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Red Blood Cell Parameters Among Malnourished Children Under Five Years Attending Al-Sabeen Hospital, Sana'a, Yemen

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Abstract

Malnutrition remains a major health issue in Yemen, particularly among children under five. It affects the hematopoietic system, leading to abnormal red blood cell parameters and anemia. This study aimed to assess RBC parameters and associated factors among malnourished children.

Methods: A cross-sectional study was conducted on 264 malnourished children diagnosed with moderate acute malnutrition (MAM) or severe acute malnutrition (SAM). We analyzed blood samples for complete blood counts. Data were collected for statistical analysis.

Results: Among the children, 51.1% had MAM, and 48.9% had SAM. Anemia was found in 59.5% of the participants. Children with SAM had significantly lower hemoglobin levels, RBC count, packed cell volume, mean corpuscular volume, mean corpuscular hemoglobin, and higher red cell distribution width (RDW-CV) (p=0.001). Abnormal RBC parameters are associated with socioeconomic and maternal factors.

Conclusion: Hematological abnormalities and anemia were prevalent among malnourished children in Sana'a, underscoring the need for targeted interventions that address family income, maternal education, and maternal health.

Article Info

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Malnutrition, anemia, red blood cell parameters, children under five, Yemen.

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1. INTRODUCTION

The World Health Organization (WHO) and the National Center for Health Statistics (NCHS) consider malnutrition a medical condition that arises from insufficient, excessive, or an incorrect ratio of key nutrients [1, 2]. Undernutrition is often linked to irregular height and weight, with certain malnourished children exhibiting a low height compared to their age, while others have an unhealthy weight compared to their height, and others are underweight for their age [3].

Malnutrition can be classified as acute or chronic. With acute malnutrition, nutritional status deteriorates rapidly over a short period [4, 5]. There are two forms of acute malnutrition: moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). SAM is the most severe and visible form of malnutrition and is associated with high mortality, especially in children under five years of age [6].

Malnutrition remains a major global health problem, affecting over 52 million children worldwide, with approximately 16 million suffering from severe acute malnutrition [7]. Undernutrition is estimated to contribute to approximately 45% of deaths in children under five years of age, accounting for approximately 3 million preventable deaths annually [8]. The WHO estimates that the global prevalence of stunting, wasting, and overweight among children under five years is 149 million, 45 million, and 37 million, respectively. Additionally, approximately 40% of children aged 6-59 months, are affected by anemia [9].

In Yemen, malnutrition rates are among the highest

worldwide. The 2013 Yemen National Health and Demographic Survey (YNHDS) reported stunting in 47%, wasting in 16%, and underweight in 39% of children under five [3, 10]. Chronic malnutrition affects over half (53.1%) of children under five, and acute malnutrition affects 13% [7]. Ongoing conflicts, food insecurity, poverty, and poor access to healthcare have exacerbated the crisis [11, 12].

One of the systems affected by malnutrition is the hematopoietic system, which leads to the decreased production of all blood cell lines [13]. Nutritional deficiencies may directly alter red blood cell (RBC) parameters such as hemoglobin (HGB), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW) [14].

Anemia is one of the most common hematological abnormalities in malnourished children. Both low hemoglobin levels and increased RDW are sensitive indicators of iron-deficiency anemia [15]. Common causes of these abnormalities include deficiencies of essential micronutrients, such as iron, vitamin A, and iodine, as well as macronutrients, particularly protein-energy malnutrition [2].

In addition to anemia, malnutrition adversely affects hematopoiesis, causing leukocyte abnormalities and thrombocytopenia, which weaken immunity and increase susceptibility to infections [16]. In Yemen, no published data specifically addressed the association between malnutrition and RBC parameter abnormalities among children under five years of age. Therefore, this study aimed to determine the prevalence of abnormal red blood cell parameters among malnourished children under five years of age attending Al-Sabeen Hospital, Sana'a, Yemen, and identify the factors associated with these abnormalities in this group.

