Androgen–erythrocyte associations in polycystic ovary syndrome and their relationships with metabolic and inflammatory markers

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Асоциации между андрогени и еритроцити при синдром на поликистозните яйчници и тяхната връзка с метаболитни и възпалителни маркери

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Abstract:

Objective: The study aim was to investigate the associations between androgen status and erythrocyte parameters in women with polycystic ovary syndrome (PCOS), as well as the relationships of the erythrocyte parameters with selected metabolic and inflammatory markers. **Materials and Methods:** The study included 182 women: 57 women with PCOS and 125 clinically healthy controls. Serum concentrations of total testosterone and dehydroepiandrosterone sulfate (DHEA-S), red blood cell count (RBC), hemoglobin (Hb), hematocrit (Hct), homeostasis model assessment 2 of insulin resistance (HOMA2-IR), triglyceride-to-high-density lipoprotein cholesterol ratio (TG/HDL-C), C-reactive protein (CRP), and C-reactive protein-to-albumin ratio (CAR) were determined. Between-group differences were assessed using the Mann–Whitney U test. Within the PCOS group, associations were analyzed using Spearman correlation, partial correlations adjusted for age and body mass index (BMI), and multiple linear regression. False discovery rate (FDR) correction was applied for multiple comparisons. **Results:** Women with PCOS had significantly higher total testosterone and DHEA-S concentrations than controls. Hct was also higher in PCOS ($p = 0.013$), whereas no statistically significant difference was found for RBC, and Hb was borderline higher in women with PCOS ($p = 0.050$). Within the PCOS group, DHEA-S showed positive correlations with Hb and Hct that persisted after adjustment for age and BMI. Total testosterone also correlated positively with RBC, Hb, and Hct, but its associations with Hb and Hct did not reach statistical significance in the multiple linear regression models. RBC count was positively correlated with HOMA2-IR, TG/HDL-C, CRP, and CAR. **Conclusion:** The results demonstrate an association between androgen status and erythrocyte parameters in PCOS, with DHEA-S positively associated with Hb and Hct. The observed correlations of RBC with metabolic and inflammatory parameters indicate that erythrocyte parameters may be associated not only with androgen status but also with metabolic and inflammatory alterations in PCOS.

Key words: PCOS, hyperandrogenism, DHEA-S, hemoglobin, erythrocytes, insulin resistance

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Резюме:

Цел: Да се изследват асоциациите между андрогенния статус и еритроцитните показатели при жени със синдром на поликистозните яйчници (PCOS), както и връзките на еритроцитните показатели с избрани метаболитни и възпалителни маркери. **Материал и методи:** В проучването бяха включени 182 жени – 57 с PCOS и 125 клинично здрави контроли. Определени бяха серумните концентрации на общ тестостерон и дехидроепиандростерон сулфат (DHEA-S), еритроцитните показатели брой на еритроцитите (RBC), хемоглобин (Hb)

и хематокрит (Hct), както и HOMA2 индекс на инсулинова резистентност (HOMA2-IR), съотношение триглицериди/HDL холестерол (TG/HDL-C), С-реактивен протеин (CRP) и съотношение С-реактивен протеин/албумин (CAR). Междугруповите различия бяха оценени чрез U-теста на Mann–Whitney. В групата с PCOS асоциациите бяха анализирани чрез корелация на Spearman, частични корелации с корекция за възраст и индекс на телесна маса (BMI) и множествена линейна регресия. За множествените сравнения беше приложена корекция за честота на фалшивите открития (FDR). **Резултати:** При жените с PCOS общият тестостерон и DHEA-S бяха статистически значимо по-високи спрямо контролите. Hct също беше по-висок при PCOS (p = 0,013), докато за RBC не беше установена статистически значима разлика, а Hb беше гранично по-висок при жените с PCOS (p = 0,050). В групата с PCOS DHEA-S показа положителни корелации с Hb и Hct, които се запазиха след корекция за възраст и BMI. Общият тестостерон също корелира положително с RBC, Hb и Hct, но асоциациите му с Hb и Hct не достигнаха статистическа значимост в моделите на множествена линейна регресия. RBC корелира положително с HOMA2-IR, TG/HDL-C, CRP и CAR. **Заключение:** Въз основа на резултатите се открива връзка между андрогенния статус и еритроцитните показатели при PCOS, като се установяват положителни асоциации на DHEA-S с Hb и Hct. Чрез установените корелации на RBC с метаболитни и възпалителни показатели се разкрива, че еритроцитните параметри могат да бъдат свързани не само с андрогенния статус, но и с метаболитните и възпалителните промени при PCOS.

