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Original Article

Physiological association of vascular cell adhesion molecule-1, intercellular adhesion molecule-1 and E-selectin in women with polycystic ovarian syndrome

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Received: 12 May 2026; **Revised:** 25 August 2026; **Accepted:** 27 August 2026

ABSTRACT

A prevalent endocrine condition associated with hormonal imbalance and elevated cardiovascular risk is polycystic ovarian syndrome, or PCOS. This study aimed to evaluate the serum levels of adhesion molecules—VCAM-1, ICAM-1, and E-selectin—in women with PCOS and to examine their potential diagnostic and physiological value. Women (50 with PCOS, 50 healthy controls) were included in this case-control study. Demographic, hormonal, and anthropometric data were collected. Serum amount of VCAM-1, ICAM-1, and E-selectin were calculated by the use of enzyme-linked immunosorbent assay. A receiver operating characteristic (ROC) curve was used to evaluate the diagnostic value of these markers. Pearson's association was employed in assessing associations between markers and clinical variables. Femaels who had PCOS harbor a substantially higher amount of VCAM-1 (3.13 ± 0.54 vs. 2.12 ± 0.68 ng/ml), ICAM-1 (223.06 ± 51.52 vs. 191.55 ± 50.03 ng/ml), and E-selectin (27.54 ± 5.67 vs. 20.07 ± 5.03 pg/ml) compared to controls (all $p < 0.01$). ROC analysis presented the area under the curve (AUC) of 0.873, 0.732, and 0.837 for VCAM-1, ICAM-1, and E-selectin, respectively. With 82% sensitivity and 80% specificity, the combined markers produced an AUC of 0.904. VCAM-1 and ICAM-1 ($r = 0.539$), VCAM-1 and E-selectin ($r = 0.374$), and ICAM-1 and E-selectin ($r = 0.341$) all showed significant positive relationships. In PCOS, adhesion molecules are markedly increased. Their strong diagnostic performance suggests potential use as physiological biomarkers for PCOS detection.

Keywords: Adhesion molecules, VCAM-1, ICAM-1, E-selectin, PCOS

Introduction

With a reported frequency of 11% to 13%, polycystic ovarian syndrome (PCOS) is a common condition marked by dysregulation of endocrine hormone levels in females; nevertheless, the cause is still unclear [1]. The fundamental pathological and physiological alterations accompanying its manifestation include hyperandrogenism and insulin resistance (IR) [2].

A prevalent manifestation of PCOS is persistent inflammation, with contemporary research indicating that individuals diagnosed with PCOS exhibit elevated concentrations of inflammatory biomarkers such as C-reactive protein (CRP), leukocytes/white blood cells (WBCs), certain interleukins, and tumor necrosis factor (TNF) [3, 4]. Chronic low-grade inflammation has been linked to endothelial dysfunction, atherosclerosis, coronary artery disease, obesity, and insulin resistance [5].

Intercellular adhesion molecule 1 (ICAM-1) and vascular cell adhesion molecule 1 (VCAM-1) are adhesion molecules belonging to the immunoglobulin superfamily, playing crucial roles in modulating the robust adherence of leukocytes to

Access this article online	
Website: www.japer.in	**E-ISSN:** 2249-3379

How to cite this article: Khazaal MS, Salih KS. Physiological association of vascular cell adhesion molecule-1, intercellular adhesion molecule-1 and E-selectin in women with polycystic ovarian syndrome. J Adv Pharm Educ Res. 2026;16(3):135-41. https://doi.org/10.51847/KJ4YIqPBYw

endothelial cells in the context of various acute or chronic inflammatory pathologies [6].

E-selectin, part of selectin family, is characterized by homologous N-terminal determinants and exhibits binding affinity for analogous fucosylated or sialylated glycan ligands [7]. Increased E-selectin levels in the blood can serve as biomarkers for endothelial cell activation in response to inflammatory stimuli. Under normal physiological conditions, E-selectin remains inactive within endothelial cells; however, it becomes activated in the presence of oxidative stress or pro-inflammatory agents (IL-1), bacterial lipopolysaccharide (LPS), tumor necrosis factor (TNF), or viral infections [8].