2. METHODS

This cross-sectional study was conducted at the Al-Sabeen Hospital in Sana'a, Yemen, from November 2024 to April 2025. Participants were selected based on specific criteria to diagnose malnutrition. SAM is defined by the presence of bilateral pitting edema, severe wasting (weight-for-height z-score [WHZ] < -3 SD), or a mid-upper arm circumference (MUAC) less than 115 mm, while MAM is defined as moderate wasting (WHZ between -2 SD and -3 SD) or MUAC between 115 mm and less than 125 mm [4, 5].

The study included all children under five of age diagnosed with malnutrition who met the inclusion criteria and had not yet received treatment at Al-Sabeen Hospital. The study excluded malnourished children who had received iron or vitamin supplements within the last four weeks, those who had received a blood transfusion in the last three months, and those diagnosed with chronic diseases such as renal failure, cancer, or liver disease. Children with tuberculosis or human immunodeficiency virus (HIV) were also excluded.

Demographic and maternal data were collected using structured questionnaires through face-to-face interviews with children's parents or guardians. Venous blood samples (3 ml containing EDTA-K3 were obtained from each participant. The samples were gently mixed and sent for laboratory analysis within 30 minutes. We performed a complete blood count using an automated blood cell counter, specifically a Sysmex XN-550 counter.

2.1. Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 26. Quantitative variables with a normal distribution are presented as mean values with their corresponding standard deviations (SD), while qualitative variables are expressed as frequencies and percentages. The independent samples t-test was used to compare the means of the continuous variables between the two groups. The chi-squared (χ^2) test was used to assess the association between the variables. Statistical significance was set at $p \leq 0.05$.

Prior to participation, all parents or guardians of the children received detailed information regarding the study methods and provided written informed consent. The study was approved by the Committee on Postgraduate Studies and Scientific Research of the Faculty of Medicine and Health Sciences, and ethical approval was obtained from the Al-Sabeen Hospital in Sana'a.

3. RESULTS

A total of 264 malnourished children were enrolled in the study. Males accounted for 50.9% (n=134), while females represented 49.1% (n=130). The highest proportion of children were aged between 10 and 20 months (34.0%). Most participants were from urban areas (70.8%). Regarding the educational level of mothers, 47.3% had a primary education, and 35.6% were illiterate. Most mothers were in good health, while 29.2% reported poor health (Table1).

The results showed that Among the malnourished children, 51.1% (n=135) were diagnosed with MAM, whereas 48.9% (n=129) were diagnosed with SAM, indicating a nearly equal distribution of malnutrition severity among the study population (Figure 1).

Table[1]: Demographic Characteristics of Study Participants

Demographic Characteristics	Category	Frequency	Percentage
Gender	Male	134	50.9
	Female	130	49.1
Age/months	<10 months	87	33.0
	10–20 months	90	34.0
	>20 months	87	33.0
Residence	Rural	77	29.2
	Urban	187	70.8
Education of mother	Illiterate	94	35.6
	Primary	125	47.3
	Secondary	32	12.1
	University	13	4.9
Mother health	Good	187	70.9
	Poor	77	29.2