Ключови думи: PCOS, хиперандрогенизъм, DHEA-S, хемоглобин, еритроцити, инсулинова резистентност

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Introduction

Polycystic ovary syndrome (PCOS) is one of the most common endocrine disorders in women of reproductive age and is characterized by a heterogeneous clinical presentation that includes hyperandrogenism, ovulatory dysfunction, and/or polycystic ovarian morphology [1, 2]. In addition to its reproductive manifestations, the syndrome is associated with a broad spectrum of metabolic abnormalities, including insulin resistance, dyslipidemia, and increased cardiometabolic risk [1, 2].

One of the major pathophysiological features of PCOS is hyperandrogenism, which may present clinically as hirsutism, acne, and androgenic alopecia or biochemically as elevated androgen concentrations [3].

The role of androgens in disturbances of ovarian function and metabolic homeostasis has been extensively studied [2, 3], whereas the potential relationship between hyperandrogenism and erythrocyte parameters remains less well characterized. This relationship is of particular interest given the well-established stimulatory effect of androgens on erythropoiesis [4, 5]. Testosterone stimulates erythropoiesis by increasing erythropoietin production, stimulating erythroid progenitor cells, and suppressing hepcidin synthesis [4, 5].

Much of the evidence for androgen-mediated stimulation of erythropoiesis derives from studies in men receiving testosterone therapy [4, 5], whereas data on the relevance of this mechanism in women with PCOS remain limited. In addition to the potential influence of androgens, erythrocyte parameters are also associated with the metabolic disturbances characteristic of PCOS. Ha et al. (2023) found that higher hemoglobin concentrations in women with PCOS were associated with insulin resistance and a less favorable metabolic profile [6]. Similarly, the population-based cohort study by Virtanen et al. (2025) demonstrated associations between hemoglobin concentration and parameters of glucose and lipid metabolism, as well as selected inflammatory markers [7]. Morphological alterations of erythrocytes have also been described in women with PCOS [8], further supporting interest in erythrocyte parameters in the context of the hormonal and metabolic disturbances associated with the syndrome.

Aim

The aim of the present study was to investigate the associations between androgen status and erythrocyte parameters in women with PCOS, as well as the relationships of the erythrocyte parameters with selected metabolic and inflammatory markers by:

Assessing the correlations of total testosterone and dehydroepiandrosterone sulfate (DHEA-S) with red blood cell count (RBC), hemoglobin (Hb), and hematocrit (Hct);

Analyzing the correlations of RBC, Hb, and Hct with homeostasis model assessment 2 of insulin resistance (HOMA2-IR), triglyceride-to-high-density lipoprotein cholesterol ratio (TG/HDL-C), C-reactive protein (CRP), and C-reactive protein-to-albumin ratio (CAR);

Evaluating whether the main androgen–erythrocyte associations persisted after adjustment for age and body mass index (BMI).

Materials and Methods

Study design

The present study was an observational analytical case-control study with prospective recruitment of participants, conducted from March 2025 to June 2026.

A total of 182 women were included and divided into two groups: 57 women with PCOS and 125 clinically healthy women comprising the control group. All the participants were evaluated according to a standardized protocol including clinical assessment, anthropometric data, and laboratory investigations.

