of hyperandrogenism in clinical work. The finding of this work is linked to the existence of high androgen levels in women with prolactinoma both before and after therapy (Cela, De Alcubierre, and Sbardella, 2025; Decrinis, et al., 2025, Corona, et al., 2024). Furthermore, this work displayed that the mean levels of fasting serum insulin, FBG, and levels of HOMA-IR are indicated as significantly

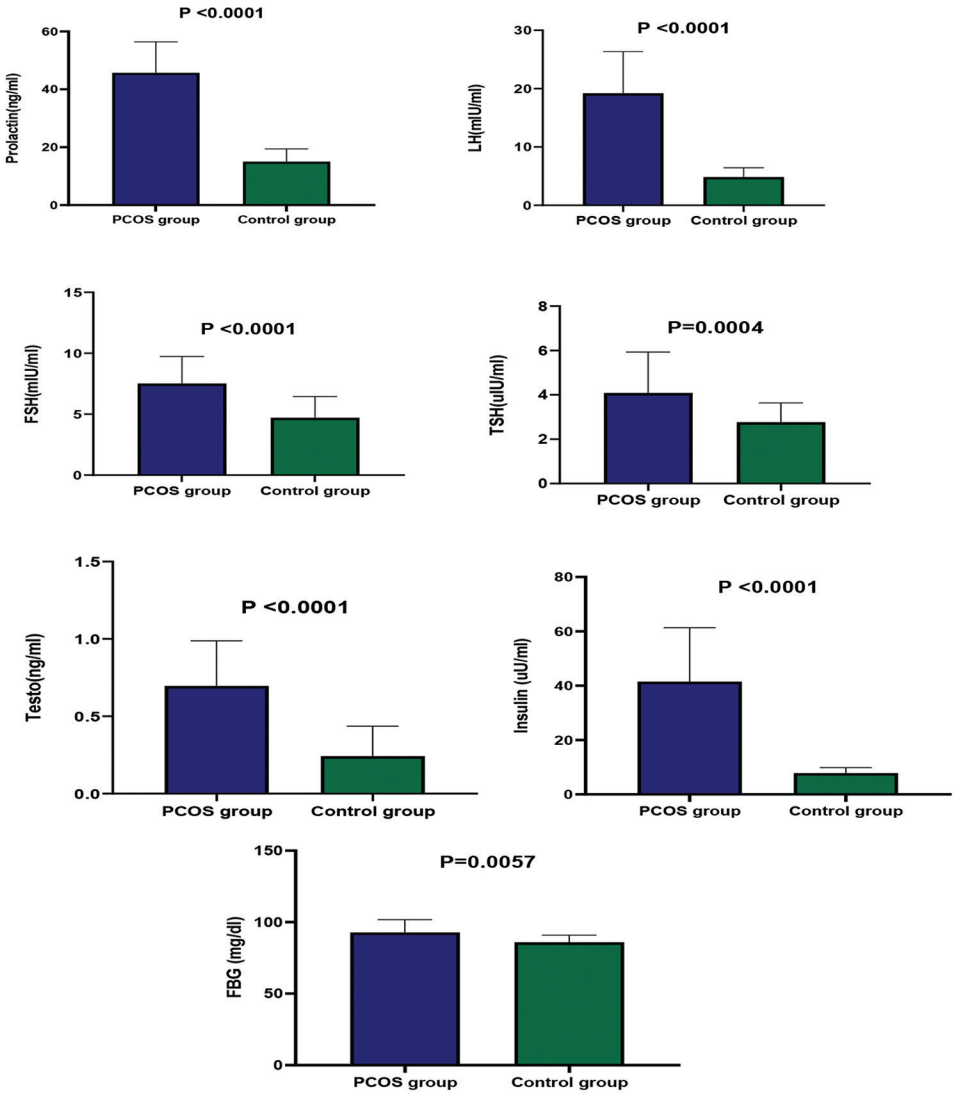

Fig. 2. The mean levels of serum Prolactin, luteinizing hormone, follicle-stimulating hormone, thyroid stimulating hormone, testosterone, insulin and fasting blood glucose between patients with polycystic ovary syndrome and control groups.

