

ORIGINAL RESEARCH

PERIOPERATIVE MEDICINE

Correlation between adiponectin levels, insulin resistance, and oxidative stress in polycystic ovary syndrome patients: implications for novel therapeutic approaches

Zainab Mohammed Talib ¹, Khwam R. Hussein ², Hasan Abd Ali Khudhair ^{3*}

Authors affiliations:

1. Zainab Mohammed Talib, College of Health and Medical Technology, Southern Technical University, Ministry of Higher Education and Scientific Research, Al-Basrah, Iraq
2. Khwam R. Hussein, Al-Nasiriyah Technical Institute, Southern Technical University, Ministry of Higher Education and Scientific Research, Iraq
3. Hasan Abd Ali Khudhair, Al-Nasiriyah Technical Institute, Southern Technical University, Ministry of Higher Education and Scientific Research, Iraq; Email: hasanabdali89@stu.edu.iq

*Correspondence: Hasan Abd Ali Khudhair, Email: hasanabdali89@stu.edu.iq

ABSTRACT

Background & objective: Polycystic ovary syndrome (PCOS) is a prevalent endocrine disorder characterized by metabolic dysfunction, including insulin resistance and oxidative stress. Adiponectin, an adipokine that has anti-inflammatory and insulin-sensitizing properties, may be essential to the pathogenesis of PCOS.

Methodology: To assess the relationship between serum adiponectin levels, IR indices (insulin, fasting blood glucose, HOMA-IR), oxidative stress (as determined by the total antioxidant capacity), and lipid profile parameters in PCOS women in comparison to healthy controls. A case-control study was conducted involving 45 PCOS patients and 45 age-matched HCs. Biochemical markers, including insulin, FBG, lipid profile, adiponectin, and TAC were analyzed. Statistical tests such as t-test, Chi-square, Spearman's correlation, and Mann-Whitney U test were applied.

Results: PCOS patients exhibited significantly elevated levels of total cholesterol, LDL-C and reduced adiponectin in comparison to healthy controls (HCs). Although levels of HOMA-IR and insulin were unexpectedly lower in PCOS patients, FBG was higher. HOMA-IR and adiponectin were discovered to have a paradoxical positive relationship. TAC showed a non-significant inverse relationship with HOMA-IR in PCOS patients but a significant one in healthy controls. Higher TAC levels were associated with elevated TG and VLDL, and reduced HDL levels.

Conclusions: The findings of the study indicate a complex interaction among adiponectin, oxidative stress, and insulin resistance in PCOS, with potential dysregulation in adiponectin signaling. Elevated TAC levels may reflect compensatory mechanisms rather than protection, emphasizing the need for targeted therapeutic strategies.

Keywords: PCOS; Adiponectin; HOMA-IR; Oxidative Stress; Dyslipidemia

Abbreviations: ADP: adiponectin, BMI: body mass index, ELISA: enzyme-linked immunosorbent assay, FBG: fasting blood glucose, HDL-C: high-density lipoprotein-cholesterol, HCs: healthy controls, HOMA-IR: homeostatic model assessment of IR, IR: insulin resistance, LDL: low-density lipoprotein, OS: oxidative stress, PCOS: Polycystic ovary syndrome, ROS: reactive oxygen species, SD: standard deviations, T2D: type 2 diabetes, TAC: total antioxidant capacity, TC: total cholesterol, TG: triglyceride, VLDL: very low-density lipoprotein.

Citation: Talib ZM, Hussein KR, Khudhair HAA. Correlation between adiponectin levels, insulin resistance, and oxidative stress in polycystic ovary syndrome patients: Implications for novel therapeutic approaches. *Anaesth. pain intensive care* 2025;29(8):919-931. DOI: 10.35975/apic.v29i8.3019.

Received: June 17, 2025; **Revised:** August 21, 2025; **Accepted:** August 21, 2025

1. INTRODUCTION

Polycystic ovary syndrome (PCOS) is one of the most common endocrine disorders affecting women of reproductive age, with a prevalence ranging from 6% to 15% globally.¹ Characterized by hyperandrogenism, ovulatory dysfunction, and polycystic ovarian morphology, PCOS significantly impacts metabolic, reproductive, and psychological health.² Among its multifaceted manifestations, insulin resistance (IR) and oxidative stress (OS) are recognized as being important factors in its pathogenesis, exacerbating metabolic and hormonal imbalances.³

Recent research suggests that OS could contribute to the PCOS incidences.⁴ Oxidative stress is defined as the overproduction of reactive oxygen species (ROS) and an imbalance between oxidants and antioxidants. Understanding the function of the OS in PCOS is crucial since it may affect the reproductive and metabolic issues that these people experience. The levels of oxidative indicators were higher in women with PCOS, based on initial studies, indicating a complicated relationship that may lead to new therapeutic possibilities.⁵

ADP, an adipocyte-derived hormone with insulin-sensitizing and anti-inflammatory properties, has emerged as a critical biomarker linking metabolic dysfunction and OS in PCOS. Its inverse relationship with IR and potential protective role against oxidative damage highlight its importance in understanding the metabolic derangements observed in these patients. Despite its significance, the exact interplay between ADP levels, IR, and OS remains inadequately explored in PCOS.⁶

This research aims to investigate the correlations between serum levels of ADP, IR indices such as fasting blood glucose (FBG) and insulin, and OS markers like total antioxidant capacity (TAC) in PCOS patients. Additionally, lipid profile parameters are analyzed to evaluate their contribution to the metabolic disturbances associated with PCOS. By elucidating these interrelationships, the research seeks to provide insights into the underlying mechanisms of PCOS and identify novel therapeutic targets to mitigate its metabolic complications.

The findings of this research are expected to enhance understanding of PCOS pathophysiology and pave the way for the development of tailored interventions that address both metabolic and OS components. This integrative approach holds promise for improving clinical outcomes and quality of life for PCOS patients.

2. METHODOLOGY

2.1. Study Design and Setting

A case-control study was conducted in Thi-Qar Governorate (Iraq) at Bent Al Huda Teaching Hospital, between September 2024 and December 2024. In this paper, two study groups are employed; 45 PCOS-afflicted women were included in the first group. All women in this group were diagnosed with PCOS based on the Revised Rotterdam 2003 criteria, which require at least two of the following three features: oligo- or anovulation, the presence of polycystic ovaries, and clinical and/or biochemical evidence of hyperandrogenism, after excluding other causes such as androgen-secreting tumors, congenital adrenal hyperplasia, Cushing's syndrome,⁷ and 45 individuals as healthy controls (HCs) were enrolled in the second group. All subjects in the study were aged between 18 and 40 years old.

This research was carried out following the principles of the Declaration of Helsinki and was ethically approved by the Ethics Committee of the Training and Human Development Unit at Thi-Qar Health Department, Iraq (Approval No. 197/2024) on September 3, 2024, as part of a master's thesis. Before joining the study, all participants provided written informed consent. They were fully briefed on the study's goals, risks, procedures, and benefits. There are no conflicts of interest, according to the authors, and the research was conducted without any financial incentives that could bias the results.

The study excluded women who recently used hormonal contraceptives, anti-androgens, or insulin sensitizers (past three months), were pregnant or breastfeeding, had chronic diseases (diabetes, hypertension, cardiovascular diseases), a history of ovarian surgery, or inadequate sample collection. Included participants met clinical and laboratory PCOS criteria (menstrual irregularities, hyperandrogenism, ultrasound-confirmed polycystic ovaries), be in the 18–40 age range, possess a body mass index (BMI) in the range of 18.5 to 35, which includes a range of normal to moderately obese individuals and had no prior medical history of endocrine abnormalities such as androgens secreted tumors, Cushing's syndrome, or congenital adrenal hyperplasia.