Cell adhesion molecules are posited to fulfill multiple critical roles within the pathophysiological processes associated with PCOS. Elucidating the function of these molecular mechanisms in PCOS may reveal potential targets for early diagnosis and clinical intervention of the disorder [9]. Kałużna *et al*. explicitly pointed that VCAM-1 levels were significantly greater in PCOS-affected women, particularly those with metabolic syndrome [10]. Moreover, ICAM-1 levels demonstrated great precision in detecting PCOS and type 2 diabetics in PCOS individuals with normal glucose tolerance [11]. Victor *et al*. reported that PCOS patients exhibited increased levels of E-Selectin [12]. Therefore, the present research analyzed the serum levels of adhesion molecules in Iraqi women with PCOS and the potential diagnostic physiological value of these molecules.

Materials and Methods

Study design and participants

This case-control research was done at the Infertility clinic /Al-Yarmouk Hospital/Iraq from January 2024 to June 2025. One hundred women (age range 20- 35 years) were enrolled in the study after taking informed written consent from all of them; 50 women with PCOS were considered as the case group, and another 50 healthy and age-matchedwomen with regular menstrual cycles and no hirsutism were considered as the control group.

The diagnosis of PCOS was established base on to the Rotterdam Diagnostic Criteria (Rotterdam ESHRE/ASRM-Sponsored, 2004). Consequently, a diagnosis of PCOS was rendered when 2 of the 3 criteria (oligo- and/or anovulation; clinical and/or biochemical manifestations of hyperandrogenism; and polycystic ovaries) were satisfied, following the exclusion of alternative etiologies for hyperandrogenism. Women presenting with hypertension, diabetes, a body mass index (BMI) exceeding 35 Kg/m², androgen-secreting neoplasms (adrenal and ovarian), late-onset congenital adrenal hyperplasia, Cushing's syndrome, ovarian failure, hyperprolactinemia, and pregnant individuals were removed from involving in the study.

Data collection

Demographic data, including age, height and weight, from which body mass index (BMI) was calculated, waist-to-hip ratio (WHR), and disease duration (in patients), were collected through direct interview.

Hormonal profile

Five mL of venous blood samples were gathered from eligible women in the early morning. Serum was separated by centrifugation. Ready commercial kits were used to estimate serum levels of total testosterone (Biotech, USA), follicle-stimulating hormone (FSH), and luteinizing hormone (LH) (Abcam, USA) using enzyme-linked immunosorbent assay (ELISA) based on the producers guidelines.

Serum levels of adhesion molecules

Serum levels of VCAM-1, ICAM-1, and E-selectin were measured using the ELISA technique. Ready commercial kits (Sunlong, China) were used for this purpose. The assay range for VCAM-1 was 0.2 ng/ml-10 ng/ml with a sensitivity of 0.05 ng/ml. The assay range for ICAM-1 was 16 ng/ml-1000 ng/ml with a sensitivity of 5.6 ng/ml. The assay range for E-selectin was 8 pg/ml-500 pg/ml with a sensitivity of 1.5 pg/ml.

Statistical analysis

SPSS software version 25.0 (SPSS, Chicago) was used to do statistical analyzes. The Student t-test was used to evaluate continuous variables, which were presented as means and standard deviations. Categorical variables were presented as counts and percentages, and assessed with the Chi-square test. The receiver operating characteristic curve (ROC) was employed to assess the diagnostic efficacy of VCAM-1, ICAM-1, and E-selectin (both individually and in combination) in differentiating between patients and control subjects. Potential correlations between VCAM-1, ICAM-1, and E-selectin and other variables were examined using Pearson's correlation test. A statistically substantial difference was seen as a p-value of less than 0.05.

Ethical approval

The College of Pharmacy at Tikrit University's Scientific and Ethical Committees granted ethical permission in compliance with the 1964 Declaration of Helsinki and its subsequent amendments, also the institutional and/or national research committee's ethical requirements. Before beginning data collection, all patients gave their verbal agreement after being informed of the study's specifics and assured of its confidentiality.