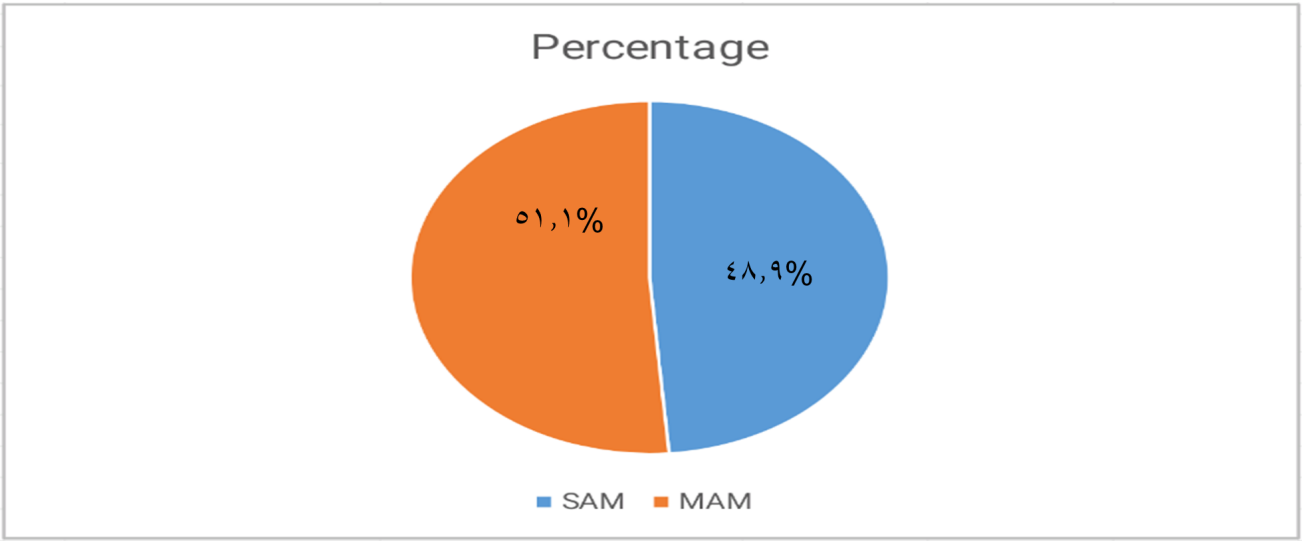

Figure 1. Prevalence of MAM and SAM among malnourished under-five children attending Al-Sabeen Hospital, Sana'a, Yemen.

The means of HGB, RBCs, PCV, MCV, and MCH were lower in children with SAM than in those with MAM. The mean RDW-CV was markedly higher in the SAM group than that in the MAM group (Table2).

Approximately 59.5% of the malnourished children had anemia. The percentages of abnormal RBCs, PCV, MCV, MCH, MCHC, and high RDW were 37.5%, 37.1%, 62.5%, 76.9%, 31.8%, and 68.6%, respectively (Figure 2).

Hemoglobin abnormalities were found in 39.5% and 60.5% of MAM and SAM cases, respectively. RBC count abnormalities occurred in 27.4% of the MAM cases and 62.6% of the SAM cases. PCV abnormalities were present in 30.6% of MAM cases and 69.4% of SAM cases. RDW-CV abnormalities were more common in SAM (58.6%) than in MAM (41.4%) (Table3).

Analysis of the RBC parameters revealed several significant associations with sociodemographic and maternal factors. Sex was not significantly associated with any of the parameters ($p < 0.05$), indicating that male and female children had comparable hematological profiles. A child's residence was significantly associated with abnormal PCV (p = 0.018) and RDW (p = 0.007), suggesting that children living in rural areas were more likely to have these abnormalities than urban children. The children's age group also influenced the hematological parameters. Children under 10 months of age showed a high prevalence of abnormal RDW (p = 0.049).

The results clearly demonstrated a strong relationship between the mother's educational level and the prevalence of abnormal red blood cell (RBC) parameters among malnourished children. Children of illiterate mothers had the

Table[2]: Comparison of red blood cell parameters between MAM and SAM children

Parameter	MAM (Mean ± SD)	SAM (Mean ± SD)	*P* value
HBG (g/dl)	11.1 ± 1.3	9.6 ± 1.7	0.001*
RBCs (10^{12}/l)	4.4 ± 0.6	4.0 ± 0.8	0.001*
PCV (%)	33.3 ± 3.8	29.7 ± 4.8	0.001*
MCV (fl)	77.1 ± 7.6	75.2 ± 10.5	0.097
MCH (pg)	25.4 ± 2.7	24.5 ± 3.8	0.019*
MCHC (g/dl)	32.0 ± 2.7	32.3 ± 1.7	0.373
RDW-CV (%)	15.1 ± 2.3	18.1 ± 3.6	0.001*

Comparisons were performed using independent Samples t-test; data are presented as the mean ± SD. *$p < 0.05$ is statistically significant.

