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White Blood Cells Parameters among Malnourished Children Under-Five Years, Aden-Yemen

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ABSTRACT

Background: Malnutrition is still a critical public health problem among children under five, with implications for immune function and hematological parameters.

Objective: This study aimed to identify abnormal WBC parameters among malnourished children under five in Aden, Yemen, and to determine the socio-demographic characteristics and other risk factors associated with abnormal WBC parameters among those children.

Methods: A cross-sectional study was conducted on 101 malnourished children under 5 years. The blood specimens were collected from all children, and an automated hematological analyzer was used to measure the WBC parameters. The SPSS software was used to analyze the data.

Results: Among 101 malnourished children, the majority were 52% females, and according to WBC parameters, leukocytosis, neutropenia, and lymphocytosis were observed at rates of 34.7%, 69.3%, and 82.2%, respectively. Elevated WBC counts were significantly associated with age group ($p = 0.005$), and high lymphocyte counts were linked to residence ($p = 0.017$), while no significant associations were found between WBC abnormalities and acute malnutrition or between low WBCs and socio-demographic characteristics and other risk factors.

Conclusion: acute malnutrition remains a significant health challenge among children under five years of age, with notable sex disparities, as females were more affected. The leukocytosis, neutropenia, and lymphocytosis were noted among malnourished children. The associations were significant between leukocytosis and age groups and between lymphocytosis and residence of children. In contrast, lacking the significant differences between abnormal WBCs parameters and acute malnutrition, and between low WBCs parameters and socio-demographic characteristics and other risk factors.

Keywords: Yemen, hematological parameters, malnutrition, children under five years old.

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INTRODUCTION

Malnutrition is a health condition that results from consuming food with either insufficient or excessive amounts of sugars, vitamins, peptides and proteins, or minerals [1]. It manifests as either undernutrition or overnutrition, characterized by a lack or increase of essential nutrients required for proper bodily function and overall health [2, 3]. There are several types of malnutrition, including undernutrition, micronutrient-related malnutrition, overnutrition, and macronutrient malnutrition [4]. Undernutrition includes wasting, which is characterized by a low weight-for-height Z-score (WHZ) that acts as an indicator for severe and recent loss of weight; stunting, referred to as a low height-for-age Z-score (HAZ) due to recurrent or chronic undernutrition; and underweight, indicated by a low weight-for-age Z-score (WAZ), which can be a combination of stunting and wasting. Additionally, micronutrient deficiencies involve a lack of essential elements, minerals, and vitamins, including iron, iodine, and vitamin A [5].

Acute malnutrition is a medical condition characterized by a rapid and severe loss of body weight resulting from insufficient nutrient intake or repeated infections [4]. It is commonly classified into two types: moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). SAM is primarily identified by the presence of edema, a WHZ below -3, or a mid-upper arm circumference (MUAC) less than 115 mm. In contrast, MAM is referred to as a WHZ ranging between (-2 and -3) or a MUAC ranging from 115 mm to less than 125 mm [2, 6]. A particular form of malnutrition is protein-energy malnutrition (PEM), which occurs *as a result of* weakening of the immune response due to reducing the numbers and functions of immune cells and cytokines essential for fighting pathogens. Deficiencies in essential micronutrients such as vitamin A, zinc, and iron further impair mucosal barriers and immune responses, increasing children's susceptibility to illnesses like pneumonia, diarrhea, tuberculosis, and measles. SAM is often associated with higher mortality rates among children suffering from infections. [7, 8].

Malnutrition and infection are closely interlinked, creating a vicious cycle in which each condition affects the other, particularly in children. Malnutrition weakens immune defenses, increasing both susceptibility to and severity of infections. Conversely, infections worsen nutritional status through mechanisms such as impaired nutrient absorption and increased metabolic demands [9]. In 2024, it was estimated that approximately 150.2 million, or 23.2%, of children under the age of five were affected by stunting. Additionally, wasting threatened the lives of around 42.8 million, or 6.6%, of children under five, while being overweight affected approximately 35.5 million children, or 5.5%, worldwide [10]. In Yemen, acute malnutrition affects about one million children under 5 years old [5].