Results and Discussion

Demographic characteristics of the study population

Tab 1 shows the demographic characteristics of women with PCOS in comparison to healthy control women. The mean age of the PCOS group was 35.64 ± 6.34 years, slightly higher than

the control group's 33.54 ± 5.79 years, though this difference was not statistically significant (p = 0.087). Women with PCOS had a significantly higher average weight (72.06 ± 9.45 kg) than controls (67.94 ± 6.71 kg, p = 0.014), and their average height was also significantly greater (161.92 ± 6.67 cm vs. 157.1 ± 7.63 cm, p = 0.001). Despite these differences, BMI did not differ considerably amongst the two groups. Disease duration, reported only for the PCOS group, averaged 9.4 ± 3.61 years with a range from 4 to 16 years **(Table 1)**.

Table 1. Demographic characteristics of PCOS patients and controls

Variables	Patient (n=50)	control (n=50)	p-value
Age, years Mean±SD Range	35.64±6.34 23-48	33.54±5.79 23-47	0.087
Weight, kg Mean ±SD Range	72.06±9.45 53-91	67.94±6.71 52-84	**0.014**
Height, cm Mean±SD Range	161.92±6.67 147-174	157.1±7.63 1.43-172	**0.001**
BMI, kg/m² Mean ±SD Range	28.21±3.94 20.94-35.52	26.71±3.8 18.65-334.96	0.095
Waist-to-hip ratio Mean ±SD Range	0.86±0.05 0.65-1.1	0.86±0.01 0.73-0.97	0.992
Disease duration, yrs Mean ±SD Range	9.4±3.61 4.0-16	---------- ---	--------

SD: standard deviation

Hormonal profile

The hormonal profile presented in **Table 2** reveals substantial distinction amongst female with PCOS and healthy controls. Follicle-stimulating hormone (FSH) amounts were substantially lower in the PCOS group, with a mean of 6.43 ± 0.7 mIU/ml compared to 8.28 ± 2.44 mIU/ml in controls (p < 0.001). In contrast, luteinizing hormone (LH) levels were markedly higher among PCOS patients (13.4 ± 0.75 mIU/ml) than in the control group (8.04 ± 2.29 mIU/ml), also showing a statistically significant difference (p < 0.001). Similarly, total testosterone levels were considerably elevated in women with PCOS, averaging 0.87 ± 0.29 ng/ml compared to 0.34 ± 0.12 ng/ml in the control group (p < 0.001).

Table 2. Hormonal profile of PCOS patients and controls

Variables	Patients (n=50)	Control (n=50)	p-value
FSH, mIU/ml Mean ±SD Range	6.43±0.7 4.78-8.24	8.28±2.44 4.02-12.29	**<0.001**
LH, mIU/ml Mean ±SD Range	13.4±0.75 11.42-15.8	8.04±2.29 3.89-11.80	**<0.001**
Total Testosterone, ng/ml Mean ±SD Range	0.87±0.29 0.47-1.91	0.34±0.12 0.09-0.53	**<0.001**

SD: standard deviation, FSH: follicle-stimulating hormone, LH: luteinizing hormone

Serum levels of adhesion molecules

Table 3 presents the serum levels of adhesion molecules—VCAM-1, ICAM-1, and E-selectin—in women with PCOS in comparison to healthy controls. The results demonstrate considerably elevated amount of all three markers in the PCOS group. VCAM-1 amounts were notably greater in individuals, with a mean of 3.13 ± 0.54 ng/ml compared to 2.12 ± 0.68 ng/ml in controls (p < 0.001). Similarly, ICAM-1 amount were considerably elevated in PCOS patients (223.06 ± 51.52 ng/ml) versus controls (191.55 ± 50.03 ng/ml, p = 0.003). E-selectin, a key marker of endothelial dysfunction, was also significantly higher in the PCOS group, with a mean of 27.54 ± 5.67 pg/ml compared to 20.07 ± 5.03 pg/ml in the control group (p < 0.001).