increased in patients with PCOS groups when compared with control cases; the p-values are ($p < 0.0001$) except for FBG ($p = 0.0057$). The mean levels of FBG, serum insulin, and HOMA-IR in patients with PCOS group are (92.79 ± 1.155 mg/dL, 41.54 ± 2.091 uU/ml, and 9.51 ± 0.0059) respectively, whereas, the mean levels of FBG, serum insulin, and HOMA-IR in control groups are (85.93 ± 1.278 mg/dL, 7.843 ± 0.3640 uU/mL, and 1.66 ± 0.0011) respectively, as shown in Table II and Fig. 2. IR and hyperinsulinemia, which are the key contributors to PCOS pathophysiology, contribute to the development of hyperandrogenism and dysfunction in reproductive age. IR is a condition where the body's cells do not respond properly to the hormone insulin. Metformin has an important role in amenorrhea, metabolic disorders, balance in the menstrual cycle, restores ovulation, and improves chances in pregnancy (Hamad and Ahmed, 2025). The results of this study indicate that those lean women with PCOS have IR due to the high levels of HOMA-IR.

The mean levels of serum T-Chol, TG, LDL, and VLDL are significantly increased in patients with PCOS as compared to healthy groups, whereas the mean levels of serum HDL are significantly decreased in the PCOS group compared to the control cases. In addition, the mean concentrations of serum T-Chol, TG, LDL, HDL, and VLDL for patients with PCOS are (181.3 ± 4.536 mg/dL, 146.2 ± 7.979 mg/dL, 110.0 ± 5.207 mg/dL, 42.72 ± 1.331 mg/dL, and 29.25 ± 1.596 mg/dL) respectively, while in control groups are (164.0 ± 4.952 mg/dL, 117.8 ± 6.884 mg/dL, 92.14 ± 4.025 mg/dL, 58.16 ± 1.646 mg/dL and 22.89 ± 1.236 mg/dL), respectively, as shown in Table III and Fig. 3.

Abnormalities in lipid profile parameters play a role in the progression of PCOS. A recent study displayed that mildly high levels of T-Chol, TG, LDL, and lower HDL levels are frequently encountered in women with PCOS (Chang, Chen, and Chen, 2024). In addition, a previous study considered the high risk for disorder in lipid metabolism due to hyperandrogenemia levels and frequent relationships with PCOS women who are obese, while previous work disagrees with our work due to women being lean in their bodies. Furthermore, a recent study has shown their results that