Study participants

PCOS group

The PCOS group included 57 women aged 18–40 years with a diagnosis of PCOS. The diagnosis was established by a specialist in obstetrics and gynecology according to the Rotterdam criteria [9], requiring the presence of at least two of the following three features: oligo- or anovulation, clinical and/or biochemical hyperandrogenism, and polycystic ovarian morphology on ultrasound.

At the time of enrollment, the participants with PCOS were not receiving hormonal, metabolic, or anti-inflammatory treatment and had not taken medications that could affect hormonal, metabolic, or inflammatory status during the preceding 6 months.

Control group

The control group included 125 clinically healthy women aged 18–40 years, age-matched to the women in the PCOS group.

Participants had regular menstrual cycles lasting 21-35 days and at least eight menstrual cycles per year, with no clinical or laboratory evidence of hyperandrogenism and no ultrasonographic evidence of polycystic ovarian morphology.

At the time of enrollment, the women in the control group were not taking hormonal medications or other drugs that could affect the investigated parameters.

Exclusion criteria

Women with thyroid disorders, hyperprolactinemia, premature ovarian insufficiency, hypothalamic amenorrhea, congenital adrenal hyperplasia, Cushing syndrome, androgen-secreting tumors, type 1 or type 2 diabetes mellitus, active infectious diseases, chronic inflammatory or autoimmune diseases, malignancy, as well as pregnant or breastfeeding women, were excluded from the study.

Ethical considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki for medical research involving human participants. The study protocol was approved by the Ethics Committee of Medical University – Sofia (Contract No. D-150/2025). All participants received detailed information about the aims and methods of the study and provided written informed consent before enrollment.

Confidentiality of personal data was ensured through coding of the information, and the results were used solely for scientific purposes.

Anthropometric data

Height and body weight were recorded for all participants.

Body mass index (BMI) was calculated using the following formula:

BMI = weight (kg)/height² (m²)

Collection and processing of biological samples

Venipuncture was performed in all participants between 08:00 and 10:00 after an 8–12-hour fasting period. In women with regular menstrual cycles, venipuncture was performed between days 2 and 5 of the cycle to minimize the influence of physiological hormonal variations.

One K_2EDTA vacuum tube was collected from each participant for hematological testing, together with two serum tubes for biochemical and hormonal analyses.

Serum samples were left at room temperature for 30 minutes and then centrifuged. The separated serum was analyzed immediately after processing.

Analytical interferences and quality control

Samples were visually assessed for hemolysis, lipemia, and icterus. All analyses were performed in accordance with the laboratory's internal quality-control procedures.

Hematological investigations

Complete blood count parameters were measured using an automated Sysmex XN-1000 hematology analyzer (Sysmex Corporation, Kobe, Japan).

Red blood cell count was determined by impedance measurement with hydrodynamic focusing.

Hemoglobin concentration was measured using a cyanide-free sodium lauryl sulfate (SLS) method. The erythrocyte parameters selected a priori for the present analysis included:

- RBC;
- Hb concentration;
- Hct.

Hormonal investigations

Serum concentrations of total testosterone and DHEA-S were measured by electrochemiluminescence immunoassay (ECLIA) on the Cobas e 402 immunochemistry module of the Cobas pure integrated solutions system (Roche Diagnostics GmbH, Mannheim, Germany).

Biochemical investigations

Serum concentrations of fasting glucose, triglycerides, HDL cholesterol, CRP, and albumin were measured on the Cobas C 303 Analytical Module of the Cobas Pure Integrated Solutions system (Roche Diagnostics GmbH, Mannheim, Germany). Fasting insulin was determined by ECLIA on the Cobas E 402 module.

Calculated metabolic indices

Insulin resistance was assessed using the updated Homeostatic Model Assessment [10]. HOMA2-IR was calculated from fasting glucose and insulin concentrations using HOMA2 Calculator, version 2.2.4, developed by the Diabetes Trials Unit, University of Oxford.

The triglyceride/HDL cholesterol ratio was calculated using the formula: TG/HDL-C = triglycerides/HDL cholesterol.