Table 3. Serum levels of adhesion molecules in PCOS patients and controls

Variables	Patients (n=50)	Control (n=50)	p-value
VCAM-1, ng/ml Mean ±SD Range	3.13±0.54 1.78-4.49	2.12±0.68 1.2-4.12	**<0.001**
ICAM-1, ng/ml Mean ±SD Range	223.06±51.52 132.9-412.9	191.55±50.03 114.9-342.8	**0.003**
E-selectin, pg/ml Mean ±SD Range	27.54±5.67 17.6-40.2	20.07±5.03 12.0-29.8	**<0.001**

SD: standard deviation. VCAM-1: Vascular cell adhesion molecule-1; ICAM-1: Intercellular adhesion molecule-1

Diagnostic value of adhesion molecules

Figure 1 shows the receiver operating characteristic (ROC) curve assessing the diagnostic performance of serum VCAM-1, ICAM-1, and E-selectin levels in distinguishing PCOS patients from healthy controls. For VCAM-1, the area under the curve (AUC) was 0.873 with a 95% confidence interval of 0.810-0.945, p<0.001. At a determined cut-off value of 2.68 ng/mL, VCAM-1 achieves a sensitivity of 82% and a specificity of 78%. For ICAM-1, the AUC was 0.732, 95%CI= 0.628-0.835, p<0.001. The sensitivity and specificity of the test were 70% and 78%, respectively. The best cut-off value was ICAM-1= 194.5 ng/mL. For E-selectin, the AUC was 0.837, 95%CI= 0.761-0.913, p<0.001. The sensitivity and specificity of the test were 80% and 78%, respectively. The best cut-off value was E-selectin = 22.45 ng/mL.

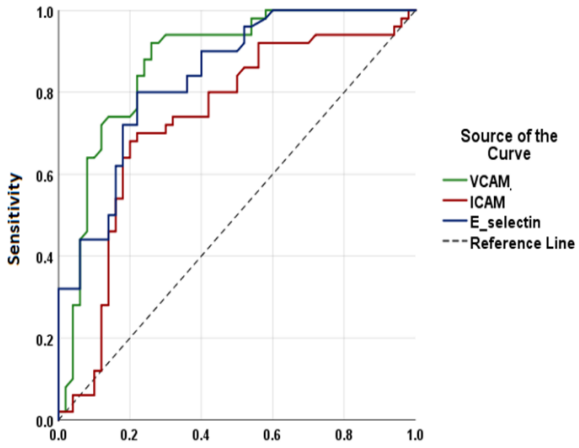

Figure 1. Receiver operating characteristic curve for VCAM-1, ICAM-1 and E-selectin in the context of discrimination between PCOS and controls

For the combination of VCAM-1, ICAM-1, and E-selectin, the AUC was 0.904, 95%CI= 0.845-0.963, p<0.001. The sensitivity and specificity of the test were 82% and 80%, respectively **(Figure 2)**.

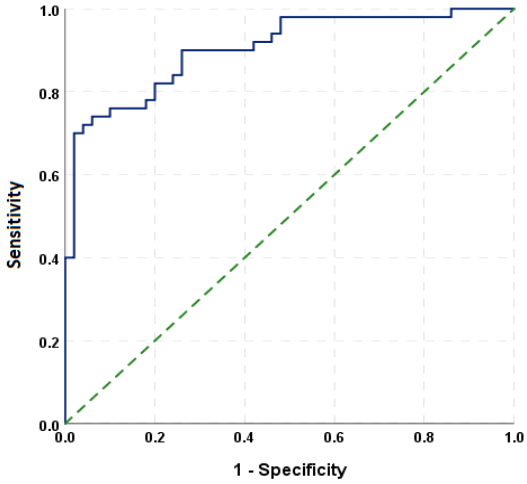

Figure 2. Receiver operating characteristic curve for the combination of VCAM-1, ICAM-1, and E-selectin in the context of discrimination between PCOS and controls

Correlation of VCAM-1, ICAM-1 and E-selectin with other variables in PCOS patients

VCAM-1, ICAM-1, and E-selectin were correlated with other factors in PCOS patients using Pearson's correlation **(Table 4)**. VCAM-1 displayed a significant positive correlation with each of ICAM-1 (r= 0.539, p<0.001) and E-selectin (r= 0.374, p=0.008). Furthermore, ICAM-1 had a substantial positive correlation with E-selectin (r= 0.341, p= 0.015).

