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ORIGINAL ARTICLE

Evaluation of the Relationship Between Polycystic Ovarian Syndrome and Hypertension: A Case-control Study

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Abstract

Background: **Polycystic Ovary Syndrome (PCOS) is a common endocrine disorder affecting reproductive-aged women. It has been associated with metabolic disturbances that may increase the risk of hypertension.**

Objective: **This study aimed to evaluate the association between PCOS and hypertension, with a particular focus on anti-Müllerian hormone (AMH) as a potential biomarker.**

Methods: **A case-control involving women aged 15−45 years (mean of age 28.666 ± 6.837) years, divided into two groups n = 45 (mean of age 31.689 ± 6.842) used as controls and n = 45 patients (mean of age 24.644 ± 5.390), The serum LH, FSH, insulin, prolactin, and testosterone were measured using ELISA.**

Result: **A significant increase ($p \leq 0.01$) was observed in diastolic pressure in PCOS patients (8.04 ± 0.82) compared to the control group (7.40 ± 0.54), No significant difference was observed in systolic blood pressure on hormonal parameters found elevated in AMH in patient (2386.14 ± 530.09) compared to control (895.01 ± 198.18), prolactin, testosterone, and LH, and a significant decrease observed in FSH.**

Conclusion: **Obesity, low-grade inflammation, and hyperinsulinemia are prevalent in PCOS, which leads to an increase in hypertension that makes women with PCOS more likely to develop hypertension and cardiovascular complications.**

Keywords: Polycystic ovarian syndrome, Hypertension

Introduction

Polycystic ovarian syndrome is recognized as a widespread endocrine disorder with an unknown cause, with an incidence ranging between 8.7 % and 17.8 % in women of reproductive age (Hofmann et al., 2024). American pathologists Irvin Stein and Michael Leventhal initially identified polycystic ovary disease in 1935 under the term Stein-Leventhal syndrome (Abdulla et al., 2024). The pathophysiology of PCOS shows intricate pathways that combine insulin resistance, chronic inflammation, and hyperandrogenism to produce a range of clinical symptoms (Mahata, 2022), including irregular periods, obesity, insulin resistance, infertility, and mental health issues (Well-being, 2024). Several cardiometabolic there are danger signs for women with PCOS, particularly those with a hyperandrogenic phenotype, which raises their risk of hypertension, the vascular characteristics of artery may also be directly impacted by androgen barriers that contribute to the process of atherogenesis excess in PCOS, Prior research on hypertension in PCOS has produced conflicting findings, even though it is one of the primary cardiovascular risk factors in the general population, Nevertheless, a different study revealed no difference in hypertension between controls and women with PCOS who are not have overweight (Burhan et al., 2019; Wu et al., 2020). However, there is evidence that PCOS individuals have higher rates of subclinical atherosclerosis, endothelial dysfunction, thicker of carotid atrial wall layers, and coronary

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artery calcification. Young, overweight women with PCOS had a five-fold greater frequency of subclinical coronary atherosclerosis than the overall population. Only a few studies have investigated hypertension in PCOS-afflicted women, and the findings have been discordant (Amiri et al., 2020). The elevated prevalence of hypertension in PCOS is thought to result from multiple interrelated mechanisms primarily hyperinsulinemia, hyperandrogenemia and obesity (Al-Fatlawi & Alsafi, 2020; Mellembakken et al., 2021). The objective of this study aimed to evaluate the association between PCOS and hypertension, with a particular focus on anti-Müllerian hormone (AMH) as a potential biomarker (see Fig. 1).

Materials and methods

Study design and participants

This case-control study was performed to evaluate selected biomarkers linked to PCOS among women aged 15–45 years. The study included 90 participants, including 45 clinically diagnosed PCOS patients and 45 healthy controls. Diagnosis was based on clinical symptoms, ultrasound examination, and laboratory criteria according to Rotterdam guidelines. The data were collected and recorded from September 2024 to December 2024 at the hospital in the Fertility Unit in Karbala. In addition, information was collected for each group according to the questionnaire.

Ethical approval and informed consent

Ethics committee approval was obtained with written consent from all participants, ensuring compliance with ethical standards for human research IQ.UOK.CAMS.DCL.REC.2.