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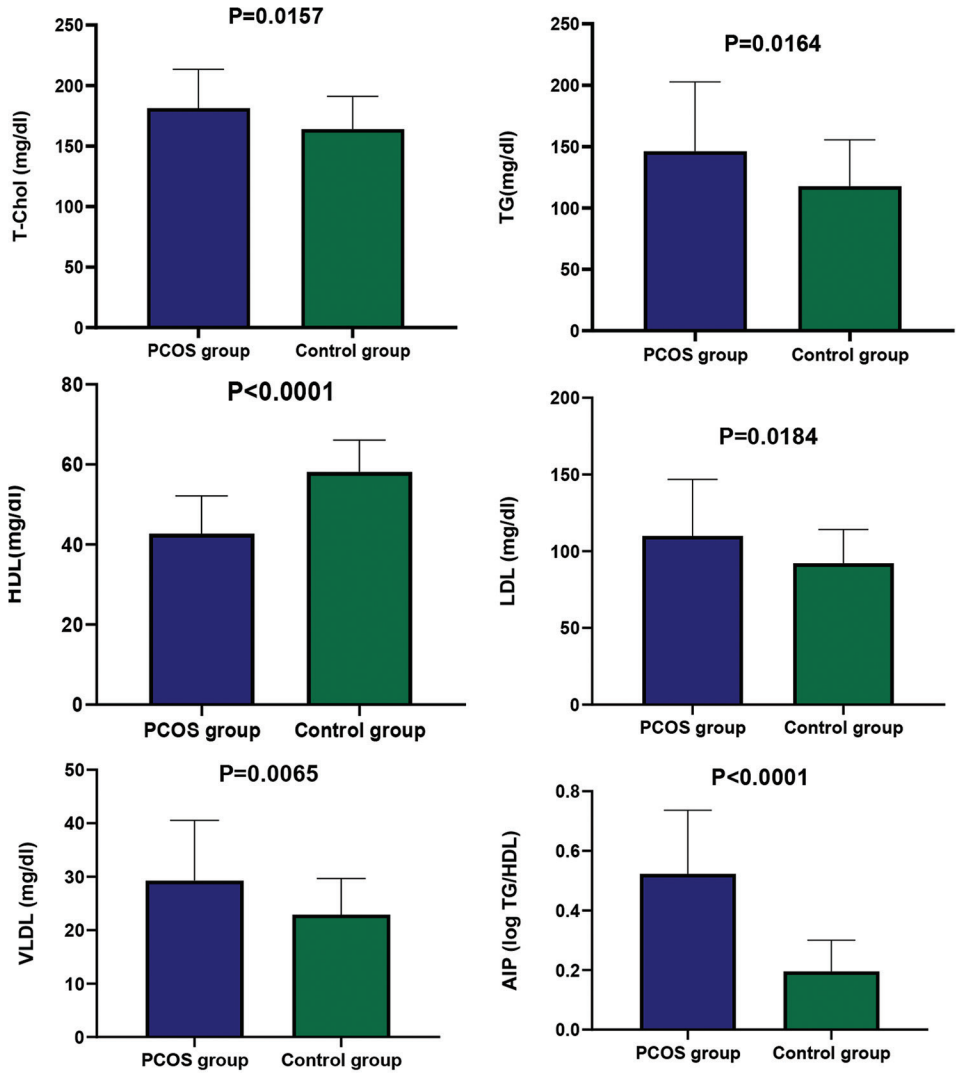

Fig. 3. The mean levels of serum total cholesterol, triglycerides, high density lipoprotein, low density lipoprotein, low density lipoprotein and atherogenic index of plasma between patients with polycystic ovary syndrome and control group.

TABLE II
Serum Levels of Prolactin, LH, FSH, TSH, Testo, Insulin, FBG, and HOMA-IR between Patients with PCOS and Control Groups.

Parameters	PCOS group n=(90)	Control group n=(30)	p-value (S)
Prolactin (ng/mL)	45.73±1.514	15.03±0.8007	<0.0001 (****)
LH (mIU/mL)	19.21±1.009	4.855±0.2897	<0.0001 (****)
FSH (mIU/mL)	7.521±0.3128	4.706±0.3183	<0.0001 (****)
TSH (uIU/mL)	4.090±0.2603	2.766±0.1592	0.0004 (***)
Testo (ng/mL)	0.6967±0.04111	0.2427±0.03530	<0.0001 (****)
Insulin (uU/mL)	41.54±2.091	7.843±0.3640	<0.0001 (****)
FBG (mg/dL)	92.79±1.155	85.93±1.278	0.0057 (**)
HOMA-IR	9.51±0.0059	1.66±0.0011	0.0001 (****)

The values expressed as (mean±SEM), for statistically significant (S) if the p-value ($p < 0.05$). **Highly significant; level of significant 1% (0.01), ***Very highly significant; level of significant 0.1% (0.001), ****Extremely significant; level of significant 0.01% (0.0001). LH: luteinizing hormone, FBG: fasting blood glucose, HOMA-IR: homeostasis model assessment for insulin resistance, FSH: follicle-stimulating hormone, TSH: thyroid-stimulating hormone, TESTo: testosterone, PCOS: Polycystic ovary syndrome

TABLE III
Serum Levels of T-CHOL, TG, LDL, HDL, VLDL, AIP and LDL/HDL Ratio between Patients with PCOS and Control Groups.