Calculated inflammatory indices

Serum CRP was measured by an immunoturbidimetric method, while albumin was measured by a bromocresol green colorimetric method.

The CRP/albumin ratio was calculated using the formula: CAR = CRP/albumin.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics, version 31.0.2.0. Distributional normality was assessed using the Shapiro–Wilk test. Because most quantitative variables showed non-Gaussian distributions, results were presented as median and interquartile range [Me (IQR)], and between-group comparisons were performed using the Mann–Whitney U test.

Within the PCOS group, the correlations of total testosterone and DHEA-S with RBC, Hb, and Hct were evaluated using Spearman rank correlation. Partial correlations adjusted for age and BMI were also calculated. In addition, the correlations of RBC, Hb, and Hct with HOMA2-IR, TG/HDL-C, CRP, and CAR were analyzed. The Benjamini–Hochberg false discovery rate (FDR) correction was applied for multiple comparisons.

Multiple linear regression models adjusted for age and BMI were used for further evaluation of the androgen–erythrocyte associations.

All the tests were two-sided. Statistical significance was accepted at $p < 0.05$ and, after FDR correction, at $q < 0.05$.

Results

The analysis included 57 women with PCOS and 125 clinically healthy controls. The main baseline, hormonal, erythrocyte, metabolic, and inflammatory characteristics of the study groups are summarized in Table 1.

Baseline characteristics of the study groups

Median age was identical in the two groups at 25.0 years, with no statistically significant difference ($p = 0.778$).

BMI was significantly higher in women with PCOS – 20.82 (20.08-23.46) kg/m² compared with 19.94 (19.37-21.36) kg/m² in controls ($p < 0.001$).

Hormonal, erythrocyte, metabolic, and inflammatory parameters

Among the hormonal parameters, women with PCOS had significantly higher concentrations of total testosterone ($p < 0.001$) and DHEA-S ($p = 0.012$).

The metabolic and inflammatory parameters HOMA2-IR, TG/HDL-C, CRP, and CAR were also significantly higher in the PCOS group.

Among the erythrocyte parameters, Hct was significantly higher in PCOS ($p = 0.013$), whereas no significant between-group difference was found for RBC ($p = 0.156$). Hb was borderline higher in women with PCOS ($p = 0.050$).

Correlations between androgens and erythrocyte parameters

Within the PCOS group, total testosterone showed statistically significant positive correlations with RBC, Hb, and Hct. DHEA-S was significantly positively correlated with Hb and Hct, but not with RBC. The largest correlation coefficients were observed for DHEA-S with Hb ($\rho = 0.399$; $p = 0.002$) and for DHEA-S with Hct ($\rho = 0.445$; $p < 0.001$). After adjustment for age and BMI, these correlations remained essentially unchanged, with partial $\rho = 0.399$ ($p = 0.003$) and $\rho = 0.444$ ($p < 0.001$), respectively.

After Benjamini–Hochberg correction, the correlations of DHEA-S with Hb and Hct and those of total testosterone with RBC, Hb, and Hct remained statistically significant. The correlation between DHEA-S and RBC remained non-significant.

The two strongest androgen–erythrocyte correlations – DHEA-S–Hb and DHEA-S–Hct – are shown in Figure 1.

The complete results of the unadjusted and age- and BMI-adjusted correlation analyses are presented in Table 2.