Healthy controls were age-matched (18-40 years) with the PCOS group, had regular menstrual cycles, no history of PCOS, and a BMI within the same range to minimize confounding effects. They did not suffer from any endocrine conditions, such as congenital adrenal hyperplasia, thyroid dysfunction, as well as Cushing's syndrome, no history of hormonal medication use, normal fertility status, and a healthy lifestyle.

From every individual, five mL of the peripheral blood was obtained through venous puncture. After allowing the obtained samples to coagulate at room temperature

Table 1: Comparison of lipid profile parameters between PCOS patients and healthy controls							
Parameters		PCOS Group		Healthy Control		P- value	
		n (%)	Mean (\pm SD)	n (%)	Mean (\pm SD)	n (%)	Mean
TC (mg/dl)	Normal	32 (71.1)	162.1	42 (93.3)	153.6	0.017	0.0022
	Moderate	10 (22.2)	209.4	3 (6.7)	215.5		
	High	3 (6.7)	262	0 (0)	0		
	Total	45 (100)	179.29 \pm 35.07	45 (100)	157.73 \pm 29.61		
TG (mg/dl)	Normal	33 (73.3)	99.24	37 (82.2)	100.44	0.573	0.5061
	Mild	11 (24.5)	224.41	8 (17.8)	217.8		
	Moderate	1 (2.2)	520.8	0 (0)	0		
	High	0 (0)	0	0 (0)	0		
	Total	45 (100)	139.21 \pm 88.22	45 (100)	121 \pm 57.73		
HDL (mg/dl)	Low	8 (17.8)	35.12	10 (22.2)	33.47	0.077	0.0929
	Normal	30 (66.6)	47.92	20 (44.5)	51.75		
	High	7 (15.6)	73.52	15 (33.3)	67.54		
	Total	45 (100)	49.63 \pm 13.34	45 (100)	52.95 \pm 13.38		
LDL (mg/dl)	Normal	24 (53.4)	79.14	35 (77.8)	70.82	0.073	0.0007
	Near/above normal	15 (33.3)	116.7	8 (17.8)	109.59		
	Borderline high	4 (8.9)	140.65	2 (4.4)	133.8		
	High	2 (4.4)	184.32	0(0)	0		
	Total	45 (100)	101.81 \pm 31.81	45(100)	80.5 \pm 25.22		
VLDL (mg/dl)	Low	0 (0)	0	0 (0)	0	0.310	0.5061
	Normal	33 (73.3)	19.84	37 (82.2)	20.08		
	High	12 (26.7)	49.82	8 (17.8)	43.56		
	Total	45 (100)	27.84 \pm 17.64	45 (100)	24.3 \pm 11.55		

TC: total cholesterol, TG: triglyceride, HDL: High density lipoprotein, LDL: low-density lipoprotein, VLDL: very low-density lipoprotein
P < 0.05 is significant; Chi-square test, Mann-Whitney U test, and Unpaired t test.

in gel vacuum tubes, the specimens underwent centrifugation for 10 minutes at 3600 xg in order to extract the serum. For later analysis, the separated serum was kept at -80°C.

A measurement of serum insulin was done in μ IU/mL utilizing the technique of enzyme-linked immunosorbent assay (ELISA) with a human insulin ELISA kit (BT LAB, China). The Mindray BS-230 instrument was used to measure serum FBG and lipid profile. It is a fully automated biochemical analyzer that operates based on spectrophotometry and biochemical enzymatic reactions using a glucose kit (Mindray, China) for FBG, a triglyceride (TG) kit, a total cholesterol (TC) kit, and a high-density lipoprotein-cholesterol (HDL-C) kit (Mindray, China) for lipid profile. The test procedure followed the instructions of the manufacturer, and results were reported in mg/dL. The following formula was used to determine the concentrations of low-density

lipoprotein (LDL) and very low-density lipoprotein (VLDL) in mg/dL, respectively;^{8,9}

$$\text{LDL (mg/dL)} = \text{Cholesterol} - (\text{HDL} + \text{VLDL})$$

$$\text{VLDL (mg/dL)} = \text{Triglyceride}/5$$

Using the following formula, the homeostatic model assessment of IR (HOMA-IR) was determined¹⁰:

$$\text{HOMA - IR} = \text{fasting insulin } (\mu\text{IU/mL}) \times \text{FBG (mg/dL)}/405$$

Serum ADP was measured in mg/dl using the ELISA technique with a human ADP ELISA kit (BT LAB, China). Serum TAC was measured in mM using the GloMax Discover instrument (Promega, USA), a multi-mode microplate reader designed for fluorescence, luminescence, absorbance detection in biochemical and molecular assays using the TAC assay kit instructions (BT LAB, China).

2.2. Statistical analysis

Table 2: Comparison of glycemic, insulin sensitivity, oxidative stress, and adipokine parameters between PCOS patients and healthy controls

Parameters		PCOS Group		Healthy Control		P- value	
		n (%)	Mean (\pm SD)	n (%)	Mean (\pm SD)	n (%)	Mean
FBS (mg/dl)	Normal	17 (37.8)	92.03	25 (55.6)	84.28	0.0403	0.0003
	Prediabetic	26 (57.8)	111.17	20 (44.4)	107		
	Diabetes	2 (4.4)	145.25	0 (0)	0		
	Total	45 (100)	105.46 \pm 14.7	45 (100)	94.3 \pm 13.51		
Insulin (μ U/ml)	Low	20 (44.4)	4.34	3 (6.7)	3.84	0.002	< 0.001
	Normal	22 (48.9)	6.54	36 (80)	7.04		
	High	3 (6.7)	15.45	6 (13.3)	12.56		
	Total	45 (100)	6.15 \pm 2.87	45 (100)	7.56 \pm 2.45		
HOMA-IR	Normal	37 (82.2)	1.33	36 (80)	1.53	0.098	0.0227
	High	8 (17.8)	2.71	9 (20)	2.63		
	Total	45 (100)	1.57 \pm 0.66	45 (100)	1.75 \pm 0.58		
TAC (mM)	Low	4 (8.9)	0.04	4 (8.9)	0.04	0.210	0.2333
	Normal	34 (75.5)	0.07	39 (86.7)	0.07		
	High	7 (15.6)	0.1	2 (4.4)	0.11		
	Total	45 (100)	0.07 \pm 0.02	45 (100)	0.07 \pm 0.02		
ADP (mg/dl)	Low	22 (48.9)	5.24	4 (8.9)	5.42	0.001	0.0008
	Normal	18 (40)	7.21	36 (80)	7.34		
	High	5 (11.1)	11.66	5 (11.1)	11.52		
	Total	45 (100)	6.74 \pm 2.14	45 (100)	7.63 \pm 1.73		

Data are presented as n (%) or mean \pm SD; P < 0.05 is significant; FBS: Fasting blood sugar, HOMA-IR: homeostatic model assessment of insulin resistance, TAC: total antioxidant capacity, ADP, adiponectin.
Unpaired t-test, Chi-square test, and Mann-Whitney U test.

Data analysis and visualization were conducted using SPSS version 22 (Inc., Chicago, IL, USA). Descriptive statistics included frequencies, means, and standard deviations (SD). The Chi-Square test was used to compare categorical data. An independent t-test assessed the statistical significance of differences in the means of continuous, normally distributed data. For variables that were not regularly distributed, the Mann-Whitney U test was employed. P-values below 0.05 were regarded as statistically significant.

