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OPEN ACCESS ORIGINAL ARTICLE

Hematological parameters among pregnant and non-pregnant women in Aldalea Governorate, Yemen: A Comparative Study

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ABSTRACT

Background: Complete blood count (CBC) is an essential diagnostic tool for assessing overall health and monitoring physiological changes. Pregnancy induces specific hematological modifications reflecting both physiological adaptations and potential pathological conditions.

Objective: This study aimed to assess hematological parameters among pregnant and non-pregnant women in Aldalea Governorate, Yemen, and to identify significant differences that may affect clinical interpretations.

Methods: A comparative cross-sectional study was conducted on 164 women (128 pregnant and 36 non-pregnant) between May and December 2023. CBC analysis was performed using the Sysmex XP-300 hematological analyzer. Data were analyzed using independent t-tests via SPSS version 21, with statistical significance set at $p<0.05$. **Results:** Pregnant women exhibited a significantly lower packed cell volume (PCV) compared to non-pregnant women (32.4 ± 4.73% vs. 37 ± 2.41%, $p<0.001$). Additionally, differential white blood cell analysis revealed a significantly elevated neutrophil percentage (60.3 ± 9.3% vs. 44.3 ± 11.83%, $p=0.04$) and a significantly reduced lymphocyte percentage (33.8 ± 8.85% vs. 45.1 ± 9.35%, $p=0.011$) among pregnant women. In contrast, differences in hemoglobin levels, red blood cell count, mean corpuscular volume, and platelet counts were not statistically significant.

Conclusion: The study demonstrates that pregnancy in Aldalea is associated with a significant reduction in PCV and marked alterations in white blood cell differentials, indicative of hemodilution and immunological adaptations. These findings underscore the need for establishing region-specific hematological reference intervals for pregnant women to enhance diagnostic accuracy and optimize clinical management.

Keywords: Hematological parameters, pregnancy, anemia, risk factors, Aldalea, Yemen.

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INTRODUCTION

The complete blood count (CBC) with differential is a cornerstone of clinical diagnostics, providing critical insights into a patient's hematological and immunological status. It evaluates red blood cell (RBC) indices, hemoglobin (Hb), and hematocrit (HCT) to assess oxygen-carrying capacity, while white blood cell (WBC) counts and differentials reflect immune competence [1]. Beyond its diagnostic utility for anemia, infections, and malignancies, the CBC is vital for monitoring physiological adaptations during pregnancy, a period marked by profound hematological changes.[2,3]

Pregnancy induces a state of controlled physiological stress, characterized by plasma volume expansion (up to 50%), increased iron demand, and hormonal fluctuations [4]. Hemodilution, driven by progesterone-mediated activation of the renin-angiotensin-aldosterone system, reduces Hb and HCT concentrations, often mimicking anemia despite elevated total RBC mass [5-7]. Concurrently, folate and vitamin B12 deficiencies—common in low-resource settings like Yemen—exacerbate megaloblastic anemia, while parasitic infections (e.g., malaria) and chronic inflammation further disrupt erythropoiesis [8-10]. Thrombocytopenia, observed in 7–12% of pregnancies, arises from hemodilution, accelerated platelet consumption, or gestational immune mechanisms [11]. Neutrophilia, a hallmark of pregnancy, reflects heightened immune tolerance to fetal antigens, whereas lymphocytopenia may indicate adaptive shifts in cell-mediated immunity .[12,13]

In Aldalea Governorate, Yemen, ongoing conflict and food insecurity exacerbate nutritional deficiencies, yet region-specific CBC reference ranges for pregnant women remain undefined. Clinicians rely on Western-derived values, risking misdiagnosis and suboptimal care. This study aims to compare hematological parameters between pregnant and non-pregnant women, and to identify sociodemographic risk factors (age, education) for abnormalities, addressing a critical gap in maternal health management.

METHODS

Study Design and subjects

A comparative cross-sectional study was conducted from May to December 2023, enrolling 128 pregnant women and 36 age-matched non-pregnant controls from Aldalea Governorate, Yemen. Participants were recruited from urban and rural clinics (e.g., Dr. Adibah Center) to ensure demographic diversity.