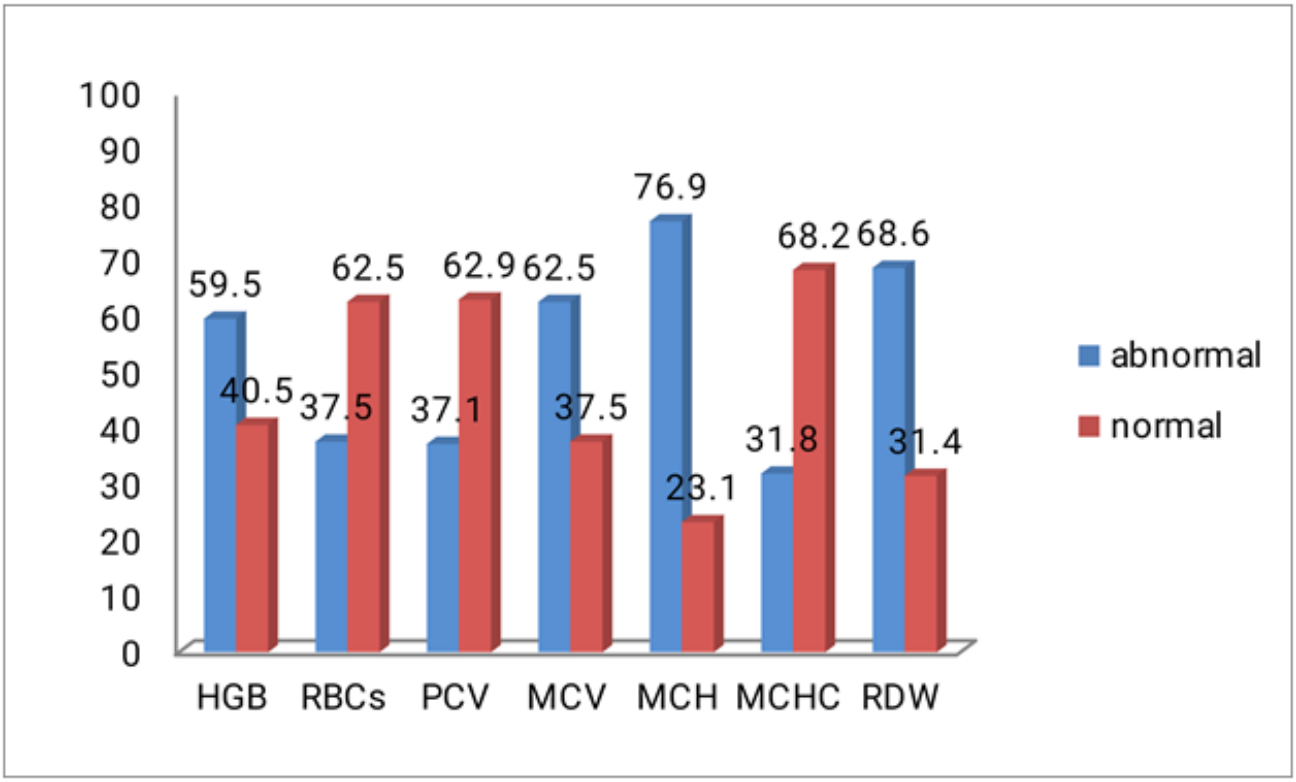

Figure 2. Prevalence of abnormal red blood cell parameters among malnourished under-five children, Sana'a, Yemen.

highest rates of abnormalities, with 76.9% showing low hemoglobin (p = 0.001), 69.2% with abnormal RBC count (p = 0.001), and 61.5% with abnormal packed cell volume (p = 0.001). Similarly, the red cell distribution width was abnormal in 76.9% of this group (p = 0.001). Children of mothers who had only a primary education also showed very high rates of abnormal hemoglobin (88.3%), abnormal RBC count (58.5%), abnormal PCV (72.3%), and abnormal RDW (86.2%). In contrast, the prevalence of abnormal RBC parameters decreased significantly with higher maternal education levels. Furthermore, a significant correlation was observed between family incomes. Children from low-income families showed a significantly higher prevalence of abnormal HBG (p = 0.001), RBCs (p = 0.001), PCV (p = 0.001), MCHC (p = 0.002), and RDW (p = 0.001) than children from middle-income households. Maternal health status also plays a key role. Children of mothers who reported poor health had a significantly higher prevalence of abnormal HBG (p = 0.001), RBCs (p = 0.001), PCV (p = 0.001), MCHC (p = 0.013), and RDW (p = 0.001) (Table4).