Table 4. Correlation of VCAM-1, ICAM-1 and E-selectin with other variables in PCOS patients

Variable	VCAM-1, ng/ml		ICAM-1, ng/ml		E-selectin, pg/ml	
	r	p-value	r	p-value	r	p-value
Age	-0.127	0.381	-0.199	0.167	-0.111	0.444
Weight	-0.259	0.069	-0.196	0.173	0.060	0.679
Height	0.201	0.161	0.067	0.644	0.089	0.540
BMI	-0.247	0.071	-0.203	0.158	0.012	0.935
WHR	-0.200	0.163	-0.057	0.692	0.152	0.294
Duration	0.058	0.691	0.138	0.340	0.033	0.820
Total testosterone	0.235	0.101	0.216	0.133	0.218	0.129
LH	0.099	0.494	0.253	0.077	0.193	0.179
FSH	-0.019	0.898	-0.105	0.467	-0.086	0.553
ICAM-1	**0.539**	**<0.001**	---	---	**0.341**	**0.015**
E-selectin	**0.374**	**0.008**	---	---	---	---

The goal of the current research assessed the blood levels of adhesion molecules—VCAM-1, ICAM-1, and E-selectin—in PCOS-affected women as well as their possible physiological diagnostic use. The study's most noteworthy findings were that PCOS individuals contained more increased serum amounts of these adhesion molecules than the controls.

This elevation aligns with numerous investigations identified within the search results. Research analyzing the expression levels of VCAM-1 in young, nonobese women diagnosed with PCOS has determined that VCAM-1 mRNA expression was substantially heightened in individuals with PCOS in comparison to the control group, even after controlling for Body Mass Index (BMI) [13]. This observation implies that the elevation of VCAM-1 may represent an inherent characteristic of PCOS, rather than merely a resultant effect of obesity or other metabolic comorbid conditions.

Another work established that VCAM-1 is activated in ovarian theca and stromal cells within a hyperandrogenic milieu, mediated by androgen receptors (ARs) present in these cellular contexts. This finding suggests a possible molecular link between endothelial dysfunction and hyperandrogenism, a hallmark of PCOS. The research demonstrated that cultures derived from human theca cells expressed both ARs and NR2F2 (a specific marker of theca cells), and that VCAM-1 mRNA and protein levels were elevated in theca cells obtained from PCOS patients when compared to control theca cells [14].

Rashad *et al*. [11] discovered that patients with PCOS exhibited elevated expression levels of ICAM-1 and corresponding serum concentrations, with the most pronounced values being evident in individuals who subsequently developed T2DM compared to those with decreased glucose tolerance or normal glucose tolerance.

Functional evidence for increased leukocyte-endothelium interactions in PCOS patients was presented by Victor *et al*. [15], who observed an increase in rolling flux and adhesion along with a decrease in polymorphonuclear cell rolling velocity. Increased levels of TNF-α, IL-6, and adhesion molecules including VCAM-1 and E-selectin coincided with these functional change. This body of research substantiates the hypothesis that systemic inflammation and endothelial activation in PCOS engender a proatherogenic environment, thereby predisposing these women to premature cardiovascular disease. Foltyn *et al*. [16] further

proven elevated levels of E-selectin in PCOS patients compared to healthy women ($p = 0.028$).

The substantial increase in adhesion molecules among women with PCOS may be attributed to several factors. Androgens (which are typically elevated in PCOS) may contribute to a proinflammatory state through various mechanisms. They have the ability to trigger the generation of reactive oxygen species (ROS), which in turn trigger proinflammatory signalling pathways and nuclear factor (NF-κB). Additionally, androgens have been shown to stimulate the production of proinflammatory cytokines such as tumor necrosis factor (TNF)-α and interleukin (IL)-6, which consequently promote the expression of adhesion molecules on endothelial cells [14, 17].