Inclusion and exclusion criteria

Eligible participants were married women aged between 15 and 45 years. Exclusion criteria included

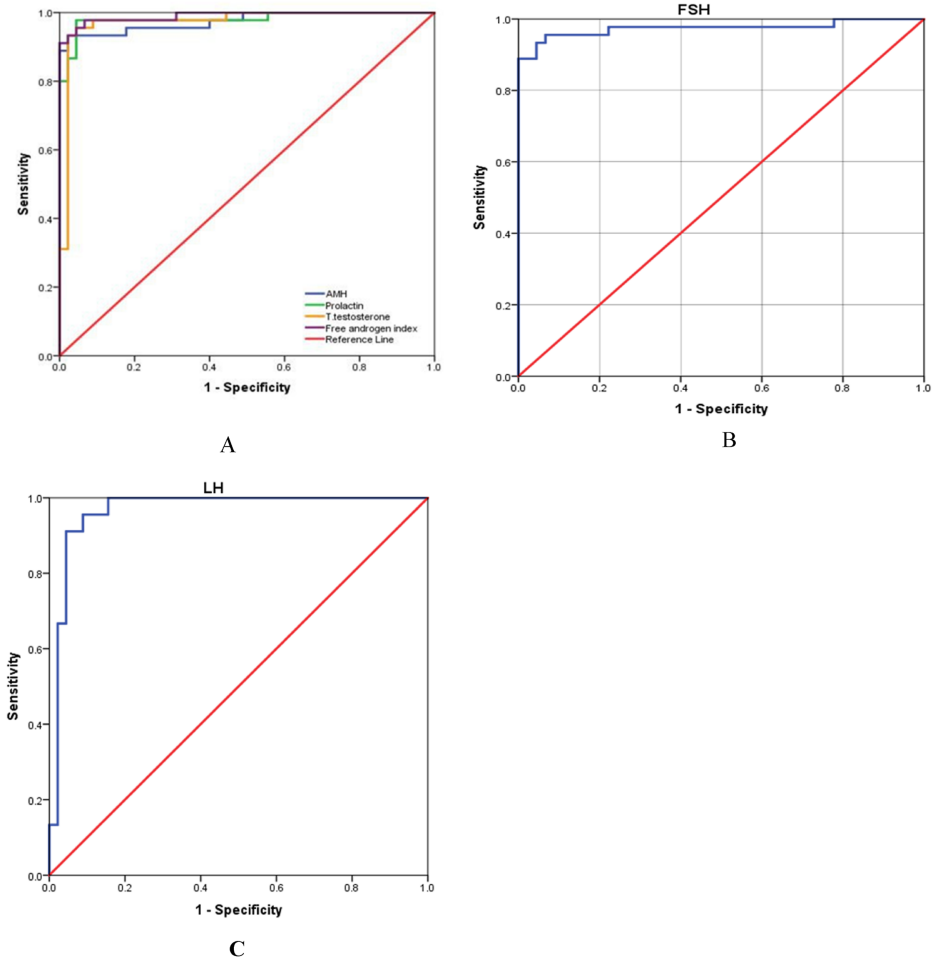

Fig. 1. Receiver operating characteristic (ROC) analysis for A: Receiver operating characteristic curve for T. testosterone, AMH, prolactin, and free androgen index parameters. B: Receiver operating characteristic curve for FSH parameter. C: Receiver operating characteristic curve for LH.

a history of diabetes mellitus, smoking, hormonal contraceptive use, and previous ovarian surgery to minimize confounding factors affecting hormonal levels.

Sample collection and processing

Venous blood samples (5 mL) were collected from each participant on 2or 3 days of menstrual cycle using standard phlebotomy techniques. Samples were divided into EDTA-coated tubes for whole blood and gel tubes for serum separation. Serum was separated by centrifugation at 3000 rpm for 10 min and stored under appropriate conditions until analysis.

Measurement of blood pressure

Equipment

BP was measured using a validated automated oscillometric sphygmomanometer (DMK Kolding Company, Denmark) was used to measure hypertension, with the appropriate cuff size determined by arm circumference. Device calibration was performed regularly.