3. RESULTS

Lipid profile analysis revealed significant differences in TC levels, which were markedly higher in the PCOS group (179.29 ± 35.07 mg/dL) compared to controls (157.73 ± 29.61 mg/dL) ($P = 0.0022$). Likewise, LDL values were significantly higher among the PCOS group (101.81 ± 31.81 mg/dL) relative to the control group (80.5 ± 25.22 mg/dL; $P = 0.0007$). These findings indicate a more atherogenic lipid profile in PCOS

women, placing them at a heightened risk for cardiovascular disease. Similar trends were observed for the frequency percentages of total cholesterol (TC) and low-density lipoprotein (LDL).

Although levels of TG were higher in the group with PCOS (139.21 ± 88.22 mg/dL) than in controls (121 ± 57.73 mg/dL), no statistically significant difference was found ($P = 0.5061$). However, one subject in the PCOS group exhibited a markedly elevated TG level (520.8 mg/dL), which may have clinical significance on an individual level. Levels of HDL were slightly lower among PCOS patients (49.63 ± 13.34 mg/dL) compared to controls (52.95 ± 13.38 mg/dL), though not reaching statistical significance ($P = 0.0929$). A greater proportion of females in the PCOS group also exhibited low HDL levels, further contributing to an adverse cardiovascular risk profile. In terms of VLDL, the groups did not differ significantly from one another, with mean levels of 27.84 ± 17.64 mg/dL within the PCOS group and 24.3 ± 11.55 mg/dL among the control group ($P = 0.5061$) (Table 1).

Table 3: Correlation of HOMA-IR and ADP levels in PCOS and healthy control

Biomarkers		HOMA-IR						(r)value	P-value	
		Normal (< 2)		High (≥ 2)		Total				
		n (%)	Mean	n (%)	Mean		n (%)			Mean
ADP (mg/dl)	PCOS Group	Low (n=22)	(90.9)20	1.20	2 (9.1)	2.36	22 (100)	1.31	0.51	0.00
		Normal (n=18)	14 (77.8)	7.14	4 (22.2)	2.52	18 (100)	1.73		
		High (n=5)	3 (60)	1.41	2 (40)	3.44	5 (100)	2.23		
		Total (n=45)	37 (82.2)	1.33	8 (17.8)	2.71	45 (100)	1.57		
	HC	Low (n=4)	4 (100)	1.42	0 (0)	0	4 (100)	1.42	0.33	0.03
		Normal (n=36)	31(86.1)	1.54	5 (13.9)	2.28	36 (100)	1.64		
		High (n=5)	1 (20)	1.64	4 (80)	3.07	5 (100)	2.79		
		Total (n=45)	36 (80)	1.53	9 (20)	2.63	45 (100)	1.75		

Spearman's correlation analysis, Unpaired t-test, Chi-square test, and Mann-Whitney U test. Data are presented as n (%) or mean value, ADP, adiponectin

Table 4: Correlation of HOMA-IR and TAC levels in PCOS and healthy control

Biomarkers		HOMA-IR						(r)valu	P	
		Normal (< 2)		High (≥ 2)		Total				
		n (%)	Mean	n (%)	Mean	n (%)	Mean			
TAC (mM)	PCOS Group	Low (n = 4)	4 (100)	1.35	0 (0)	0	4 (100)	1.35	-0.23	0.13
		Normal (n = 34)	26 (76.5)	1.34	8 (23.5)	2.72	34 (100)	1.66		
		High (n = 7)	7 (100)	1.28	0 (0)	0	7 (100)	1.28		
		Total (n = 45)	37 (82.2)	1.33	8 (17.8)	2.71	45 (100)	1.57		
	HC	Low (n = 4)	2 (50)	1.78	2 (50)	2.85	4 (100)	2.31	-0.30	0.04
		Normal (n = 39)	32 (82.1)	1.54	7 (17.9)	2.57	39 (100)	1.72		
		High (n = 2)	2 (100)	1.18	0 (0)	0	2 (100)	1.18		
		Total (n = 45)	36 (80)	1.53	9 (20)	2.63	45 (100)	1.75		

Data are presented as n (%) or mean ± SD; P < 0.05 is significant; Spearman's correlation analysis, Chi-square test, Unpaired t-test, and Mann-Whitney U test.

Levels of FBG demonstrated a statistically significant increase in the group with PCOS (105.46 ± 14.7 mg/dL) in comparison to the control group (94.3 ± 13.51 mg/dL), with a p-value of 0.0003. A greater percentage of PCOS participants fell into the prediabetic and diabetic categories, supporting that PCOS is associated with increased IR and impaired glucose metabolism.

The comparison of insulin levels between the PCOS group and HC in the current research revealed significant differences in both frequency distributions ($P = 0.002$) and mean values ($P < 0.001$). The percentage of people with low levels of insulin was higher in the PCOS group (44.4%) than in controls (6.7%), and the mean insulin level was lower in PCOS patients (6.15 ± 2.87 μ IU/mL) than in HC (7.56 ± 2.45 μ IU/mL). Regarding HOMA-IR, the frequency of IR (high HOMA-IR) was comparable

between groups (17.8% in PCOS vs. 20% in controls; $P = 0.098$). However, the mean HOMA-IR was

significantly lower in the PCOS group (1.57 ± 0.66) compared to controls (1.75 ± 0.58) ($P = 0.0227$). While IR is typically more pronounced in PCOS, the current results may reflect a heterogeneous PCOS cohort or the influence of confounding factors such as BMI, dietary habits, or levels of physical activity, which were not controlled in this investigation.

TAC revealed no significant variations between healthy individuals and PCOS patients, either in frequency distribution ($P = 0.210$) or mean values ($P = 0.2333$). Both groups exhibited comparable TAC levels (0.07 ± 0.02 mM), indicating that systemic OS, as measured by TAC, may not differ substantially in this cohort or may require more sensitive OS markers for detection. Levels

Table 5: Correlation of ADP and TAC levels in PCOS and healthy control groups

Biomarkers		ADP (mg/dl)								(r) value	P-value	
		Low (<6)		Normal (6-10)		High (> 10)		Total				
		n (%)	Mean	n (%)	Mean	n (%)	Mean	n (%)	Mean			
TAC (mM)	PCOS	Low (n = 4)	1 (25)	5.10	2 (50)	6.49	1 (25)	11.9	4 (100)	7.5	-0.02	0.87
		Normal (n = 34)	17 (50)	5.15	14 (41.2)	7.3	3 (8.8)	11.8	34 (100)	6.64		
		High (n = 7)	4 (57.1)	5.69	2 (28.6)	7.29	1 (14.3)	10.43	7 (100)	6.83		
		Total (n = 45)	22 (48.9)	5.24	18 (40)	7.21	5 (11.1)	11.66	45 (100)	6.74		
TAC (mM)	HC	Low (n = 4)	0 (0)	0	3 (75)	8.14	1 (25)	12.02	4 (100)	9.11	-0.20	0.19
		Normal (n = 39)	4 (10.2)	5.42	31 (79.5)	7.23	4 (10.3)	11.4	39 (100)	7.47		
		High (n = 2)	0 (0)	0	2 (100)	7.83	0 (0)	0	2 (100)	7.83		
		Total (n = 45)	4 (8.9)	5.42	36 (80)	7.34	5 (11.1)	11.52	45 (100)	7.63		

Data are presented as n (%) or mean ± SD; P < 0.05 is significant; Spearman's correlation analysis, Chi-square test, Unpaired t-test, and Mann-Whitney U test.

of ADP were significantly lower within the PCOS group (6.74 ± 2.14 mg/dL) than in the control group (7.63 ± 1.73 mg/dL), with highly significant differences in both mean values (P = 0.0008) and frequency distributions (P = 0.001). Nearly half of the PCOS patients (48.9%) had low ADP levels compared to only 8.9% of the controls, supporting the association between PCOS and metabolic dysfunction (Table 2).