Table 1. Baseline characteristics of the study groups

Parameter (unit of measurement)	Controls (n = 125) (Me (IQR)	PCOS (n = 57) (Me (IQR)	p-value
Age (years)	25.0 (22.0–30.0)	25.0 (22.0–31.5)	0.778
BMI (kg/m²)	19.94 (19.37–21.36)	20.82 (20.08–23.46)	**< 0.001**
Total testosterone (nmol/L)	1.10 (0.84–1.45)	1.56 (1.13–2.01)	**< 0.001**
DHEA-S (μmol/L)	6.30 (4.95–8.15)	7.60 (5.55–10.05)	**0.012**
RBC (×10¹²/L)	4.60 (4.30–4.80)	4.60 (4.40–4.90)	0.156
Hb (g/L)	133 (125–141)	137 (130–141)	0.050
Hct (L/L)	0.40 (0.38–0.42)	0.41 (0.39–0.42)	**0.013**
HOMA2-IR	1.02 (0.75–1.24)	1.16 (0.91–1.73)	**0.002**
TG/HDL-C	0.38 (0.29–0.49)	0.58 (0.40–0.88)	**< 0.001**
CRP (mg/L)	0.80 (0.50–1.50)	1.20 (0.65–3.85)	**0.005**
CAR	0.020 (0.010–0.036)	0.030 (0.013–0.097)	**0.004**

Note: Data are presented as median and interquartile range [Me (IQR)]. Between-group comparisons were performed using the Mann–Whitney U test. BMI – body mass index; CAR – C-reactive protein-to-albumin ratio; CRP – C-reactive protein; DHEA-S – dehydroepiandrosterone sulfate; Hb – hemoglobin; Hct – hematocrit; HOMA2-IR – Homeostatic Model Assessment 2 of insulin resistance; RBC – red blood cell count; TG/HDL-C – triglyceride-to-high-density lipoprotein cholesterol ratio. Statistically significant p-values (p < 0.05) are shown in bold.

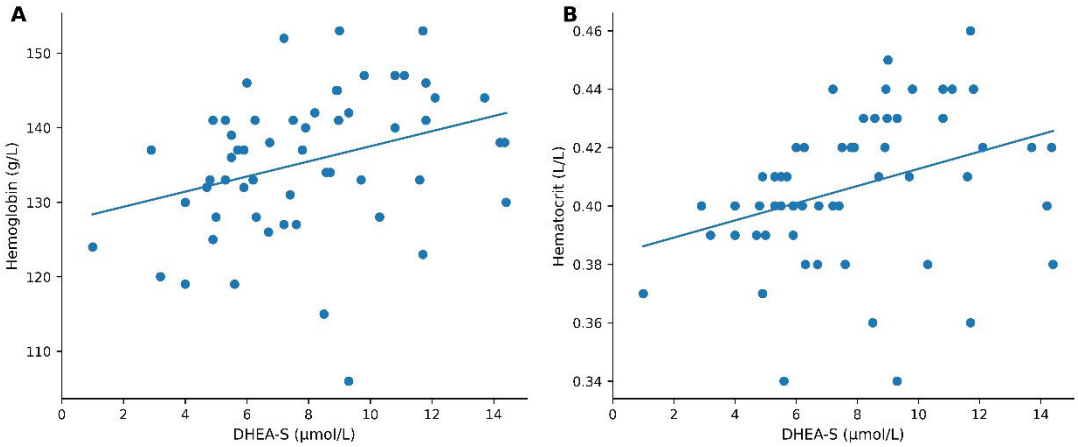

Figure 1. Correlations of dehydroepiandrosterone sulfate with hemoglobin and hematocrit in women with polycystic ovary syndrome

Note: A – dehydroepiandrosterone sulfate and hemoglobin; B – dehydroepiandrosterone sulfate and hematocrit. Individual observations and trend lines are shown. DHEA-S – dehydroepiandrosterone sulfate.

Table 2. Correlations between androgen concentrations and erythrocyte parameters in women with polycystic ovary syndrome

Erythrocyte parameter	Androgen	Spearman ρ	p-value	Partial ρ adjusted for age and BMI	p-value for partial correlation	FDR q-value
RBC	Testosterone	0.299	**0.024**	0.295	**0.029**	**0.034**
RBC	DHEA-S	0.202	0.132	0.203	0.138	0.138
Hb	Testosterone	0.308	**0.020**	0.306	**0.023**	**0.034**
Hb	DHEA-S	0.399	**0.002**	0.399	**0.003**	**0.008**
Hct	Testosterone	0.337	**0.010**	0.336	**0.012**	**0.024**
Hct	DHEA-S	0.445	**< 0.001**	0.444	**< 0.001**	**0.004**

Note: Partial Spearman correlations were adjusted for age and body mass index. False discovery rate q-values were calculated using the Benjamini–Hochberg method for the six primary androgen–erythrocyte comparisons. Statistically significant p- and q-values (<0.05) are shown in bold. BMI – body mass index; DHEA-S – dehydroepiandrosterone sulfate; FDR – false discovery rate; Hb – hemoglobin; Hct – hematocrit; RBC – red blood cell count.