Pre-measurement protocol

Participants avoided caffeine, exercise, and smoking 30 min prior, emptied their bladder, and rested for ≥5 min in a quiet, temperature-controlled room.

Measurement procedure

BP was measured in the seated position with back supported, feet flat, and the arm at heart level. Three consecutive readings were obtained at 1–2 min intervals from the non-dominant arm. The first reading was discarded, and the mean of the second and third readings was used.

Data recording

Systolic and diastolic BP, heart rate, arm circumference, cuff size, and time of measurement were documented. Hypertension was defined as ≥130/80 mmHg according to ACC/AHA 2017 guidelines.

Measurement of biochemical and hormonal markers

Levels of anti-Müllerian hormone (AMH), luteinizing hormone (LH), follicle-stimulating hormone (FSH), prolactin, and testosterone were quantified using enzyme-linked immunosorbent assay (ELISA) kits following the manufacturer's protocols. Optical density readings were measured at 450 nm.

Statistical analysis

Data analysis was performed using IBM SPSS software (version 23). Descriptive statistics were computed to summarize means and standard deviations. The Shapiro–Wilk test assessed normality, and Levene's test evaluated variance homogeneity. Group comparisons employed independent t-tests or Mann–Whitney U tests as appropriate. Statistical significance was set at $p < 0.01$.

Sample size determination

To identify clinically significant variations in serum Hormone levels between PCOS patients and healthy controls, the sample size for this case-control study was determined. Applying two independent means with equal group sizes, the comparison formula:

$$N = 2\left(Z^1_{-\frac{a}{2}} + Z^1\_B\right)^2 .a^2 \diagdown (\mu 1 - \mu 2)^2$$

Where n is the sample size per group,

$Z^1_{-\frac{a}{2}}$ is the Z-value corresponding to a 95 % confidence level (1.96).

Z^1_B is the Z-value corresponding to 80 % power (0.84).

a is the estimated standard deviation, and ($\mu 1 - \mu 2$) is the minimum detectable difference in mean values of the biomarker between the two groups.

Based on previous literature assessing Hormones levels in PCOS patients, an estimated pooled standard deviation (α) of 5.0 and a minimum clinically significant difference ($\mu 1$-$\mu 2$) of 3.0 were assumed. Substituting the values into the formula:

$$n = 2(1.96 + 0.84)2.5^2 \diagdown (3)^2 = 2(7.84)\ (25) \diagdown 9 = 392 \diagdown 9 \approx 46.33$$

As a result, 46 people per group was the estimated sample size. In order to provide sufficient statistical power and account for possible non-responses or exclusions, the final sample size was modified to include 45 PCOS patients and 45 healthy controls, for a total of 90 study participants.

Result

Estimation of systolic pressure in PCOS patients according to different demographic criteria

The result in table (1) found a significant increase ($p \leq 0.05$) in systolic pressure based on last date of delivery (two years) address (urban), age (less than

30) between PCOS patients (13.000 ± 1.732) (11.938 ± 0.982) (11.912 ± 0.996) compared to the control group (11.375 ± 0.744) (11.389 ± 0.608) (11.350 ± 0.745) and also found a significant increase ($p \leq 0.01$) in diastolic pressure in PCOS patients in (Non, two years and more than two years) (8.043 ± 0.878) (8.667 ± 0.577) (8.000 ± 0.791), respectively compared to the control group (7.000 ± 0.0001) (7.500 ± 0.535) and (7.438 ± 0.564), as in Table 1.

Estimation of blood pressure levels based on types of infertility in PCOS patients compared to control group

The result in table (2) found a significant increase ($p \leq 0.01$) in diastolic pressure in the PCOS patients in primary and secondary infertility (8.043 ± 0.878) (8.045 ± 0.785) compared to the control group (7.400 ± 0.539), as in Table 2.

Estimation of systolic and diastolic pressure in PCOS patients according to different demographic criteria

Result in the Tables 3 and 4 show a significant elevated (0.0033) in diastolic pressure in date of last delivery (none), type of delivery (ceserian), and body mass index (overweight).