Table 3 illustrates the correlation of IR (measured through HOMA-IR) and ADP levels in PCOS women compared to HCs. A positive correlation that was statistically significant was found among individuals

with PCOS between HOMA-IR values and ADP levels (r = 0.51, P = 0.00). Participants with high ADP exhibited a significantly higher mean HOMA-IR (2.23) in comparison to those with low ADP, with a mean HOMA-IR of 1.31. Notably, 3/5 (60%) of the PCOS participants with high ADP exhibited normal HOMA-IR compared to those with low ADP 20/22 (90.9%). This positive correlation in PCOS indicates that higher IR (HOMA-IR) is related to increased ADP levels. This finding contradicts the usual role of ADP, which typically decreases as IR increases, suggesting a possible dysregulation in ADP signaling in PCOS. A positive correlation that is statistically significant was similarly

Table 6: Association between ADP levels and metabolic parameters in PCOS and control groups

Variables/ Groups		ADP (mg/dl)			P-value
		Low (<6)	Normal (6-10)	High (>10)	
FBS (mg/dl)	G1	106.4 ± 13.3	108.5 ± 15.7	90.4 ± 8.4	0.0017
	G2	100.9 ± 21.1	93.8 ± 13.3	92.3 ± 9.2	0.0042
TC (mg/dl)	G1	176.1 ± 33.6	189.2 ± 35.9	157.6 ± 32.4	0.0145
	G2	146.3 ± 19.7	159 ± 30.6	157.4 ± 32	0.0589
TG (mg/dl)	G1	139.9 ± 110.7	134.4 ± 48.7	153.5 ± 104.3	0.6615
	G2	75.8 ± 34.6	128 ± 61.3	109.7 ± 15.2	0.0430
HDL (mg/dl)	G1	50.7 ± 15.2	49.7 ± 12.4	44.8 ± 7.5	0.7368
	G2	58.4 ± 10	53.6 ± 14.2	44 ± 11.3	0.0128
LDL (mg/dl)	G1	97.5 ± 31.3	112.5 ± 32.6	82.1 ± 20.5	0.0003
	G2	72.8 ± 17.5	79.8 ± 25.4	91.5 ± 30.4	0.4228
VLDL (mg/dl)	G1	28.0 ± 22.1	26.9 ± 9.7	30.7 ± 20.9	0.8483
	G2	15.2 ± 6.9	25.6 ± 12.3	21.9 ± 3	0.0527

G1: polycystic ovary syndrome patient group; G2: healthy control group;
Data are presented as n (%) or mean ± SD; P < 0.05 is significant; Spearman's correlation analysis, Chi-square test, Unpaired t-test, and Mann-Whitney U test.

Table 7: Association between TAC levels and metabolic parameters in PCOS and control groups					
Variables/ Groups		TAC (mM)			P-value
		Low (< 0.05)	Normal (0.05-0.09)	High (> 0.1)	
FBS (mg/dl)	G1	111 ± 30	103.5 ± 13.1	111.7 ± 10.1	0.4007
	G2	93.6 ± 16.4	94.2 ± 13.7	98.4 ± 7.6	0.2121
TC (mg/dl)	G1	167.9 ± 50.5	176.8 ± 32.1	197.9 ± 39.3	0.3786
	G2	151.6 ± 10.4	159.4 ± 31	137 ± 23.8	0.0431
TG (mg/dl)	G1	107.8 ± 52.4	119.2 ± 53.4	254.4 ± 146.9	0.0017
	G2	110.4 ± 9.8	120.2 ± 61	164.3 ± 30.9	0.1000
HDL (mg/dl)	G1	51.1 ± 12.4	51.3 ± 14	40.6 ± 6.5	0.0195
	G2	49.7 ± 11	53.7 ± 14.3	45.3 ± 11.8	0.0256
LDL (mg/dl)	G1	95.2 ± 41.7	101.6 ± 30.7	106.4 ± 36.8	0.3878
	G2	79.7 ± 6.8	81.7 ± 25.7	58.9 ± 41.7	0.2788
VLDL (mg/dl)	G1	21.6 ± 10.5	23.8 ± 10.7	50.9 ± 29.4	0.0011
	G2	22.1 ± 2	24 ± 12.2	32.9 ± 6.2	0.0110

G1: polycystic ovary syndrome patient group; G2: healthy control group;
Data are presented as n (%) or mean ± SD; P < 0.05 is significant; Spearman's correlation analysis, Chi-square test, Unpaired t-test, and Mann-Whitney U test.

observed in the HCs groups ($r = 0.33$, $P = 0.03$). Participants with high ADP exhibited a substantially higher mean HOMA-IR concentration (2.79) compared to those with low ADP, who had a mean HOMA-IR of 1.42. All of the PCOS individuals with low ADP level (100%) fell within the normal HOMA-IR range compared to those with high ADP level (20%). In HCs, the positive correlation suggests a more variable pattern, which most likely reflects homeostatic regulation among non-PCOS individuals.

Table 4 demonstrates the relationship between the levels of TAC and HOMA-IR in the PCOS and HCs groups. Among PCOS patients, there was a negative association found between TAC and HOMA-IR values ($r = -0.23$). Participants with high TAC exhibited a slightly lower mean HOMA-IR (1.28) in comparison to those with low TAC, with a mean HOMA-IR of 1.35. This negative correlation suggests higher TAC might be associated with lower IR; however, has no statistical significance ($P = 0.13$). Likewise, the HCs group revealed a statistically significant inverse relationship between levels of HOMA-IR and TAC ($r = -0.30$, $P = 0.04$). The mean HOMA-IR level among HCs individuals with high TAC was 1.18, compared to 2.31 in those with low TAC levels. Notably, all (100%) of HCs participants with high TAC fell within the normal HOMA-IR compared to participants with low TAC (50%). This suggests that the level of antioxidants might have a greater protective effect on insulin sensitivity in HCs.

Table 5 demonstrates the relationship between TAC and ADP levels in the PCOS and HC groups. Among PCOS patients, the values of TAC and ADP were shown to be negatively correlated ($r = -0.02$). Participants with high TAC exhibited a lower mean ADP (6.83 mg/dl) compared to those with low TAC, with a mean ADP of 7.5 mg/dl. Half of the PCOS individuals with low TAC levels (50%) fell within the normal ADP range compared to those with high TAC levels (28.6%); however, the result has no statistical significance ($P = 0.87$). Likewise, the HC group showed an inverse relationship between TAC and ADP levels ($r = -0.20$). However, the association did not reach statistical significance ($P = 0.19$). The mean ADP level among HC individuals with high TAC was 7.83 mg/dL, in comparison to 9.11 mg/dL in those with low TAC levels. Notably, all (100%) of HC participants with high TAC fell within the normal ADP compared to participants with low TAC (75%). The inverse relationship between TAC and ADP in both groups was linked to increased ADP secretion as a compensation for heightened OS.

Table 6 explores the relationship between ADP levels and different metabolic parameters in both the PCOS (G1) and HC (G2) groups. A significant link was observed between ADP and FBG levels in the group with PCOS ($P = 0.0017$). Specifically, individuals with high ADP levels had lower FBG levels (90.4 ± 8.4 mg/dL) compared to those with low or normal levels, confirming that ADP enhances insulin sensitivity. Furthermore, there was a statistically significant correlation between

TC levels and ADP ($P = 0.0145$), as well as between ADP and LDL levels ($P = 0.0003$) in the PCOS group. Participants with high ADP had notably lower levels of TC (157.6 ± 32.4 mg/dl) and LDL (82.1 ± 20.5 mg/dL) than those with normal or low ADP, suggesting that elevated ADP may have a cardioprotective impact. However, no statistically significant correlations were observed between adiponectin (ADP) and triglycerides (TG), high-density lipoprotein (HDL), or very low-density lipoprotein (VLDL) levels. In the control group, fasting blood glucose (FBG), TG, and HDL showed statistically significant variations in ADP levels ($P < 0.05$), confirming that ADP is inversely associated with key markers of metabolic dysfunction in both PCOS and control groups. This finding reinforces its role as a protective adipokine. In contrast, VLDL, low-density lipoprotein (LDL), and total cholesterol (TC) did not reach statistical significance in the control group.