Metabolic and inflammatory correlations

The correlations of RBC, Hb, and Hct with HOMA2-IR, TG/HDL-C, CRP, and CAR were additionally evaluated. The largest number of statistically significant correlations was observed for RBC.

After adjustment for age and BMI, RBC was positively correlated with HOMA2-IR, TG/HDL-C, CRP, and CAR, and all four correlations remained statistically significant after FDR correction. A significant positive correlation was observed between RBC and TG/HDL-C (partial ρ = 0.440; p < 0.001; q = 0.009), as shown in Figure 2. Hct was also positively correlated with TG/HDL-C (partial ρ = 0.372; p = 0.005; q = 0.031). No statistically significant adjusted correlations were found between Hb and the investigated metabolic and inflammatory parameters (Table 3).

Multiple linear regression

In the multiple linear regression models, DHEA-S remained significantly and positively associated with Hb and Hct after adjustment for age and BMI. A 1 µmol/L increase in DHEA-S was associated with a 1.07 g/L increase in Hb (B = 1.071; 95% CI 0.236–1.907; p = 0.013) and a 0.0031 L/L increase in Hct (B = 0.00314; 95% CI 0.00089–0.00538; p = 0.007). The associations of total testosterone with Hb and Hct did not reach statistical significance after adjustment for age and BMI (Table 4).

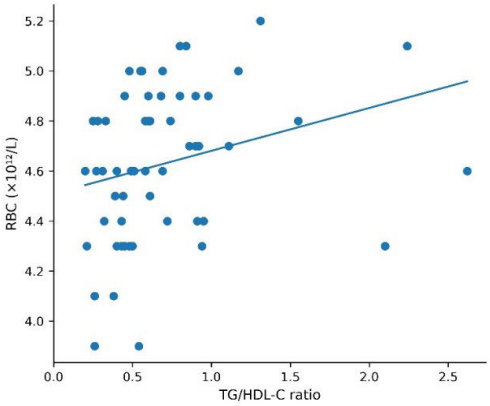

Figure 2. Correlations between red blood cell count and the triglyceride/high-density lipoprotein cholesterol ratio in women with polycystic ovary syndrome

Note: Individual observations and the trend line are shown. RBC – red blood cell count; TG/HDL-C – triglyceride/high-density lipoprotein cholesterol ratio.

Table 3. Age- and body mass index-adjusted correlations of erythrocyte parameters with metabolic and inflammatory markers in women with polycystic ovary syndrome

Erythrocyte parameter	Marker	Partial ρ	p-value	FDR q-value
RBC	HOMA2-IR	0.319	0.018	0.049
RBC	TG/HDL-C	0.440	<0.001	0.009
RBC	CRP	0.312	0.020	0.049
RBC	CAR	0.323	0.016	0.049
Hb	HOMA2-IR	0.025	0.856	0.856
Hb	TG/HDL-C	0.253	0.063	0.126
Hb	CRP	0.043	0.754	0.823
Hb	CAR	0.046	0.736	0.823
Hct	HOMA2-IR	0.146	0.289	0.385
Hct	TG/HDL-C	0.372	0.005	0.031
Hct	CRP	0.186	0.173	0.259
Hct	CAR	0.204	0.134	0.230

Note: Partial Spearman correlations were adjusted for age and body mass index. FDR q-values were calculated using the Benjamini–Hochberg method for the 12 secondary comparisons between erythrocyte and metabolic/inflammatory parameters. Statistically significant p- and q-values (p < 0.05; q < 0.05) are shown in bold. CAR – C-reactive protein-to-albumin ratio; CRP – C-reactive protein; FDR – false discovery rate; Hb – hemoglobin; Hct – hematocrit; HOMA2-IR – Homeostatic Model Assessment 2 of insulin resistance; RBC – red blood cell count; TG/HDL-C – triglyceride-to-high-density lipoprotein cholesterol ratio.