Level of blood pressure and hormones in PCOS patients as compared to controls

As a result of the Table (5) found high significant elevated ($p \leq 0.01$) in hormonal parameters that include (LH, prolactin, testosterone and AMH) in PCOS patients (2.73 ± 0.51) (64.21 ± 11.66) (3.33 ± 0.75) (2386.14 ± 530.09), (773.23 ± 152.41), respectively, compared to the control (1.08 ± 0.05) (20.74 ± 4.33) (0.51 ± 0.16) (895.01 ± 198.18) (104.59 ± 13.55), and significant decrease ($p \leq 0.01$) in FSH in the PCOS patient (2.61 ± 0.61) compared to the control (5.72 ± 0.70), Also found a significant increase ($p \leq 0.05$) in systolic pressure in the PCOS patients (11.93 ± 1.01) compared to the control group (11.51 ± 0.73) and in diastolic pressure found a significant increase ($p \leq 0.01$) in the PCOS patients (8.04 ± 0.82) compared to the control group (7.40 ± 0.54), as in Table 5.

Table 2. Estimation of blood pressure levels based on types of infertility in PCOS patients compared to control group.

Parameters	Type of infertility	Mean	Std. Deviation	P-value
Systolic pressure (mmHg)	Primary	12.043	1.022	0.0570
	Secondary	11.818	1.006	
	Control	11.511	0.727	
Diastolic pressure (mmHg)	Primary	8.043	0.878	0.0001
	Secondary	8.045	0.785	
	Control	7.400	0.539	

Estimation of blood pressure based on clinical criteria in the PCOS patient compared to the control group

In table (6) found a significant increase ($p \leq 0.01$) in diastolic pressure was found in the PCOS patients (7.778 ± 0.667) (8.111 ± 0.854) (8.190 ± 0.873) (7.917 ± 0.776) (8.043 ± 0.878) (8.045 ± 0.785)

Table 1. Estimation of Systolic pressure in PCOS patients according to different demographic criteria.

Parameters	Level	Control	Patient	Total	P-value
Date of last delivery	None	6.67 %	51.11 %	28.89 %	0.0006
	One Year	4.44 %	4.44 %	4.44 %	
	Two Year	17.78 %	6.67 %	12.22 %	
	More than Two Year	71.11 %	37.78 %	54.44 %	
Type of delivery	None	0.00 %	51.11 %	25.56 %	0.0001
	Csarean	22.22 %	24.44 %	23.33 %	
	Natural	77.78 %	24.44 %	51.11 %	
Address	Rural	60.00 %	28.89 %	44.44 %	0.003
	Urban	40.00 %	71.11 %	55.56 %	
Nature of food	Unhealthy	46.67 %	71.11 %	58.89 %	0.018
	Healthy	53.33 %	28.89 %	41.11 %	
BMI Group	Normal	28.89 %	17.78 %	23.33 %	0.0602
	Overweight	53.33 %	42.22 %	47.78 %	
	Obese	17.78 %	40.00 %	28.89 %	
Age	Less than 30	25.800 ± 2.802	25.529 ± 3.887	24.370 ± 3.667	0.0270
	Greater than 30	36.400 ± 5.252	32.128 ± 3.970	35.111 ± 5.225	0.0137

- The chi-square test has been utilized to analyze the categorical variables.
- Association is significant at the 0.05 level.

Table 3. Estimation of systolic pressure in PCOS patients according to different demographic criteria.

Demographic parameters	Groups	Control		Patient		95 % CI of the Difference	P-value
		Mean	Std. Deviation	Mean	Std. Deviation		
Last date of delivery	None	11.333	0.577	12.043	1.022	−1.96, 0.54	0.2550
	One Year	11.000	0.000	11.500	0.707	−2.65, 1.65	0.4226
	Two Year	11.375	0.744	13.000	1.732	−3.22, −0.02	0.0477
	More than 2 years	11.594	0.756	11.647	0.786	−0.51, 0.40	0.8177
Type of delivery	Cesarian	11.300	1.059	12.000	1.183	−1.73, 0.33	0.1710
	Nature	11.571	0.608	11.636	0.809	−0.52, 0.39	0.7770
Address	Rural	11.593	0.797	11.923	1.115	−0.95, 0.29	0.2886
	Urban	11.389	0.608	11.938	0.982	−1.06, −0.03	0.0370
Age	Less than 30	11.350	0.745	11.912	0.996	−1.07, −0.04	0.0334
	More than 30	11.640	0.700	12.000	1.095	−1.13, 0.41	0.3330
Nature of food	Healthy	11.458	0.658	0.660	0.996	−0.54, 0.38	0.7261
	Unhealthy	11.571	0.811	1.088	1.095	−1.04, 0.03	0.0511
BMI	Normal	11.538	0.776	11.625	0.744	−0.80, 0.63	0.8038
	Overweight	11.375	0.711	11.579	0.961	0.31, 0.71	0.4283
	Obese	11.875	0.641	12.444	0.984	−1.35, 0.21	0.1483