Inclusion and Exclusion Criteria

- **Inclusion:** Yemeni females aged 15–45 years, residing in Aldalea.
- **Exclusion:** Non-Yemeni nationals, chronic illnesses (e.g., renal disease), or recent blood transfusions.

Sample Size Calculation

The minimum sample size was calculated using the formula:

$$\mathbf{N}=\frac{z^2 p(1-P)}{b^2}=\frac{1.96^2\times 48.7\%(1-48.7\%)}{(3\%)^2}=1070$$

Where z=1.96z=1.96 (95% confidence level), p= 48.7% (prevalence of anemia from a prior Yemeni study [14]), and b=3% (margin of error).

The sample size was adjusted using the finite population correction formula:

n =n0 / 1+ n0 −1 / N

Where:

- n0 = 1070 (initial sample size)
- N= 120 (estimated total population of pregnant women attending the health facility during the study period).

Applying the formula:

n=1070 / 1+1070−1 / 120 = 107.98, however, 128 pregnant women were enrolled to enhance statistical power.

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Data Collection and Laboratory Analysis

Venous blood (2 mL in EDTA) was collected under sterile conditions. CBC parameters (Hb, HCT, RBC, WBC, platelets, MCV, MCH, MCHC, and differential counts) were analyzed within 2 hours using a Sysmex XP-300 analyzer (electrical impedance method). Internal quality controls and standardized protocols ensured accuracy.

Statistical Analysis

Data were analyzed using SPSS v21. Continuous variables were presented as mean ± SD and compared using independent t-tests. Categorical variables (such as age and education) were expressed as frequencies and percentages. Normal reference ranges for hemoglobin levels followed WHO guidelines [15]. Statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval was granted by Aldalea University Institutional Review Board (No. MED-2023-015). Written informed consent was obtained from all participants after explaining study objectives and procedures.

Laboratory diagnosis

Blood samples received processing within two hours of collection, and laboratory exams were undertaken following established protocols, with periodic cross-checking for quality control. Hematological parameters were examined using an automated particle cell counter (Sysmex XP-300), based on the electrical impedance theory. A suspension of blood cells is fed through a tiny aperture simultaneously with an electric current. As individual blood cells cross the orifice, they create changes in electrical impedance, proportionate to their size. Each cell, floating in a conductive liquid (diluent), functions as an insulator, briefly raising the electrical resistance between submerged electrodes on each side of the aperture. This creates detectable electrical pulses, enabling precise cell counting.

To assure accuracy, a vacuum-controlled mechanism pulls the diluted cell suspension through the aperture at a prescribed volume. The number of pulses recorded correlates to the particle count, whereas differences in electrical resistance define cell size distribution. The Sysmex XP-300 measures about 100 times more cells per sample compared to typical microscopic counting methods, hence decreasing statistical errors by nearly tenfold.

RESULTS

Findings of Table 1, figure 1 and figure 2 revealed that the study involved 128 participants predominantly in the 15–30 year age range, with 40.9% aged 15–20 and 44.1% aged 21–30. Nearly half (47.7%) of the participants had primary education, followed by secondary education (26.6%), with smaller proportions being illiterate (19.5%) or graduates (6.2%). This distribution provides a context for understanding the study population’s educational and age backgrounds.

Table 1: Demographic characteristics of participants, n= 128

		Frequency (n)	Percentage (%)
Age group	15 -20 years	52	40.9%
	21-30 years	56	44.1%
	More than 30 years	20	15%
Education level	Primary	61	47.7%
	Secondary	34	26.6%
	illiterate	25	19.5%
	Graduate	8	6.2%