Table 7 evaluates the association between serum TAC levels and metabolic profiles in both study groups. Within the PCOS cohort, TAC levels were significantly associated with TG ($P = 0.0017$), where individuals with high TAC levels exhibited higher TG (254.4 ± 146.9 mg/dL) compared to those with normal and low TAC levels. Although TAC is often thought to be a protective antioxidant marker, this finding is paradoxical and may indicate a compensatory elevation in antioxidant defenses in response to elevated oxidative stress. VLDL also significantly increased with TAC ($P = 0.0011$). Additionally, a statistically significant relationship was found between TAC levels and HDL ($P = 0.0195$), with the lowest HDL values noted in those with high TAC levels (40.6 ± 6.5 mg/dL), potentially reflecting disturbed lipid metabolism despite higher antioxidant status. No significant associations were noted with FBG, TC, and LDL ($P > 0.05$). In the control group, TC and HDL showed significant differences across TAC levels ($p = 0.0431$ and $P = 0.0256$, respectively), indicating that redox state may affect lipid metabolism even in healthy people. VLDL also increased with TAC ($P = 0.0110$), supporting the hypothesis that antioxidant mechanisms may be reactive rather than protective in certain metabolic states.

4. DISCUSSION

Lipid profile analysis in the present study revealed significant dyslipidemia among women with PCOS, reinforcing the well-established link between PCOS and cardiovascular risk. Levels of total cholesterol were significantly greater in the PCOS group than in the HC group. Similarly, LDL cholesterol was markedly elevated in PCOS participants versus controls (Table 1). These findings align with numerous previous reports demonstrating that women with PCOS frequently

present with a pro-atherogenic lipid profile, characterized by increased levels of TC and LDL-C.¹¹ Although TG levels were higher in the PCOS group than in controls, the difference did not reach statistical significance. Nevertheless, the presence of an extreme outlier with a TG level of 520.8 mg/dl in the PCOS group warrants clinical attention, given that severe hypertriglyceridemia is associated with an increased risk of acute pancreatitis.¹² These results are consistent with the results of Wild et al.(1985),¹³ who reported highly variable TG levels among PCOS patients, often influenced by obesity and dietary factors. HDL-C levels were slightly lower in the PCOS group compared to controls, although the difference was not statistically significant. Notably, a larger proportion of PCOS women exhibited low HDL-C levels, which is concerning given that low HDL-C is an independent risk factor for cardiovascular disease.¹⁴ These results align with the meta-analysis. by Wild et al.,¹⁵ it demonstrated that HDL-C is generally lower in women with PCOS across different ethnic groups. VLDL-C levels were comparable between groups. This finding implies that while VLDL may slightly increase in PCOS, the changes are often less pronounced compared to alterations in LDL-C and HDL-C, consistent with findings from Wild.¹¹

The present study identified significant alterations in glycemic parameters and adipokine levels among PCOS-afflicted women, consistent with the established metabolic dysfunction observed in this population (Table 2). Levels of FBG were significantly higher in the PCOS group in comparison to HC, with a greater proportion of PCOS subjects falling into prediabetic and diabetic categories. These results align with previous evidence indicating that PCOS is an independent risk factor for impaired glucose tolerance and type 2 diabetes (T2D), irrespective of BMI.¹⁶ Interestingly, although significant differences were observed in insulin frequency distribution and mean insulin levels, the mean value of insulin was lower in the PCOS group in comparison to controls. Similarly, the mean HOMA-IR was also lower in PCOS patients than in controls. This finding contrasts with the classical association of PCOS with elevated insulin and HOMA-IR levels.¹⁷ A potential explanation could be the inclusion of a larger proportion of lean or non-obese PCOS phenotypes in this cohort, who may have relatively preserved insulin sensitivity compared to obese PCOS individuals.¹⁸ Additionally, lifestyle factors such as physical activity and dietary intake, which were not controlled for in the current analysis, could have significantly influenced insulin dynamics.¹⁹ It is also important to consider that IR in PCOS may not always be reflected in fasting measurements alone; postprandial or dynamic assessments (e.g., oral glucose tolerance test-derived

indices) may provide a more accurate representation of metabolic status.²⁰

Total antioxidant capacity, a measure of systemic OS defense, did not show a significant difference between controls and PCOS patients in this study. Both groups exhibited comparable mean TAC levels. While several studies have reported increased OS in PCOS, often characterized by elevated lipid peroxidation and reduced antioxidant defense.²¹ TAC as a global measure may lack sensitivity to subtle shifts in redox balance. Moreover, OS is influenced by numerous factors including obesity, inflammation, and lifestyle habits, which were not uniformly controlled in this population.²² This finding suggests that TAC alone may not be sufficient to capture the complexity of OS alterations in PCOS and supports the need for complementary markers such as superoxide dismutase, glutathione peroxidase, or malondialdehyde, for a more comprehensive assessment.²³

ADP, an adipokine with potent anti-inflammatory and insulin-sensitizing properties, was significantly lower in the PCOS group compared to HC. Nearly half of the PCOS patients exhibited low ADP levels versus only 8.9% of controls, highlighting a robust association between hypoadiponectinemia and PCOS-related metabolic dysfunction. These results corroborate findings from previous studies reporting reduced ADP levels in PCOS, particularly in association with visceral obesity and low-grade chronic inflammation.²⁴ Diminished ADP levels may exacerbate the cardiovascular risk profile in PCOS by promoting endothelial dysfunction and atherogenesis.²⁵

Studies demonstrated that levels of ADP have a positive correlation with the sensitivity of cells to insulin and are inversely associated with IR and diabetic predisposing factors.²⁶ Unexpectedly, our study demonstrated that the serum ADP level positively correlated with IR (Table 3), contradicting the traditional view that ADP is known for its insulin-sensitizing effects and that lower ADP levels are typically associated with higher IR. Additionally, this contradicts a study performed by Arif et al.(2024),²⁷ which reveals that HOMA-IR correlates inversely with serum ADP levels in females with PCOS. This finding suggests that abdominal fat indirectly contributes to IR in PCOS by reducing ADP secretion. Moreover, lower serum ADP levels are linked to more severe IR in PCOS. In PCOS, the positive relationship between ADP and HOMA-IR may result from compensatory responses, changes in ADP structure or function, resistance to ADP, and the inflammatory condition. Unlike the general population, higher ADP levels in PCOS do not always indicate better metabolic health, highlighting the need for a more nuanced understanding of ADP dynamics in this disorder.

The research observed that TAC negatively correlated with HOMA-IR in both the PCOS and HCs groups, but it was only significant in the HCs group (Table 4). Kanafchian et al.(2020),²⁸ also found that TAC with HOMA-IR in obese PCOS had a negative correlation. A significant negative correlation of TAC was found with HOMA-IR ($r = -.403$, $P < .000$) in a study conducted by Fatima et al.(2024),²⁹. Additionally, Papatlou et al.(2016),³⁰ also reported that an increase in ROS positively correlated with HOMA IR. Hyperglycemia and higher levels of free fatty acids in IR lead to increased OS, heightening ROS production and decreasing TAC.³¹ These studies collectively indicate that a lower TAC correlates with increased IR in patients with PCOS, as determined by HOMA-IR. This correlation emphasizes the possible involvement of OS in PCOS pathophysiology and highlights the importance of antioxidant therapy for managing IR in these individuals.