- Independent T-Test and Mann–Whitney U test have been utilized to conduct a comparative analysis between two groups on the same continuous variable.
- Bonferroni-adjusted significance level set at 0.0033.

compared to the control group (7.400 ± 0.539) (7.400 ± 0.539) (7.400 ± 0.539) as in Table 6.

Area under ROC curve (AUC) analysis for research parameters

As result in Table 7 found that t.testosterone 95 % (CI 0.938–1.000: P-value 0.001: cutoff point:1.198: AUC:97.333 %, with Sensitivity to Specificity 95.556 %–95.355 %; and accuracy: 95.556 %. Prolactin 95 % (CI 0.973–1.000: P-value 0.001: cutoff point:5.335: AUC:98.123 %, with sensitivity to specificity 97.778 %–95.456 %; and accuracy 96.667 FSH 95 % (CI 0.939–1.000: P-value 0.001: cutoff point:4.329: AUC:97.432 %, with sensitivity to specificity 95.452 %–93.333% ; and accuracy: 94.444 %. LH 95 % (CI 0.925–1.000: P-value 0.001: cutoff point:2.455: AUC:96.642 %, with sensitivity to specificity 95.556%–95.535 %; and accuracy: 93.333 %. Also, for AMH 95 % (CI 0.946–1.000: P-value 0.001: cutoff point:1465.212: AUC:97.531 %, with Sensitivity to Specificity 93.432 %–97.780 %; and accuracy: 95.556 % as in Table 6.

Table 4. Estimation of Diastolic pressure in PCOS patients according to demographic criteria.

Classification	Groups	Control		Patient		95 % CI of the Difference	P-value
		Mean	Std. Deviation	Mean	Std. Deviation		
Date of last delivery	None	7.000	0.0001	8.043	0.878	−2.10, 0.02	<0.0001
	One Year	7.000	0.0001	7.500	0.707	−2.65, 1.65	0.4226
	Two Year	7.500	0.535	8.667	0.577	−2.00, −0.33	0.0114
	More than 2 years	7.438	0.564	8.000	0.791	−0.95, −0.17	0.0059
Type of delivery	Cesarian	7.300	0.483	8.273	0.786	−1.57, −0.36	0.003
	Nature	7.429	0.558	7.818	0.751	−0.81, 0.03	0.070
Address	Rural	7.370	0.565	7.923	0.760	−0.98, −0.12	0.0136
	Urban	7.444	0.511	8.094	0.856	−1.09, −0.20	0.0052
Age	Less than 30	7.400	0.503	8.029	0.797	−1.02, −0.23	0.0025
	More than 30	7.400	0.577	8.091	0.944	−1.20, −0.17	0.0105
Nature of food	Healthy	7.375	0.576	8.000	0.707	−1.06, −0.18	0.0063
	Unhealthy	7.429	0.507	8.063	0.878	−1.05, −0.20	0.0043
BMI	Normal	7.538	0.660	7.750	0.886	−0.91, 0.49	0.5385
	Overweight	7.375	0.495	8.000	0.816	−1.03, −0.21	0.0035
	Obese	7.250	0.463	8.222	0.808	−1.60, −0.33	0.0043

- Independent T-Test and Mann–Whitney U test have been utilized to conduct a comparative analysis between two groups on the same continuous variable.
- Bonferroni-adjusted significance level set at 0.0033.