The white blood cell (WBC) parameters are essential diagnostic tools used to assess and differentiate various health conditions, including infections, inflammation, and hematological disorders [11]. WBC parameters, including total WBC count, differential counts (neutrophils, lymphocytes, monocytes, eosinophils, and basophils), and functional capacity, are significantly altered in malnourished states [12].

In Yemen, only one study was conducted to determine the abnormal red blood cell (RBC) parameters among malnourished children under five years [1]. There is a scarcity of published data on the association between malnutrition and WBC parameters in children under five years of age. This study aimed to identify abnormal WBC parameters among malnourished children under five in Aden Governorate, Yemen, and to determine the socio-demographic characteristics and other risk factors associated with abnormal WBC parameters among those children.

METHODS

Study Design

This hospital-based cross-sectional study was conducted on 101 malnourished children under five years of age who were admitted to the nutrition clinic of Al-Sadaqa Teaching Hospital, Aden, during the period from January to June 2024.

Sample Size Calculation

The calculated sample size for the estimate was based on the prevalence of malnutrition estimated in the Aden governorate [13], which was p = 5.8%; then q = 94.2%, and the degree of precision = 5%.

Using the following formula

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$$n = \frac{Z^2 \times p\%q}{d^2}$$

N = required sample size, Z = (1.96) for a 95% confidence grade, d = 5% margin of error, p = (5.8%) the prevalence of acute malnutrition, and q = (1-p%) expected prevalence of undernourished children.

$N = \frac{(1.96^2)\times 5.8\%(1-5.8\%)}{(5\%^2)}$ = 83.95

Thus, the sample size was 83.95 children. The total sample size was 101 malnourished children who accepted to participate in this study.

Data Collection

The data were collected using a previously designed questionnaire, which was modified for this study. The questionnaire included variables such as age, sex, residence, and anthropometric measurements used to diagnose the type of acute malnutrition (height, weight, MUAC, and Z-score). It also recorded the presence of microbial infections in the children, as well as parental education level, occupation, family size, and the mother's breastfeeding status [14, 15].

Inclusion and Exclusion Criteria

Malnourished children under five years of age were enrolled, while non-malnourished children, children older than five years, those who had received a blood transfusion in the last three months, and children diagnosed with chronic diseases such as renal failure, cancer, liver disease, tuberculosis (TB), or acquired immunodeficiency syndrome (AIDS) were excluded.

Sample Preparation

Five ml of venous blood was collected and withdrawn into tubes containing ethylenediaminetetraacetic acid (EDTA), and WBC parameters were measured using an automated hematological analyzer from Sysmex Company.

Ethical Clearance and Informed Consent

The ethical approval for this study was obtained from the Ethics Committee of the Faculty of Medicine and Health Sciences, University of Science and Technology, Aden (MEC No. MEC/AD0120). Informed consent was also taken from parents of children.

Statistical Analysis

The data were analyzed using the statistical package for social sciences (SPSS) software (version 21). The qualitative data was expressed as percentages, and the probability between two or more variables was calculated by using the chi-square (x^2) test where the significant P-value was (≤ 0.05).

RESULTS

Totally, all 101 children under five years of age who enrolled in this study were malnourished, with females comprising the highest percentage at 52% (Table 1).