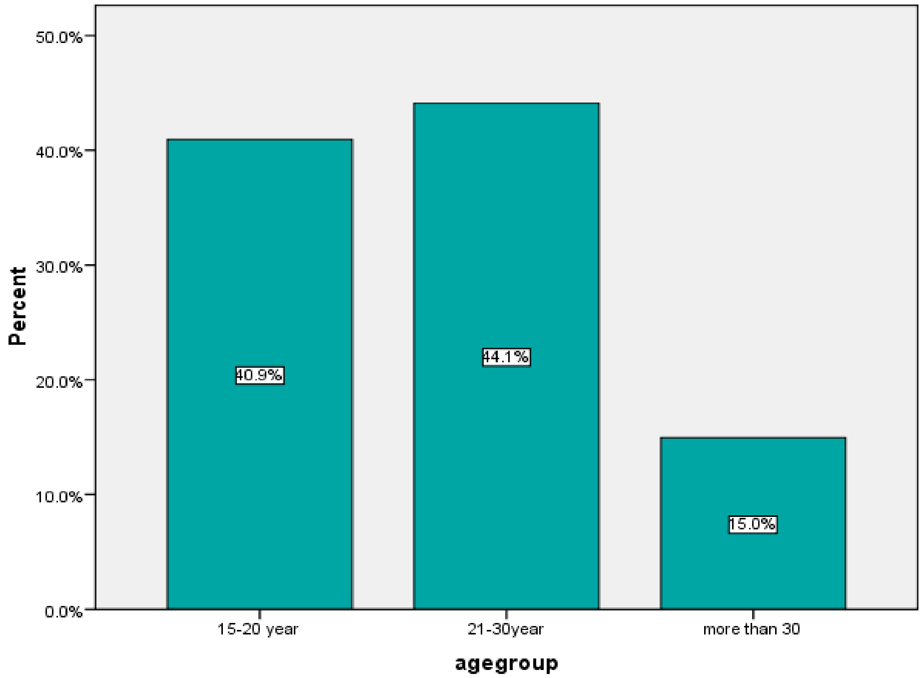

Figure 1: Frequency of Study Group According to Age group

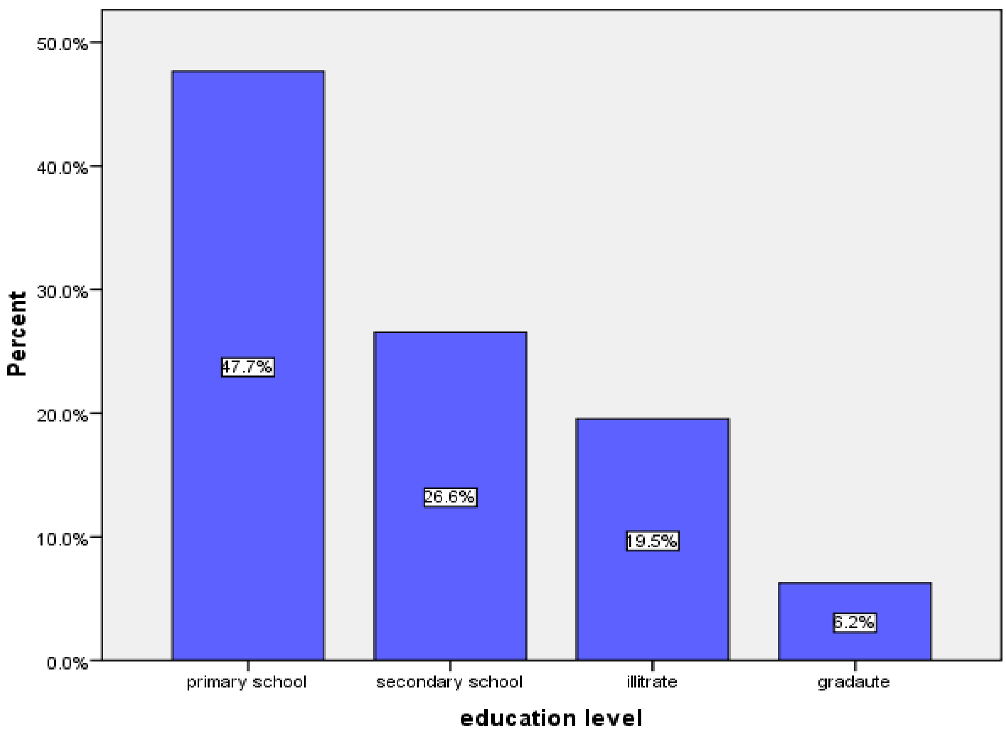

Figure 2: Distribution of Study Group According to Education Level

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Table 2 provides a concise reference for hematological parameters normal ranges. For example, hemoglobin (Hb) levels are considered normal if they fall between 12–16 g/dL in non-pregnant women (10.5–14 g/dL in pregnant women), with values below indicating anemia and those above suggesting polycythemia. Similarly, red blood cell (RBC) counts and packed cell volume (PCV) are adjusted for pregnancy due to hemodilution effects, with abnormal low values pointing to anemia and high values indicating possible dehydration or polycythemia. The red cell indices—MCV, MCH, and MCHC—assist in assessing cell size and hemoglobin content, helping to differentiate between types of anemia. The white blood cell (WBC) count range is slightly elevated during pregnancy, reflecting normal physiological changes, while deviations might indicate infection or immunological issues. Platelet counts below 150×10^9/L may suggest thrombocytopenia, whereas counts above 400×10^9/L could point to thrombocytosis. Lastly, the differential counts show that neutrophil percentages above the normal upper limit (70%) may signal bacterial infections or inflammation, while lymphocyte percentages outside the 20–45% range may reflect immunodeficiency or reactive lymphocytosis. Overall, this table serves as an essential tool for clinicians to differentiate between normal physiological changes and potential pathological conditions.

Table 2: References values for Normal and Abnormal Hematological Parameters in Pregnant and Non-Pregnant Women [15]

Hematological Parameter	Normal Range	Abnormal (Low)	Abnormal (High)
Hb (g/dL)	12.0–16.0 (non-pregnant) 10.5–14.0 (pregnant)	<10.5 (anemia)	>16.0 (polycythemia)
RBC ($\times10^{12}$/L)	3.8–5.2 (pregnant) 4.2–5.4 (non-pregnant)	<3.8 (anemia)	>5.4 (polycythemia)