The current study examined the relationship between TAC and ADP levels among PCOS women and HCs, revealing an inverse, though statistically non-significant, correlation in both groups (Table 5). In patients with PCOS, higher levels of TAC were associated with slightly lower mean ADP levels, and a similar trend was observed in HCs. These findings suggest that increased antioxidant defense may correspond to reduced circulating ADP, possibly reflecting a compensatory response to OS. While the correlation coefficients were modest, the directionality of the relationship aligns with some previous investigations. For instance, Matsuda and Shimomura³² reported that serum ADP levels may increase in states of OS as a compensatory mechanism to mitigate ROS-induced damage, a concept that may explain the inverse trend observed in this study. Similarly, Beltowski et al.(2008),³³ emphasized ADP anti-inflammatory and antioxidative roles, noting that its expression often rises in response to redox imbalance. In PCOS, the interplay between OS and adipokines like ADP is complex. ADP is often reduced in PCOS patients, particularly those with IR, obesity, or chronic inflammation. Nevertheless, in certain subgroups with compensatory mechanisms against metabolic stress, a paradoxical elevation of ADP may occur. The trend observed in this study, where participants with lower TAC showed slightly higher ADP levels, may reflect an adaptive response aimed at restoring redox balance. Importantly, the observed correlations in both groups were not statistically significant suggesting that while a biological trend may exist, it may not be robust or consistent across individuals. This could be due to several factors, including sample size limitations, interindividual variability in ADP isoforms, and unmeasured confounders such as dietary antioxidant intake, inflammation, or insulin sensitivity.

Notably, 100% of HCs with high TAC fell within the normal ADP range, compared to only 75% with low TAC. This finding may indicate a protective association in metabolically healthy individuals, wherein preserved antioxidant capacity supports a favorable ADP profile, although this trend also did not reach statistical significance. The adipose-derived protein ADP is essential for controlling the body's metabolic processes by preventing vascular changes and regulating lipid and carbohydrate homeostasis.³⁴ In the PCOS group, increased ADP is associated with significantly lower FBG (Table 6). This inverse association supports findings by Al-Mayoofee et al. (2024),³⁵ who observed that ADP enhances insulin sensitivity by suppressing hepatic glucose production and increasing glucose uptake in skeletal muscles. Similarly, Yamamoto et al. (2014),³⁶ confirmed that ADP, irrespective of visceral fat, plays a positive function in glucose tolerance. Moreover, Lindberg et al. (2015),³⁷ corroborated that increased levels of ADP are positively associated with a lower risk of cardiovascular problems and T2D incidence. Levels of TC and LDL were significantly inversely associated with ADP in the group with PCOS. This aligns with Lei et al. (2013),³⁸ who reported that ADP is essential for cardiovascular disorders, as it inhibits foam cell formation and enhances lipid clearance, suggesting cardioprotective properties.

The present study revealed a paradoxical association between elevated serum TAC levels and adverse lipid profiles in women with PCOS (Table 7). Specifically, TAC had an inverse relationship with HDL and a positive relationship with TG and VLDL levels. These findings challenge the traditional perception of TAC as a protective biomarker and suggest a more complex interaction between OS, antioxidant responses, and lipid metabolism in PCOS.

Several studies have reported similar paradoxes in OS profiles among PCOS patients. For instance, a study by AbdulAzeez et al. (2022) demonstrated increased malondialdehyde (a marker of lipid peroxidation) and elevated TAC levels in PCOS patients, suggesting that increased TAC may represent a compensatory response to heightened OS rather than a sign of better redox balance.³⁹ Similarly, Duleba and Dokras (2011) emphasized that OS in PCOS is associated with both pro-oxidant and antioxidant alterations, reinforcing the idea that increased TAC may coexist with metabolic dysregulation.⁴⁰

The significant positive correlation between TAC and TG/VLDL observed in the current study is supported by reports from Chen et al. (2014), who found dyslipidemia and oxidative imbalance to be interlinked in PCOS, particularly in individuals with IR and central adiposity.⁴¹ Furthermore, Avelar et al. (2015)

highlighted that systemic antioxidant capacity can increase in response to lipid overload and metabolic stress, reflecting a reactive process to counteract ROS-induced lipid damage.⁴² The inverse association between TAC and HDL in PCOS is particularly notable. HDL is known not only for its lipid transport role but also for its antioxidative functions. Dysfunctional HDL, commonly observed in PCOS, loses its antioxidant properties and may even become pro-oxidant under chronic OS conditions.⁴³ Thus, the low HDL levels in individuals with high TAC may point to impaired HDL functionality despite the elevated systemic antioxidant defenses.

Within the control cohort, significant correlations between TAC and both TC and HDL were also observed. These findings align with those of Lubrano et al.,⁴⁴ who demonstrated that even in healthy individuals, redox status is intricately linked to lipid metabolism, with elevated TAC occasionally accompanying dyslipidemia under conditions of subclinical inflammation or dietary stress. The increase in VLDL with TAC in HC further supports the hypothesis that elevated antioxidant activity might be reactive to early metabolic stressors, even before overt metabolic disease manifests.

Overall, the observed pattern suggests that increased TAC, especially in metabolically stressed individuals such as those with PCOS, may not reflect a favorable metabolic state. Instead, it may serve as an indirect marker of heightened oxidative pressure, where the body mounts a compensatory antioxidant response. This aligns with the “antioxidant paradox” previously described in metabolic disorders, wherein antioxidant levels rise not due to protection, but due to necessity.⁴⁵

5. LIMITATIONS

This study has several limitations that should be acknowledged. The relatively small sample size may reduce the statistical power and restrict the applicability of the findings to a wider context population. Additionally, important confounding factors such as BMI, dietary habits, physical activity, and inflammatory markers were not controlled or assessed, which may have influenced the observed associations between ADP, IR, and OS. Furthermore, OS was assessed solely through TAC, which, while informative, may not fully capture the complexity of redox status; more sensitive and specific markers such as malondialdehyde or glutathione peroxidase could provide a more comprehensive evaluation. Lastly, the study measured total ADP without distinguishing between its isoforms (e.g., high-molecular-weight ADP), which may have differing biological activities and relevance to insulin sensitivity and metabolic risk in PCOS.

6. CONCLUSION

This research underscores the complex interrelationship between ADP, IR, and OS in PCOS. While ADP levels were significantly lower in PCOS, an unexpected positive correlation with HOMA-IR was observed, indicating possible dysregulation in ADP signaling. TAC levels did not differ significantly between groups, but its inverse relationship with HOMA-IR and paradoxical associations with lipid parameters suggest it may act as a compensatory marker rather than a protective one. These findings highlight the multifactorial nature of metabolic dysfunction in PCOS and suggest that ADP and OS-related mechanisms could serve as potential therapeutic targets.

7. Data availability

The numerical data generated during this research is available with the authors.

8. Conflict of interest

All authors declare that there was no conflict of interest.

9. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Ethical considerations

This research was carried out following the principles of the Declaration of Helsinki and was ethically approved by the Ethics Committee of the Training and Human Development Unit at Thi-Qar Health Department, Iraq (Approval No. 197/2024) on September 3, 2024, as part of a master's thesis.

Before joining the study, all participants provided written informed consent. They were fully briefed on the study's goals, risks, procedures, and benefits.

11. Authors' contribution

ZMT: Data collection, writing, and analysis.

KRH: In charge of coming up with the concept and gathering the data.