Table 5. Level of blood pressure and hormones in PCOS patients as compared to controls.

Parameters	Level	Mean	Std. Deviation	95 % CI of the Difference	P-value
T.testosterone (ng\ml)	Control	1.08	0.05	−1.80, −1.48	<0.0001
	Patient	2.73	0.51		
Prolactin (ng\ml)	Control	20.74	4.33	−47.18, −39.75	<0.0001
	Patient	64.21	11.66		
FSH(ng\ml)	Control	5.72	0.70	2.83, 3.38	0.0004
	Patient	2.61	0.61		
LH (ng\dl)	Control	0.51	0.16	−3.04, −2.58	0.0008
	Patient	3.33	0.75		
AMH	Control	895.01	198.18	−1660.12, −1322.13	0.0001
	Patient	2386.14	530.09		
Systolic pressure (mmHg)	Control	11.51	0.73	−0.79, −0.05	0.0250
	Patient	11.93	1.01		
Diastolic pressure (mmHg)	Control	7.40	0.54	−0.93, −0.35	0.0001
	Patient	8.04	0.82		

- Independent T-Test and Mann–Whitney U test have been utilized to conduct a comparative analysis between two groups on the same continuous variable.
- The mean difference is significant at the 0.05 level.

Discussions

We found elevated of hypertension in women have PCOS due to obesity and bad life style, and PCOS is the primary correlation with metabolic syndrome such as diabetes, heart disease elevated blood pressure (BP) is thought to be present in approximately 40 % of women with PCOS (Joksimovic Jovic et al., 2021). We found elevate the danger of hypertension in PCOS women compared to control women, which raises the risk of cardiovascular disease, metabolic disorders, and psychological issues, individuals with PCOS typically exhibit these diseases earlier than controls, compared to those with PCOS and a BMI higher than 25 are more likely to experience long-term health issues (Dason et al., 2024). Another reason for high blood pressure is to worry about fertility problems because hormonal abnormalities can leads to irregular ovulation and reduce the chances of pregnancy, so all these factors contributing to the development of HT (Joshi, 2024). Which agreement with the study (Haddawi et al., 2025).

Table 6. Estimation of blood pressure based on clinical criteria in the PCOS patient compared to the control group.

Parameters	Clinical criteria	Level	Mean	Std. Deviation	95 % CI of the Difference	P-value
Systolic pressure (mmHg)		No	12.000	1.000	−0.07, 1.05	0.0800
		Yes	11.917	1.025	0.01, 0.79	
		Control	11.511	0.727	–	
Diastolic pressure (mmHg)m	Hairstism	No	7.778	0.667	−0.03, 0.78	0.0008
		Yes	8.111	0.854	0.40, 1.02	
		Control	7.400	0.539	–	
Systolic pressure (mmHg)		No	12.095	1.044	0.06, 1.10	0.0430
		Yes	11.792	0.977	−0.13, 0.69	
		Control	11.511	0.727	–	
Diastolic pressure (mmHg)	Acne	No	8.190	0.873	0.36, 1.21	0.0007
		Yes	7.917	0.776	0.19, 0.83	
		Control	7.400	0.539	–	
Systolic pressure (mmHg)		Para	12.043	1.022	0.10, 0.96	0.0570
		Gravida	11.818	1.006	−0.12, 0.73	
		Control	11.511	0.727	–	
Diastolic pressure (mmHg)	Para\Gravida	Para	8.043	0.878	0.30, 0.98	0.0001
		Gravida	8.045	0.785	0.31, 0.97	
		Control	7.400	0.539	–	

- ANOVA and Kruskal–Wallis tests have been utilized to discern statistically significant differences across multiple independent groups.
- The mean difference is significant at the 0.05 level.

Table 7. Area under ROC curve (AUC) analysis for research parameters.