Given that insulin has proinflammatory effects at high doses and activates NF-κB and other proinflammatory transcription factors to stimulate the production of cytokines and adhesion molecules, this association is biologically feasible [18].

The persistent elevation of adhesion molecules in women diagnosed with PCOS carries significant implications for cardiovascular risk assessment in this demographic. The quantification of VCAM-1, ICAM-1, and E-selectin may aid in identifying PCOS patients who are at the highest risk for developing endothelial dysfunction and subsequent cardiovascular events [11]. An important early step in the development of atherosclerotic plaques is this mechanism. After entering the subendothelial area, these immune cells undergo differentiation into macrophages, absorb oxidized lipids, and develop into foam cells, which are the distinctive cells of fatty streaks, the first evident atherosclerotic lesions [15].

In the present study, ROC curves revealed that VCAM-1 had the highest AUC (0.873), followed by E-selectin (0.837) and ICAM-1 (0.732). All markers showed significant diagnostic value ($p<0.001$) with sensitivities and specificities around 70–82% and optimal cut-off values identified. However, a combination of these markers raises the AUC to 0.904 with a sensitivity and specificity of 82% and 80%, respectively. Little research have tested the analytic value of these molecules in detecting PCOS. Rashad *et al*. [11] examined the diagnostic utility of ICAM-1 measurements in PCOS. The study revealed that ICAM-1 had an AUC of 0.988 (95% CI = 0.980–0.997) with sensitivity = 99.4%, specificity = 85%, and the cutoff value (121.2 ng/ml). Furthermore, ROC analysis revealed that, when combining serum ICAM1 and expression levels to distinguish PCOS from control, the AUC was 0.989 (95% CI 5 0.980–0.997, P < 0.001) with sensitivity = 99.4%, specificity = 85.8%. This variation between the two studies may be ascribed to different factors, the most important of which are variations in study populations (ethnicity, age, disease severity), sample size, and methods used for measuring ICAM-1.

In the present study, none of the included adhesion molecules had a significant correlation with the demographic or hormonal profile of the patients. In contrast, Victor *et al*. demonstrated that these molecules positively correlated with basal and stimulated insulin, fasting triglycerides, BMI, and WHR, while negatively correlating with HDL cholesterol [15]. Foltyn *et al*. [16] showed a positive association in-between E-selectin and glucose ($p = 0.0001$), triglycerides ($p = 0.014$), and uric acid ($p = 0.008$). The lack of such correlations in the current study may be attributed to the fact that the present study did not estimate lipid profile and has a relatively small sample size [19-27].

The current research has a number of limitations despite the insightful findings. First, generalizability may be limited since the sample size might not accurately reflect the larger population. Second, potential perplexing factors like dietary habits, physical activity levels, insulin resistance, and inflammatory comorbidities (e.g., obesity, metabolic syndrome) were not controlled, which may influence serum adhesion molecule levels. Third, the study did not evaluate longitudinal changes in these markers or their response to treatment, which could further clarify their clinical utility.

Conclusion

This literature showed that women with PCOS exhibit significantly elevated serum status of VCAM-1, ICAM-1, and E-selectin in comparison to healthy controls. These adhesion molecules showed strong diagnostic potential, particularly when combined. Adhesion molecules may be considered as supplementary biomarkers for early identification and monitoring of PCOS, especially in patients at risk of cardiovascular complications. Further research should investigate whether changes in the levels of these markers could serve as indicators of treatment response, particularly for lifestyle or pharmacologic interventions aimed at reducing inflammation or improving endothelial function.

Patients consent

Prior to the commencement of data collection, a written informed consent was procured from each participant following a comprehensive explanation of the study's objectives. The confidentiality of the data throughout the research was assured, and the participants were informed that the data would be utilized solely for research purposes.

Acknowledgments: None

Conflict of interest: None

Financial support: None

Ethics statement: The study design was approved by the Institutional Review Board of Al-Shaab university (No. 124-2026).

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