Table 4. Multiple linear regression analysis of associations between androgens and erythrocyte parameters in women with polycystic ovary syndrome

Dependent variable (unit of measurement)	Main predictor (unit of measurement))	B	95% CI	p-value	Model R^2
Hb (g/L)	DHEA-S (µmol/L)	1.071	0.236 to 1.907	0.013	0.111
Hct (L/L)	DHEA-S (µmol/L)	0.00314	0.00089 to 0.00538	0.007	0.130
Hb (g/L)	Testosterone (nmol/L)	3.521	−0.258 to 7.301	0.067	0.062
Hct (L/L)	Testosterone (nmol/L)	0.00965	−0.00060 to 0.01990	0.064	0.064

Note: All models were adjusted for age and body mass index. B – unstandardized regression coefficient; CI – confidence interval; Hb – hemoglobin; Hct – hematocrit; DHEA-S – dehydroepiandrosterone sulfate; R^2 – R-squared. Statistically significant p-values (p < 0.05) are shown in bold.

Discussion

The present study identified an association between androgen status and erythrocyte parameters in women with PCOS. DHEA-S showed positive associations with both Hb and Hct. DHEA-S predominantly reflects adrenal androgen production and may complement the assessment of biochemical hyperandrogenism in PCOS [11–13]. The associations of DHEA-S with Hb and Hct persisted after adjustment for age and BMI and remained statistically significant in the multiple linear regression models, supporting a consistent relationship between adrenal androgen activity and these erythrocyte parameters in PCOS.

Total testosterone also correlated positively with RBC, Hb, and Hct, but its associations with Hb and Hct did not reach statistical significance in the regression models.

Our findings complement those of Boucher et al. (2024), who, in a study including 1,223 women with PCOS and 517 controls, reported a higher frequency of elevated DHEA-S concentrations among women with PCOS [11].

The observed associations are consistent with the known effects of androgens on erythropoiesis, mediated through effects on erythropoietin production, erythroid progenitor cells, and iron metabolism [4, 5].

Evidence on the relationship between androgen status and erythrocyte parameters in PCOS remains limited. Ha et al. (2023) reported that higher Hb concentrations in women with PCOS were associated with higher BMI, fasting insulin, post-load insulin, and HOMA-IR values [6].

A more direct association between Hb and androgen status was demonstrated in the large population-based study, which included 20,602 women, by Wang et al. in 2025. The authors found that higher Hb concentrations were associated with PCOS, hyperandrogenism, and higher testosterone levels, and suggested a potential role of the HIF-1 signaling pathway [14].

Between-group differences in erythrocyte parameters were modest. Hct was significantly higher in women with PCOS, whereas no significant difference was found for RBC, and Hb showed a borderline between-group difference ($p = 0.050$). Therefore, the results do not indicate clinically significant erythrocytosis, but rather subtle changes in erythrocyte parameters and their relationship with androgen status. Changes in red blood cell indices, including RDW, Hb, and Hct, have also been investigated in previous studies of women with PCOS [15, 16].

In addition to the androgen associations, RBC count also correlated with metabolic parameters. After adjustment for age and BMI, RBC was positively correlated with HOMA2-IR and TG/HDL-C, with the largest adjusted correlation coefficient observed for TG/HDL-C. A 2025 systematic review and meta-analysis including 61 observational studies also reported higher TG/HDL-C values in women with PCOS, together with higher indices of insulin resistance [17]. The observed correlation between RBC and TG/HDL-C may be interpreted in the context of the increased cardiometabolic risk associated with PCOS [18, 19].