Metrics		T. testosterone	Prolactin	FSH	LH	AMH
Std. Error		0.018	0.013	0.018	0.021	0.015
Asymptotic Sig.		0.001	0.003	0.009	0.002	0.008
Asymptotic 95 % Confidence Interval	Lower Bound	0.938	0.955	0.939	0.946	0.946
	Upper Bound	1.000	1.000	1.000	1.000	1.000
Cutoff Point		1.198	35.143	4.329	2.455	1465.212
Area Under Curve (AUC)		97.333 %	98.123 %	97.432 %	96.642 %	97.531 %
Sensitivity		95.556 %	97.778 %	95.452 %	91.111 %	93.432 %
Specificity		95.355 %	95.456 %	93.333 %	95.535 %	97.780 %
Accuracy		95.556 %	96.667 %	94.444 %	93.333 %	95.556 %
Positive Predictive Value		95.455 %	95.652 %	93.478 %	95.349 %	97.674 %
Negative Predictive Value		93.478 %	97.727 %	95.455 %	91.489 %	93.617 %

Our study agreement with study found that increase hypertension in premenopausal women with PCOS versus control (Bentley-Lewis et al., 2011). But study in Erbil found no risk of hypertension in PCOS women due to the most of inclusion in PCOS group and control group are young age (15–34) years and rare to have hypertension in this age group (Saleh & Ahmed, 2021).

We found FSH level was reduced that effect on impair follicle development and, as a result, anovulation, whereas the disrupted hypothalamic-pituitary-ovarian (HPO) axis has been linked to decreased FSH secretion, elevated LH frequency, and enhanced theca cell production of androgens combined with insulin resistance, follicular stagnation that lead to infertility (Kadhim et al., 2025). Pathogenesis of PCOS is unclear, but some research show the neuroendocrine system plays a significant role in the mechanism underling PCOS, alongside metabolic and hormonal factors, a dysregulation in the pattern of gonadotropin-releasing hormone production can lead to disruptions in the hypothalamic-pituitary-ovarian or adrenal axis, which have been connected to polycystic ovary syndrome (Al-Fatlawi, 2022; Camili et al., 2024). That agreement with (Pratama et al., 2024).

Our study showed elevated of AMH in PCOS patient versus to control due to the enhanced production and release of AMH by the preantral and tiny antral follicles, AMH levels rise proportionately to the antral follicle count (AFC) at a steady 0.2 ng/ml for each follicle. Furthermore, granulosa cells in PCOS patients' follicles have been demonstrated to generate 75 times as much AMH as normal cell (Challab, 2025). Agreement with study (Zhang et al., 2024).

We found increase systolic blood pressure in PCOS women less than 30 years that may be due to bad food choices, obesity, physical inactivity, genetic factors and sedentary lifestyles all contribute to the greater frequency of PCOS in younger generations (Mohapatra & Samantaray, 2024).

In our study found elevated diastolic pressure in PCOS women who have hairstism and acne that the most clinical feature of PCOS women result from elevated testosterone due to obesity (Hussein et al., 2025). In this study found no a significant difference in systolic pressure in PCOS women according to clinical feature.

Previous studies documented comparable results on ROC showing that Prolactin's AUC, sensitivity, and specificity were (83.2 %, 77 %, 88 %) (Pedachenko et al., 2021). And Testosterone (88.9 %, 92.6 %, 85.4 %) (Adam et al., 2024). LH (93.2 %; 86.3 %: 95 %) (Alhassan et al., 2023). FSH sensitivity of 65.00 % and specificity of 87.80 % (Tang & Li, 2022).

Conclusion

Women with PCOS exhibit higher diastolic blood pressure, potentially due to obesity, hyperinsulinemia, and hormonal imbalances, suggesting increased hypertension risk in this population.

Ethics information

This study was approved by the ethics committee of Department of Clinical Laboratories/College of Applied Medical Sciences/University of Karbala (Ref: IQ.UOK.CAMS.DCL.REC.2). After the Ministry of Health and Environment granted permission to conduct the study, samples were collected and starting the study. The study participants gave their permission to collect socio-demographic data as well as undertake experiments on the selected samples with respecting patient confidentiality.

Authors' contributions

Ayat Salim contributed to the conceptualization and design of the study, developed the

methodological framework, and prepared the original draft of the manuscript. Author B. was responsible for data curation and performed the formal statistical analysis. **Abeer C. Y. Al-Fatlawi** contributed to the investigation process and validation of the findings. **Wassan Ghazi Al-Safee** provided overall supervision, project administration, and critical review of the manuscript.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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