4. DISCUSSION

Malnutrition is a major public health challenge in developing countries, especially in conflict-affected areas such as Yemen, where children under five years of age are among the most vulnerable groups. In our study, the prevalence was 51.1% for MAM and 48.9% for SAM, indicating a nearly equal distribution of

Table[3]: Frequencies of abnormal red blood cell parameters among children with MAM and SAM

Parameter		MAM (n = 135)		SAM (n = 129)		*P* value
		n	(%)	n	(%)	
HBG (g/dl)	Normal	73	68.2	34	31.8	0.001*
	Abnormal	62	39.5	95	60.5	
RBC ($\times 10^{12}$/L)	Normal	98	59.4	67	40.6	0.001*
	Abnormal	37	37.4	62	62.6	
PCV (%)	Normal	105	63.3	61	36.7	0.001*
	Abnormal	30	30.6	68	69.4	
MCV (fl)	Normal	57	57.6	42	42.4	0.105
	Abnormal	78	47.3	87	52.7	
MCH (pg)	Normal	33	54.1	28	45.9	0.598
	Abnormal	102	50.2	101	49.8	
MCHC (g/dl)	Normal	98	54.4	82	45.6	0.115
	Abnormal	37	44.0	47	56.0	
RDW-CV (%)	Normal	60	72.3	23	27.7	0.001*
	Abnormal	75	41.4	106	58.6	

*"Data are number (%); comparisons by Chi-square test; $p < 0.05$ significant; n = number of individuals."

Table[4]: Association of abnormal red blood cell parameters with sociodemographic characteristics among malnourished children under five attending Al-Sabeen Hospital, Sana'a, Yemen.

Variable	HBG		RBCs		PCV		MCV		MCH		MCHC		RDW	
	N (%)	*P*	N (%)	*P*	N (%)	*P*	N (%)	*P*	N (%)	*P*	N (%)	*P*	N (%)	*P*
Sex														
Male (n = 134)	80 (60.6)	0.707	45 (34.1)	0.253	50 (37.9)	0.799	87 (65.9)	0.253	104 (78.8)	0.465	43 (32.6)	0.792	95 (72.0)	0.233
Female (n = 130)	77 (58.3)		54 (40.9)		48 (36.4)		78 (59.1)		99 (75.0)		41 (31.1)		86 (65.2)	
Residence														
Rural (n = 77)	49 (63.6)	0.376	33 (42.9)	0.249	37 (48.1)	0.018	49 (63.6)	0.807	60 (77.9)	0.799	27 (35.1)	0.467	62 (80.5)	0.007*
Urban (n = 187)	108 (57.8)		66 (35.3)		61 (32.6)		116 (62.0)		143 (76.5)		57 (30.5)		119 (63.6)	
Age														
< 10 (n = 87)	57 (65.5)	0.318	36 (41.1)	0.194	37 (42.5)	0.422	54 (62.1)	0.365	72 (82.8)	0.084	26 (29.9)	0.098	65 (74.7)	0.049*
10–20 (n = 90)	49 (54.4)		27 (30.0)		30 (33.3)		61 (67.8)		71 (78.9)		36 (40.0)		65 (72.2)	
> 20 (n = 87)	51 (58.6)		36 (41.4)		31 (35.6)		50 (57.5)		60 (69.0)		22 (25.3)		51 (58.6)	
Education of Mother														
Illiterate (n = 13)	10 (76.9)	0.001*	9 (69.2)	0.001*	8 (61.5)	0.001*	10 (76.9)	0.470	10 (76.9)	0.503	6 (46.2)	0.056	10 (76.9)	0.001*
Primary (n = 94)	83 (88.3)		55 (58.5)		68 (72.3)		62 (66.0)		76 (80.9)		34 (36.2)		81 (86.2)	
Secondary (n = 125)	57 (45.6)		30 (24.0)		19 (15.2)		73 (58.4)		91 (72.8)		40 (32.0)		76 (60.8)	
University (n = 32)	7 (21.9)		5 (32.0)		3 (9.4)		20 (62.5)		26 (81.2)		4 (12.5)		14 (43.8)	
Family income														
Low (n = 114)	95 (83.3)	0.001*	65 (57.0)	0.001*	78 (68.4)	0.001*	76 (66.7)	0.223	85 (74.6)	0.433	48 (42.1)	0.002*	93 (81.6)	0.001*
Middle (n = 150)	62 (41.3)		34 (22.7)		20 (13.3)		89 (59.3)		118 (78.7)		36 (24.0)		88 (58.7)	
Mother health														
Good (n = 187)	84 (44.9)	0.001*	47 (25.1)	0.001*	40 (21.4)	0.001*	115 (61.5)	0.600	144 (77.0)	0.947	51 (27.3)	0.013	115 (61.5)	0.001*
Bad (n = 77)	73 (94.8)		52 (67.5)		58 (75.3)		50 (64.9)		59 (76.6)		33 (42.9)		66 (85.7)	