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Table 1: Socio-demographic characteristics of malnourished children under 5 years, Aden- Yemen

Variable	No	%	Variable	No	%
Sex			Education of Mother		
Male	46	45.5	Illiterate	50	49.5
Female	55	54.5	Primary	35	34.5
Age/months			Secondary	13	12.9
<10 Months	34	33.7	University	3	3.0
10-20 Months	31	30.7	Occupation of Father		
>20Months	36	35.6	Daily Laborer	47	46.5
Residence			Private	30	29.5
Urban	87	86.1	Government Employee	18	17.8
Rural	14	13.9	Without work	6	5.9
Education of Father			Occupation of Mother		
Illiterate	34	33.7	Housewife	97	96.
Primary	33	32.7	Daily Laborer	2	2.0
Secondary	29	28.7	Private	2	2.0
University	5	5.0			

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The largest proportion of malnourished children was 51.5% for MAM, while SAM was 48.5% (Figure 1).

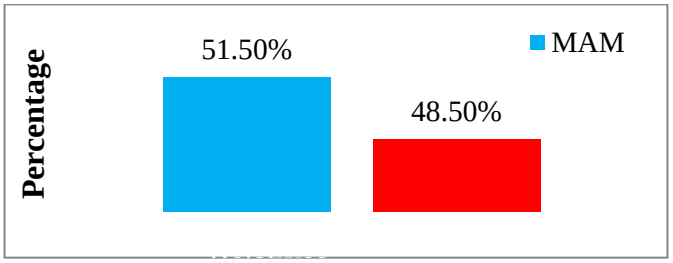

Figure 1: The prevalence of acute malnutrition (MAM and SAM) among children under 5 years, Aden- Yemen

The majority of children 63(62.4%) exhibited normal WBCs counts, while 35(34.7% had leukocytosis and 3 (3 % had leukopenia (Figure 2).

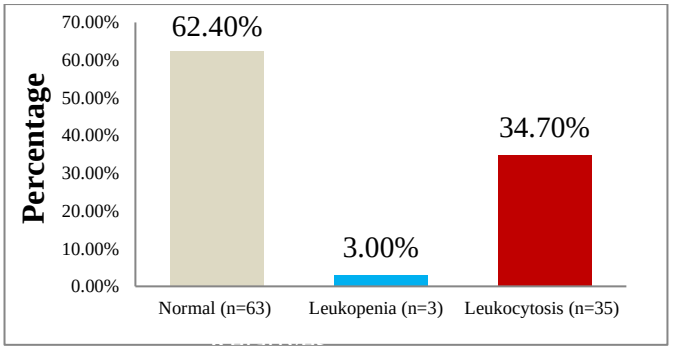

Figure 2: The prevalence of abnormal WBCs among malnourished children under five years, Aden, Yemen

The normal neutrophil count was in 29 (28.7%) of children, while neutropenia was the most common abnormality among children, 70 (69.3%), and 2 (2%) of children had neutrophilia (Figure 3).

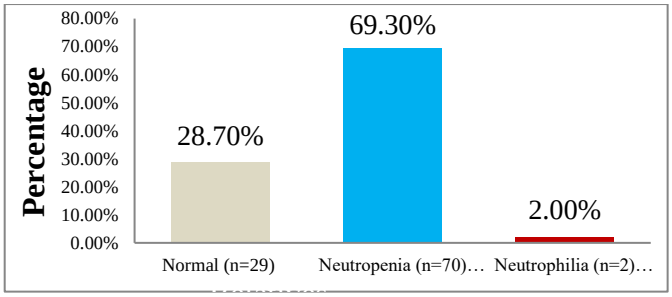

Figure 3: The prevalence of abnormal neutrophils among malnourished children under-five years, Aden-Yemen

The children with normal lymphocyte counts were 10 (9.9%), and lymphocytosis had the highest rates in 83 (82.2%) of the children, while 8 (7.9%) of them had lymphopenia (Figure 4).