Packed Cell Volume (PCV) / Hematocrit (%)	36–46 (non-pregnant) 30–40 (pregnant)	<30 (anemia, hemodilution)	>46 (polycythemia, dehydration)
Mean Corpuscular Volume (MCV) (fL)	80–100	<80 (microcytosis, iron deficiency)	>100 (macrocytosis, B12/folate deficiency)
Mean Corpuscular Hemoglobin (MCH) (pg)	27–32	<27 (hypochromia, iron deficiency)	>32 (macrocytic anemia)
Mean Corpuscular Hemoglobin Concentration (MCHC) (g/dL)	32–36	<32 (hypochromia, iron deficiency)	>36 (spherocytosis, dehydration)
WB) ($\times10^9$/L)	4.0–11.0 (non-pregnant) 6.0–16.0 (pregnant)	<4.0 (leukopenia, viral infections)	>16.0 (infection, inflammation)
PLT ($\times10^9$/L)	150–400	<150 (thrombocytopenia, gestational thrombocytopenia)	>400 (thrombocytosis, inflammation)
Neutrophils (%)	40–70	<40 (neutropenia, severe infections)	>70 (neutrophilia, bacterial infections)
Lymphocytes (%)	20–45	<20 (lymphopenia, stress, HIV)	>45 (lymphocytosis, viral infections)

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The analysis in Table 3 was performed using an independent t-test, which is appropriate when comparing the means of two distinct groups—in this case, pregnant versus non-pregnant women. This test assesses whether the differences in hematological parameters between these independent samples are statistically significant.

For instance, although hemoglobin levels and RBC counts were lower in pregnant women, their p-values (0.09 and 0.118, respectively) indicate that these differences could be due to chance. In contrast, the significant reduction in PCV (p = 0.00) clearly suggests a true difference likely reflecting the dilutional effect of increased plasma volume during pregnancy. Similarly, the independent t-test revealed statistically significant differences in the differential white blood cell counts, with increased neutrophil percentages (p = 0.04) and decreased lymphocyte percentages (p = 0.011) in pregnant women, underscoring immunological adaptations during pregnancy.