HAAK: Worked together on the manuscript's conception, composition, data analysis, assessment, submission, revisions, and final proofreading

12. REFERENCES

- Rudnicka E, Duszewska AM, Kucharski M, Tyczyński P, Smolarczyk R. Oxidative stress and reproductive function: oxidative stress in polycystic ovary syndrome. *Reproduction*. 2022;164(6):F145–54. DOI: [10.1530/REP-22-0152](https://doi.org/10.1530/REP-22-0152)
- Singh S, Pal N, Shubham S, Sarma DK, Verma V, Marotta

F, et al. Polycystic ovary syndrome: etiology, current management, and future therapeutics. *J Clin Med*. 2023;12(4):1454.

DOI: [10.3390/jcm12041454](https://doi.org/10.3390/jcm12041454)

- Harada M. Pathophysiology of polycystic ovary syndrome revisited: Current understanding and perspectives regarding future research. *Reprod Med Biol*. 2022;21(1):e12487. DOI: [10.1002/rmb2.12487](https://doi.org/10.1002/rmb2.12487)
- Uçkan K, Demir H, Turan K, Sarıkaya E, Demir C. Role of oxidative stress in obese and nonobese PCOS patients. *Int J Clin Pract*. 2022;2022(1):4579831. DOI: [10.1155/2022/4579831](https://doi.org/10.1155/2022/4579831)
- Murri M, Luque-Ramírez M, Insenser M, Ojeda-Ojeda M, Escobar-Morreale HF. Circulating markers of oxidative stress and polycystic ovary syndrome (PCOS): a systematic review and meta-analysis. *Hum Reprod Update*. 2013;19(3):268–88. DOI: [10.1093/humupd/dms059](https://doi.org/10.1093/humupd/dms059)
- Michalakis KG, Segars JH. The role of adiponectin in reproduction: from polycystic ovary syndrome to assisted reproduction. *Fertil Steril*. 2010;94(6):1949–57. DOI: [10.1016/j.fertnstert.2010.05.010](https://doi.org/10.1016/j.fertnstert.2010.05.010)
- Group REPCW. Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome (PCOS). *Hum Reprod*. 2004;19(1):41–7. DOI: [10.1093/humrep/deh098](https://doi.org/10.1093/humrep/deh098)
- Piani F, Cicero AFG, Ventura F, Dormi A, Fogacci F, Patrono D, et al. Evaluation of twelve formulas for LDL-C estimation in a large, blinded, random Italian population. *Int J Cardiol*. 2021;330:221–7. DOI: [10.1016/j.ijcard.2021.02.009](https://doi.org/10.1016/j.ijcard.2021.02.009)
- Lee J, Jang S, Jeong H, Ryu OH. Validation of the Friedewald formula for estimating low density lipoprotein cholesterol: the Korea National Health and Nutrition Examination Survey, 2009 to 2011. *Korean J Intern Med*. 2018;35(1):150. DOI: [10.3904/kjim.2017.233](https://doi.org/10.3904/kjim.2017.233)
- Lee SH, Ahn MB, Choi YJ, Kim SK, Kim SH, Cho WK, et al. Comparison of different criteria for the definition of insulin resistance and its relationship to metabolic risk in children and adolescents. *Ann Pediatr Endocrinol Metab*. 2020;25(4):227–33. DOI: [10.6065/apem.2040002.001](https://doi.org/10.6065/apem.2040002.001)
- Wild RA. Dyslipidemia in PCOS. *Steroids*. 2012;77(4):295–9. DOI: [10.1016/j.steroids.2011.12.002](https://doi.org/10.1016/j.steroids.2011.12.002)
- Berglund L, Brunzell JD, Goldberg AC, Goldberg IJ, Sacks F, Murad MH, et al. Evaluation and treatment of hypertriglyceridemia: an Endocrine Society clinical practice guideline. *J Clin Endocrinol Metab*. 2012;97(9):2969–89. DOI: [10.1210/jc.2011-3213](https://doi.org/10.1210/jc.2011-3213)
- Wild RA, Painter PC, Coulson PB, CARRUTH KB, Ranney GB. Lipoprotein lipid concentrations and cardiovascular risk in women with polycystic ovary syndrome. *J Clin Endocrinol Metab*. 1985;61(5):946–51. DOI: [10.1210/jcem-61-5-946](https://doi.org/10.1210/jcem-61-5-946)
- (NCEP) NCEP. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, Third

- Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Tre. *Circulation*. 2002;106(25):3143–421. DOI: [10.1161/CIRCULATIONAHA.106.25.3143](https://doi.org/10.1161/CIRCULATIONAHA.106.25.3143)
15. VKpLAQAIAAJ&oi=fnd&pg=PR2&dq=12.%09(NCEP)+NCEP.+Expert+Panel+on+Detection,+Evaluation,+and+Treatment+of+High+Blood+Cholesterol+in+Adults,+Third+Report+of+the+National+Cholesterol+Education+Program+(NCEP)+Expert+Panel+on+Detection,+Evaluation,+and+Treatment+of+High+Blood+Cholesterol+in+Adults+(Adult+Tre.+Circulation.+2002%3B106(25):3143%E2%80%93421.+&ots=jXnqZhFGlr&sig=EaKibTLvg8tn8c0U5Iw7oogORdU
 16. Wild RA, Rizzo M, Clifton S, Carmina E. Lipid levels in polycystic ovary syndrome: systematic review and meta-analysis. *Fertil Steril*. 2011;95(3):1073–9. DOI: [10.1016/j.fertnstert.2010.12.027](https://doi.org/10.1016/j.fertnstert.2010.12.027)
 17. Moran LJ, Misso ML, Wild RA, Norman RJ. Impaired glucose tolerance, type 2 diabetes and metabolic syndrome in polycystic ovary syndrome: a systematic review and meta-analysis. *Hum Reprod Update*. 2010;16(4):347–63. DOI: [10.1093/humupd/dmq001](https://doi.org/10.1093/humupd/dmq001)
 18. Dunaif A. Insulin resistance and the polycystic ovary syndrome: mechanism and implications for pathogenesis. *Endocr Rev*. 1997;18(6):774–800. DOI: [10.1210/edrv.18.6.0318](https://doi.org/10.1210/edrv.18.6.0318)
 19. Daan NMP, Louwers Y V, Koster MPH, Eijkemans MJC, de Rijke YB, Lentjes EWG, et al. Cardiovascular and metabolic profiles amongst different polycystic ovary syndrome phenotypes: who is really at risk? *Fertil Steril*. 2014;102(5):1444–51. DOI: [10.1016/j.fertnstert.2014.08.001](https://doi.org/10.1016/j.fertnstert.2014.08.001)
 20. Goodarzi MO, Azziz R. Diagnosis, epidemiology, and genetics of the polycystic ovary syndrome. *Best Pract Res Clin Endocrinol Metab*. 2006;20(2):193–205. DOI: [10.1016/j.beem.2006.02.005](https://doi.org/10.1016/j.beem.2006.02.005)
 21. Vrbikova J, Hainer V. Obesity and polycystic ovary syndrome. *Obes Facts*. 2009;2(1):26–35. DOI: [10.1159/000194971](https://doi.org/10.1159/000194971)
 22. González F. Inflammation in polycystic ovary syndrome: underpinning of insulin resistance and ovarian dysfunction. *Steroids*. 2012;77(4):300–5. DOI: [10.1016/j.steroids.2011.12.003](https://doi.org/10.1016/j.steroids.2011.12.003)
 23. Sabuncu T, Vural H, Harma M, Harma M. Oxidative stress in polycystic ovary syndrome and its contribution to the risk of cardiovascular disease☆. *Clin Biochem*. 2001;34(5):407–13. DOI: [10.1016/S0009-9120\(01\)00245-4](https://doi.org/10.1016/S0009-9120(01)00245-4)
 24. Zhong P, Guan B, Lin Y, Zhang S. Changes in inflammatory factors, oxidative stress, glucose and lipid metabolism, and insulin resistance in patients with polycystic ovary syndrome. *Cell Mol Biol*. 2021;67(5):45–50. DOI: [10.14715/cmb/2021.67.5.6](https://doi.org/10.14715/cmb/2021.67.5.6)
 25. Toulis KA, Goulis DG, Farmakiotis D, Georgopoulos NA, Katsikis I, Tarlatzis BC, et al. Adiponectin levels in women with polycystic ovary syndrome: a systematic review and a meta-analysis. *Hum Reprod Update*. 2009;15(3):297–307. DOI: [10.1093/humupd/dmp006](https://doi.org/10.1093/humupd/dmp006)
 26. Ouchi N, Parker JL, Lugus JJ, Walsh K. Adipokines in inflammation and metabolic disease. *Nat Rev Immunol*. 2011;11(2):85–97. DOI: [10.1038/nri2921](https://doi.org/10.1038/nri2921)
 27. Jiang Y, Owei I, Wan J, Ebenibo S, Dagogo-Jack S. Adiponectin levels predict prediabetes risk: the Pathobiology of Prediabetes in A Biracial Cohort (POP-ABC) study. *BMJ Open Diabetes Res Care*. 2016;4(1):e000194. DOI: [10.1136/bmjdr-2016-000194](https://doi.org/10.1136/bmjdr-2016-000194)
 28. Arif A, Anees R, Rashid A, Ahmed N. A Comparative Study of Serum Adiponectin and Insulin Resistance In Patients With Polycystic Ovary Syndrome. *Pakistan Armed Forces Med J*. 2024;74(5):1384. DOI: [10.51253/pafmj.v74i5.11360](https://doi.org/10.51253/pafmj.v74i5.11360)
 29. Kanafchian M, Esmaeilzadeh S, Mahjoub S, Rahsepar M, Ghasemi M. Status of serum copper, magnesium, and total antioxidant capacity in patients with polycystic ovary syndrome. *Biol Trace Elem Res*. 2020;193:111–7. DOI: [10.1007/s12011-019-01705-7](https://doi.org/10.1007/s12011-019-01705-7)
 30. Fatima M, Illahi MI, Kulsoom O, Salahuddin H, Amjad S. Insight into Total Antioxidant Capacity and its Relationship with Insulin Resistance among Polycystic Ovary Syndrome Patients. 2024;20(08).
 31. Papalou O, M. Victor V, Diamanti-Kandarakis E. Oxidative stress in polycystic ovary syndrome. *Curr Pharm Des*. 2016;22(18):2709–22. DOI: [10.2174/1381612822666160216151852](https://doi.org/10.2174/1381612822666160216151852)
 32. Malini SS. Insulin resistance and Oxidant-Antioxidant Markers in Young Women with Polycystic Ovarian Syndrome. *Bull Pure Appl Sci*. 2023;42A(1):106 DOI: [10.48165/bpas.2023.42A.1.9](https://doi.org/10.48165/bpas.2023.42A.1.9)
 33. Matsuda M, Shimomura I. Roles of adiponectin and oxidative stress in obesity-associated metabolic and cardiovascular diseases. *Rev Endocr Metab Disord*. 2014;15:1–10. DOI: [10.1007/s11154-013-9271-7](https://doi.org/10.1007/s11154-013-9271-7)
 34. Beltowski J, Jamroz-Wisniewska A, Widomska S. Adiponectin and its role in cardiovascular diseases. *Cardiovasc Haematol Disord Targets (Formerly Curr Drug Targets-Cardiovascular Hematol Disord)*. 2008;8(1):7–46. DOI: [10.2174/187152908783884920](https://doi.org/10.2174/187152908783884920)
 35. Esfahani M, Movahedian A, Baranchi M, Goodarzi MT. Adiponectin: an adipokine with protective features against metabolic syndrome. *Iran J Basic Med Sci*. 2015;18(5):430. <https://doi.org/10.22038/ijbms.2015.440>
 36. Al-Mayoofee SHB, Missaoui N, Hmissa S, Al-Snafi AE. Adipokines in Relation to Weight, Lipid Profile and Glycemic State in Women with Polycystic Ovary Syndrome. *J Obstet Gynecol Cancer Res*. 2024;9(4):422–7. DOI: [10.30699/jogcr.9.4.422](https://doi.org/10.30699/jogcr.9.4.422)
 37. Yamamoto S, Matsushita Y, Nakagawa T, Hayashi T, Noda M, Mizoue T. Circulating adiponectin levels and

- risk of type 2 diabetes in the Japanese. *Nutr Diabetes*. 2014;4(8):e130–e130. DOI: [10.1038/nutd.2014.27](https://doi.org/10.1038/nutd.2014.27)
38. Lindberg S, Jensen JS, Bjerre M, Pedersen SH, Frystyk J, Flyvbjerg A, et al. Adiponectin, type 2 diabetes and cardiovascular risk. *Eur J Prev Cardiol*. 2015;22(3):276–83. DOI: [10.1177/2047487313514894](https://doi.org/10.1177/2047487313514894)
 39. Lei X, Qiu S, Yang G, Wu Q. Adiponectin and metabolic cardiovascular diseases: Therapeutic opportunities and challenges. *Genes Dis*. 2023;10(4):1525–36. DOI: [10.1016/j.gendis.2022.10.018](https://doi.org/10.1016/j.gendis.2022.10.018)
 40. AbdulAzeez IM, Biliaminu SA, Oladosu WO, Okesina AB. Serum Malondialdehyde and antioxidant enzymes as bioindicator of oxidative stress in women with PCOS at UITH, Ilorin. *Trop J Heal Sci*. 2022;29(1):23–7. <https://dx.doi.org/10.4314/tjhc.v29i1.5>
 41. Duleba AJ, Dokras A. Is PCOS an inflammatory process? *Fertil Steril*. 2012;97(1):7–12. DOI: [10.1016/j.fertnstert.2011.11.023](https://doi.org/10.1016/j.fertnstert.2011.11.023)
 42. Chen L, Xu WM, Zhang D. Association of abdominal obesity, insulin resistance, and oxidative stress in adipose tissue in women with polycystic ovary syndrome. *Fertil Steril*. 2014;102(4):1167–74. DOI: [10.1016/j.fertnstert.2014.06.027](https://doi.org/10.1016/j.fertnstert.2014.06.027)
 43. Avelar TMT, Storch AS, Castro LA, Azevedo GVMM, Ferraz L, Lopes PF. Oxidative stress in the pathophysiology of metabolic syndrome: which mechanisms are involved? *J Bras Patol e Med Lab*. 2015;51:231–9. DOI: [10.5935/1676-2444.20150039](https://doi.org/10.5935/1676-2444.20150039)
 44. Zhang J, Zhang Y, Liu H, Bai H, Wang Y, Jiang C, et al. Antioxidant properties of high-density lipoproteins are impaired in women with polycystic ovary syndrome. *Fertil Steril*. 2015;103(5):1346–54. DOI: [10.1016/j.fertnstert.2015.02.024](https://doi.org/10.1016/j.fertnstert.2015.02.024)
 45. Lubrano C, Valacchi G, Specchia P, Gnessi L, Rubanenko EP, Shuginina EA, et al. Integrated haematological profiles of redox status, lipid, and inflammatory protein biomarkers in benign obesity and unhealthy obesity with metabolic syndrome. *Oxid Med Cell Longev*. 2015;2015(1):490613. DOI: [10.1155/2015/490613](https://doi.org/10.1155/2015/490613)
 46. Pizzino G, Irrera N, Cucinotta M, Pallio G, Mannino F, Arcoraci V, et al. Oxidative stress: harms and benefits for human health. *Oxid Med Cell Longev*. 2017;2017(1):8416763. DOI: [10.1530/REP-22-0152](https://doi.org/10.1530/REP-22-0152)