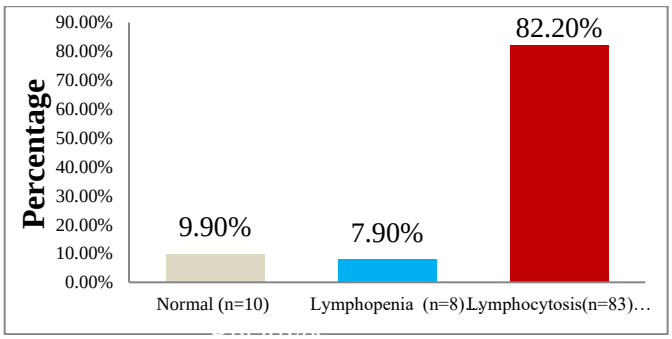

Figure 4: The prevalence of abnormal lymphocytes among malnourished children under-five years, Aden-Yemen

The high WBC count was 51.4% among SAM children and 48.6% among MAM children. The low WBC count and neutrophils and high and low lymphocytes among children with MAM were 66.7%, 51.4%, 53.0%, and 25%, respectively. In contrast, SAM was characterized by leukocytosis, neutrophilia, lymphocytosis, and lymphopenia at rates of 51.4%, 50.0%, 70.0%, and 75%, respectively. The neutropenia was equal at 50% among both children with MAM and SAM children. Despite these results, there was no statistically significant association observed between abnormal white blood cell parameters and acute malnutrition (Table 2).

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Table 2: Association of abnormal WBCs parameters with acute malnutrition among children under 5 years, Aden-Yemen

WBCs parameters	MAM		SAM		P
	No	%	No	%	
↑WBCs (cells/µL) (n=35)	17	48.6	18	51.4	0.414
↓WBCs (cells/µL) (n=3)	2	66.7	1	33.3	0.522
↑Neutrophils (n=2)	1	50.0	1	50.0	0.737
↓Neutrophils (n=70)	36	51.4	34	48.6	0.579
↑LYM (cells/µL) (n=83)	44	53.0	39	47.0	0.345
↓LYM (cells/µL) (n=8)	2	25.0	6	75.0	0.116

WBCs: White blood cells; LYM: Lymphocyte; SAM: Severe acute malnutrition; MAM: Moderate acute malnutrition; P: Probability value ≤ 0.05 (significant).

According to the association of high WBC parameters with socio-demographic characteristics and other risk factors among malnourished children, the significant highest leukocytosis was among children in the age group <10 months (47.1%, p = 0.005). The significant association was lacking between high WBC parameters (Table 3).

and other socio-demographic characteristics and other risk factors among malnourished children, and the neutrophilia also had no significant association with either socio-demographic or other risk factors. Meanwhile, the only urban residence had a significant association with high lymphocyte (86.2%, p = 0.017).

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Table 3: Association of high WBCs parameters with socio-demographic characteristics and other risk factors among malnourished children under 5 years, Aden, Yemen