*"Data are number (%); comparisons by Chi-square test; $p < 0.05$ significant; n = number of individuals."

malnutrition severity among children under five years of age attending Al-Sabeen Hospital. The current results are similar to those reported by Saleh et al. [14] in Aden, Yemen, where the prevalence was 51.5% for MAM and 48.5% for SAM. A similar study in Nigeria reported a SAM prevalence of (50%) [17]. However, lower SAM rates have been reported in other countries such as Zambia (27.0%) [18], Ethiopia (21.2%) [19], Sri Lanka (8.7%) [20], Sudan (6.5%) [21], Nepal (5.8%) [22], and Mali (4.4%) [23]. Variations in malnutrition prevalence between countries may be attributed to socioeconomic differences, maternal education, feeding practices, seasonal food availability, and methodological variations in the study design [24].

In the current study, the prevalence of anemia was 59.5%, which is lower than the 81.4% reported by Saleh et al. [14], and the higher rates reported in India (95%) [25], Brazil (88%) [26], Uganda (71.9%) [27], Cameroon (70.5%) [28], Senegal (69.3%) [29], and Rwanda (69%) [30]. However, the current findings are closer to those of Bangladesh (56.5%) [31] and Sri Lanka (55.5%) [20]. In contrast, lower rates have been reported in Ethiopia (39.7%) [32], Nigeria (9.7%) [33], and the Congo (9.3%) [34]. Variations in the prevalence of anemia across studies may be explained by differences in socioeconomic status, maternal health, dietary diversity, infections, and regional disparities in micronutrient availability [13, 35].

This study found several significant associations between abnormal RBC parameters and key socio-demographic variables. There was no significant association between a child's sex and hematological parameters. In contrast, Saleh et al. [14] found a significant association between a child's sex and RBC abnormalities. However, this study showed that a child's residence significantly influenced abnormal PCV ($p = 0.018$) and RDW ($p = 0.007$), with rural children being more affected. The current findings are in agreement with those of Saleh et al. [14] and Takele et al. [36], who also linked a higher prevalence of anemia in rural areas to factors such as low maternal education and a lack of medical services [37].

Maternal educational level was one of the strongest predictors of abnormal hematological values in this study. The current findings are consistent with those of Getawa et al. [13] and highlight that maternal education is crucial for protecting children from anemia [38].

Furthermore, the study found a significant association between low family income and a higher prevalence of abnormal HGB, RBCs, PCV, MCHC, and RDW. Finally, poor maternal health status was significantly associated with a higher prevalence of abnormalities in the same parameters. The results underscore the complex interplay between socioeconomic factors and maternal well-being in child-health outcomes. These findings emphasize that malnutrition and its associated hematological abnormalities are multifaceted public health issues with long-lasting consequences [35].

5. CONCLUSION

This study highlights the strong association between malnutrition and the hematological profile of children under five years of age in Sana'a, Yemen. The study demonstrated a high prevalence of abnormal RBC parameters, particularly anemia. Children diagnosed with SAM exhibit more severe abnormalities in HGB, RBC count, PCV, and RDW than those diagnosed with MAM. Maternal education, family income, and maternal health status were the most significant predictors of abnormal RBC parameters. Interventions addressing family income, maternal education, and maternal health are essential to improve hematological status and overall child health in malnourished populations.

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