The relationship between erythrocytes and metabolic disturbances in PCOS is also supported by the study of Dey et al. (2024). The authors described alterations in erythrocyte morphology, erythrocyte membrane lipid content, and markers of oxidative stress in women with PCOS and dyslipidemia [8]. These findings suggest that erythrocytes may be influenced by the metabolic and oxidative environment in PCOS.

RBC count was also positively correlated with CRP and CAR after adjustment for age and BMI. A previous case-control study likewise reported higher CAR values in women with PCOS than in healthy controls [20]. However, these correlations do not demonstrate a direct effect of inflammation on erythropoiesis. Evidence from systematic reviews indicates increased inflammatory activity in PCOS, including alterations in CRP, hs-CRP, and IL-6 [21, 22]. The observed correlations may be interpreted in the context of the interrelated metabolic, oxidative, and inflammatory disturbances characteristic of PCOS [23–26].

Unlike RBC, Hb did not show statistically significant adjusted correlations with HOMA2-IR, CRP, or CAR, despite its positive correlation with DHEA-S. This differs from the findings of Ha et al. (2023), who reported associations between Hb and several measures of glucose metabolism in women with PCOS [6]. Differences between the studied populations may contribute to this discrepancy. The women in our study were predominantly young and had relatively low BMI values. Virtanen et al. (2025) also showed that BMI explains part of the metabolic associations of Hb in women with PCOS [7].

The present findings indicate different patterns among individual erythrocyte parameters. In our analysis, Hb and Hct were more closely related to the androgen component, particularly DHEA-S, whereas RBC showed more pronounced correlations with HOMA2-IR, TG/HDL-C, CRP, and CAR. This suggests that individual erythrocyte parameters may reflect different aspects of the hormonal, metabolic, and inflammatory alterations in PCOS.

A 2024 review of systematic reviews including data from more than 190,000 women identified an-

drogen measures, CRP, HOMA-IR, fasting insulin, triglycerides, HDL cholesterol, ferritin, and iron as potentially important biomarkers in PCOS [27]. Our results suggest that routine erythrocyte parameters may provide additional information when interpreted together with hormonal and metabolic alterations.

Nevertheless, Hb, Hct, and RBC should not be considered diagnostic markers of PCOS. Between-group differences were modest, with substantial overlap between women with PCOS and controls. The potential value of these parameters is more likely as complementary laboratory information regarding hormonal and metabolic alterations in women with an established diagnosis of PCOS.

Strengths and limitations

A strength of the study is the use of a standardized protocol for evaluating participants. Women receiving hormonal, insulin-sensitizing, or anti-inflammatory treatment were excluded, limiting medication-related effects on the investigated parameters. Blood sampling was standardized with respect to fasting status and menstrual-cycle phase when applicable. Associations were also evaluated after adjustment for age and BMI, and FDR correction was applied for multiple comparisons.

The study also has limitations. The observational case-control design does not allow causal inferences. The number of women with PCOS was relatively small, which may limit the generalizability of the findings. Free testosterone, SHBG, erythropoietin, hepcidin, ferritin, transferrin saturation, and other markers of iron metabolism were not assessed. Their inclusion in future studies would be valuable for clarifying the mechanisms linking androgen status with Hb and Hct, particularly in view of evidence of altered hepcidin and iron metabolism in PCOS [28, 29]. Disturbances in iron homeostasis and related mechanisms of ferroptosis have also been discussed as a potential component of PCOS pathophysiology [30].

Conclusion

Our findings support a relationship between androgen status and erythrocyte parameters in women with PCOS and suggest that this relationship may be linked to the metabolic profile of the syndrome. The observed associations highlight the potential relevance of routinely available hematological parameters in the broader assessment of PCOS. Further studies in larger populations are needed to confirm these findings and clarify their clinical significance.

Conflict of Interest:
The authors declare no conflict of interest.

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