Variable	High WBCs			High Neutro			High Lymph		
	No	%	P	No	%	P	No	%	P
Sex									
Male (n=46)	20	43.5	0.068	0	0.0	0.294	37	80.4	0.436
Female (n=55)	15	27.3		2	3.6		46	83.6	
Age group months									
<10 (n=34)	16	47.1	0.005	0	0.0	0.591	29	85.3	0.376
10-20 (n=31)	14	45.2		1	3.2		23	74.2	
>20(n=36)	5	13.9		1	2.8		31	86.1	
Residence									
Urban (n=87)	29	33.3	0.341	2	2.3	0.741	75	86.2	0.017
Rural (n=14)	6	42.9		0	0.0		8	82.2	
Education of the father									
Illiterate (n=34)	14	41.2	0.270	0	0.0	0.167	26	76.5	0.539
Primary (n=33)	7	21.2		0	0.0		27	81.8	
Secondary (n=29)	12	41.4		2	6.9		25	86.2	
University (n=5)	2	40.0		0	0.0		5	100.0	
Education of the mother									
Illiterate (n=50)	16	32.0	0.412	0	0.0	0.335	40	80.0	0.665
Primary (n=35)	15	42.9		1	2.9		29	82.9	
Secondary (n=13)	4	30.8		1	7.7		12	92.3	
University (n=3)	0	0.0		0	0.0		2	66.7	
Occupation of father									
Daily Laborer (n=47)	16	34.0	0.786	0	0.0	0.468	37	78.7	0.631
Private (n=30)	9	30.0		1	3.3		25	83.3	
Government Employee (n=18)	7	38.9		1	5.6		15	83.3	
Without work (n=6)	3	50.0		0	0.0		6	100.0	
Occupation of the mother									
Housewife (n=97)	35	36.1	0.175	2	2.1	0.959	80	82.5	0.396
Daily Laborer (n=2)	0	0.0		0	0.0		2	100.0	
Private (n=2)	0	0.0		0	0.0		1	50.0	
Family size									
≤ 4 (n=45)	16	35.6	0.515	1	2.2	0.695	37	82.2	0.601
>4 (n=56)	19	33.9		1	1.8		46	82.1	
Breastfeeding (0-23 Months)									
Yes (n=55)	19	34.5	0.573	0	0.0	0.205	47	85.5	0.248
No (n=46)	16	34.8		2	4.3		36	78.3	
Infection									
Bacterial infection (n=15)	8	53.3	0. 90	1	6.7	0.276	11	73.3	0.261
Parasitic infection (n=8)	2	25.0	0.431	0	0.0	----	7	87.5	0.565

P: Probability value ≤ 0.05 (significant) WBCs: White blood cells; LYM: Lymphocyte; Neutro: Neutrophils

The significant association was lacking between low WBCs parameters and socio-demographic characteristics and other risk factors among malnourished children (Table 4).

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Table 4: Association of low WBCs parameters with socio-demographic characteristics and other risk factors among malnourished children under 5 years, Aden- Yemen

Variable	Low WBCs			Low Neutro			Low Lymph		
	No	%	P	No	%	P	No	%	P
Sex									
Male (n=46)	2	4.3	0.433	33	71.7	0.395	3	6.5	0.462
Female (n=55)	1	1.8		37	67.3		5	9.1	
Age group months									
<10 (n=34)	1	2.9	0.994	26	76.5	0.508	1	2.9	0.330
10-20 (n=31)	1	3.2		21	67.7		4	12.9	
>20(n=36)	1	2.8		23	63.9		3	8.3	
Residence									
Urban (n=87)	3	3.4	0.636	62	71.3	0.223	5	5.7	0.079
Rural (n=14)	0	0.0		8	57.1		3	21.4	
Education of the father									
Illiterate (n=34)	1	2.9	0.545	23	67.6	0.815	4	11.8	0.725
Primary (n=33)	2	6.1		22	66.7		2	6.1	
Secondary (n=29)	c	0.0		22	75.9		2	6.9	
University (n=5)	0	0.0		3	60.0		0	0.0	
Education of the mother									
Illiterate (n=50)	2	4.0	0.879	33	66.0	0.416	5	10.0	0.852
Primary (n=35)	1	2.9		26	74.3		2	5.7	
Secondary (n=13)	0	0.0		10	76.9		1	7.7	
University (n=3)	0	0.0		1	33.3		0	0.0	
Occupation of father									
Daily Laborer (n=47)	1	2.1	0.518	32	68.1	0.353	5	10.0	0.550
Private (n=30)	2	6.7		19	63.3		1	3.3	
Government Employee (n=18)	0	0.0		13	72.2		2	11.1	
Without work (n=6)	0	0.0		6	100.0		0	0.0	
Occupation of the mother									
Housewife (n=97)	3	3.1	0.938	68	70.1	0.694	8	8.2	0.836
Daily Laborer (n=2)	0	0.0		1	50.0		0	0.0	
Private (n=2)	0	0.0		1	50.0		0	0.0	
Family size									
≤ 4 (n=45)	3	6.7	0.85	31	68.9	0.553	4	8.9	0.514
>4 (n=56)	0	0.0		39	69.6		4	7.1	
Breastfeeding (0-23 Months)									
Yes (n=55)	3	5.5	0.157	41	74.5	0.151	4	7.3	0.538
No (n=46)	0	0.0		29	63.0		4	8.7	
Infection									
Bacterial infection (n=15)	0	0.0	-----	10	66.7	0.514	2	13.3	0.339
Parasitic infection (n=8)	0	0.0	-----	4	50.0	0.199	0	0.0	-----