Table 3: Factors contributing to abnormal hematological parameters among pregnant and non pregnant women at Aldalea-Yemen

Hematological parameters	Pregnant women(128) Mean ± SD	Non Pregnant women(36)	P. Value
Hb g/dl	10.5 ±1.3	12.6 ±1.2STD	**0.09**
RBCx10^12 cell/L	4.1 ± 57	4.72±30STD	0.118
PCV %	32.4±4.73	37 ±2.41STD	**0.00**
MCV FL	75.3±8.13	79.4±5.60STD	0.16
MCH Pg	26±3.85	26±2.49STD	0.149
MCHC g/dl	32.8±3.17	33.8±1.33STD	0.175
WBCx10^9 cell/L	7.1±1.95	6.1±2.36STD	**0.09**
PLTx10^9 cell/L	146±12	333.9±1STD	0.160
Neutrophil %	60.3±93	44.3±11.83STD	**0.04**
Lymphocyte%	33.8±8.85	45.10±9.35STD	**0.011**

P value <0.05 indicate level of significance (Independent t test)

DISCUSSION

This study aimed to establish hematological parameter values specific to pregnant women in Aldalea, Yemen, where clinicians currently rely on reference values derived from Western populations. Such reliance may lead to diagnostic inaccuracies given the region's distinct genetic, environmental, and nutritional backgrounds.

The majority of the 128 participants were young (predominantly between 15–30 years) and had a primary education, reflecting the local population's socio-demographic characteristics. These factors may influence hematological profiles and underscore the importance of developing local reference intervals.

This study, conducted in Aldalea, Yemen, aimed to establish locally relevant hematological reference values for pregnant women by comparing them with non-pregnant controls using independent t-tests. Focusing solely on the statistically significant differences in Table 2, three key findings emerged: a significant reduction in PCV, an elevated neutrophil percentage, and a reduced lymphocyte percentage in pregnant women.

Pregnant women exhibited a significantly lower PCV compared to non-pregnant women. This finding is similar to another study conducted by [16]. This reduction is attributable to the well-documented hemodilution effect during pregnancy, where plasma volume increases disproportionately relative to red blood cell mass. Such a dilutional effect is a physiological adaptation designed to meet the increased circulatory demands of both the mother and the developing fetus, as supported by previous studies.[16]

The study also revealed significant shifts in leukocyte distributions. Pregnant women had a markedly higher neutrophil percentage coupled with a significantly lower lymphocyte percentage which was in line with one study conducted by [17]. These findings reflect the immunomodulatory changes inherent to pregnancy. The increased neutrophil count suggests an enhanced innate immune response, which is thought to facilitate fetal tolerance by shifting the maternal immune system toward a Th2-dominant profile. Conversely, the decrease in lymphocyte percentage may indicate a redistribution of lymphocyte subsets or changes in cellular trafficking, aligning with observations from other studies.[18,19]

The significant hematological alterations identified in this study are consistent with reports in the existing literature that attribute such changes to the physiological adaptations of pregnancy [20,21]. However, discrepancies with other studies may result from differences in population characteristics, nutritional status, and laboratory methodologies. In Aldalea, where clinicians currently rely on reference values derived from Western populations, these significant findings underscore the critical need to develop region-specific reference intervals. Adopting locally validated standards will likely enhance diagnostic accuracy and improve clinical decision-making for pregnant women in this region.

CONCLUSION

In conclusion, the significant reduction in PCV and the notable alterations in white blood cell differentials—specifically, the increased neutrophil and decreased lymphocyte percentages—highlight the hematological adaptations during pregnancy. These findings not only reinforce the physiological processes of hemodilution and immune modulation but also emphasize the importance of establishing local reference ranges to ensure precise and effective clinical management in Aldalea.

CONFLICT OF INTEREST

The authors declare that no conflict of interest.

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