Parameters	PCOS group n=(90)	Control group n=(30)	p-value (S)
T-Chol (mg/dL)	181.3±4.536	164.0±4.952	0.0157 (*)
TG (mg/dL)	146.2±7.979	117.8±6.884	0.0164 (*)
LDL (mg/dL)	110.0±5.207	92.14±4.025	0.0184 (*)
HDL (mg/dL)	42.72±1.331	58.16±1.646	<0.0001 (****)
VLDL (mg/dL)	29.25±1.596	22.89±1.236	0.0065 (**)
AIP (logTG/HDL)	0.5232±0.03112	0.1959±0.02171	<0.0001 (****)
LDL/HDL ratio	2.7±3.89	1.59±2.46	<0.0001 (****)

The values expressed as (mean±SEM), for statistically significant (S) if the p value ($p < 0.05$). *Statistically significant; level of significant 5% (0.05), **Highly significant; level of significant 1% (0.01), ****Extremely significant; level of significant 0.01% (0.0001). AIP: Atherogenic index of plasma, LDL: Low-density lipoprotein, HDL: High-density lipoprotein, TG: Triglycerides, VLDL: Very low-density lipoprotein, T-ChoL: Total cholesterol, PCOS: Polycystic ovary syndrome

women with PCOS had increased T-Chol and LDL levels and lower HDL cholesterol compared with control groups (Kaur and Kaur, 2024; Suchta, et al., 2025). Dyslipidemia is the most common disorder that occurs in PCOS patients, which

is a risk factor for CVD in the future (Parveen, et al., 2024). Previous studies believed that overweight and obesity are the only two effective disorders strongly related to metabolic PCOS, infertility problems, and high levels of androgen (Imannezhad, et al., 2025). AIP indicates an excellent biomarker for the evaluation of the risk of atherogenicity and cardiometabolic health (Hamadameen and Hamad, 2023). The findings from this work demonstrate that those lean women with PCOS who have a problem with menstrual cycle, hyperprolactinemia, and high levels of HOMA-IR contribute to a problem with T2DM and infertility in the future. The mean levels for LDL/HDL ratio and AIP log (TG/HDL) in the PCOS group are (2.7 ± 3.89 and 0.5232 ± 0.03112), respectively, while in the control groups are (1.59 ± 2.46 and 0.1959 ± 0.02171), respectively, with p-values of ($p < 0.0001$). Our study indicates, from abnormalities in the lipid profile parameters and also from the calculation of AIP logs (TG/HDL), that lean women with PCOS have a high risk of CVD in the future.

IV. Conclusion

From the calculation of the AIP log (TG/HDL), we predicted that lean women with PCOS have a risk of CVD in the future, due to the high level of AIP. This work indicates from the calculation of BMI (kg/m^2) that women with PCOS have regular, normal bodies, and no significant difference was found between the PCOS and control groups. This study illustrated that the parameters of Prolactin, LH, FSH, TSH, Testo, insulin, and FBG were significantly increased in lean women with PCOS as compared with healthy groups. In addition, the lipid profile parameters of T-Chol, TG, LDL, and VLDL were significantly elevated in lean women with PCOS as compared with healthy individuals, while the parameter of serum HDL significantly decreased in the PCOS group compared with the control groups. Moreover, the median and IQR levels for serum Mg indicate no significant difference between the PCOS and normal groups. The results of this study indicate that those lean women with PCOS who have a problem with menstrual cycle, hyperprolactinemia, dyslipidemia, and high levels of HOMA-IR contribute to a problem with T2DM, CVD, and infertility in the future. The findings from this work recommend further detailed studies and future work in this area with higher sample sizes, oxidative stress biomarkers, and some protein parameters.

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