P: Probability value ≤ 0.05 (significant) WBCs: White blood cells; LYM: Lymphocyte; Neutro: Neutrophils.

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DISCUSSION

Due to the increased vulnerability of this age group, malnutrition among displaced children continues to be a serious public health concern [16]. Acute malnutrition is a primary cause of mortality and morbidity among children under five, leading to long-term impairments in health and growth [17]. In the current study, most of the children affected by malnutrition were females. This finding aligns with studies conducted in Nigeria, Ethiopia, Vietnam, and Yemen [13, 14, 18-20].

This disparity is attributed to a combination of social, cultural, and economic factors that contribute to gender differences in nutrition. Additional contributing factors include maternal undernutrition, poor low status, limited education for girls and mothers, and greater exposure to crises such as conflict and food shortages [21].

The present study recorded that 34.7% of children exhibit leukocytosis. Similar findings were found in several previous studies [14, 22-26]. Increased WBC count may be related to microbial infections, especially intestinal or respiratory tract infections, including pneumonia, diarrhea, or sepsis, rather than being solely a consequence of malnutrition [22,27,28].

Meanwhile, the leukopenia was observed in only 3.0% of malnourished children. Different studies revealed similar findings [15, 29-31]. Malnutrition affects the bone marrow, where blood cells are produced, potentially causing a deficiency in the number of white blood cells or impairing their function, thereby increasing the risk of recurrent infections [9, 32]. Malnutrition, especially severe forms such as protein-energy malnutrition, significantly impairs myelopoiesis—the formation of granulocytic and monocytic progenitors—in the bone marrow and spleen, causing reduced neutrophil production under steady-state conditions and diminished emergency myelopoiesis during infection. The resulting impaired granulopoiesis contributes to an increased susceptibility to bacterial infections in malnourished individuals [33].

The present data showed that abnormal neutrophils were 69.3% neutropenia vs 2% neutrophilia. A study was done among children in Congo that showed the highest percentage of neutrophils [33]. Different studies reported that neutrophilia was higher than neutropenia among children [22, 23, 34, 35, 36, 38]. Increased neutrophil levels among malnourished children may be due to a response to acute and chronic infections and other inflammatory conditions [14].

Regarding abnormal lymphocytes in our data, lymphocytosis was in 82.2% of the children, while lymphopenia was in 7.9%. This result was disagreed with by two studies conducted in Ecuador and Zambia [27, 38]. Severe malnutrition is typically associated with lymphopenia, resulting from thymic atrophy and decreased lymphocyte production [22, 25]. These variations may be attributed to several factors, particularly the presence of viral infections such as Epstein-Barr virus and cytomegalovirus, as well as chronic infections like tuberculosis among the studied children. These infections stimulate the immune system, leading to reactive lymphocytosis as part of the prolonged immune response [37, 38]. The immune system may compensate by increasing lymphocyte numbers to counterbalance other immune deficits. This adaptive response helps manage ongoing antigenic stimulation in an immunocompromised host [39].

In contrast to previous studies conducted in Nigeria, India, Egypt, and Pakistan, there were no statistically significant associations between abnormal WBC parameters and acute malnutrition among children in this study. Those studies have demonstrated a statistically significant relationship between white blood cell counts and lymphocyte levels in children suffering from acute malnutrition. [3, 23, 34, 40, 41]. The low sample size in our study may be the main cause of the lack of significant associations.

According to the socio-demographic characteristics of children, there was a significant association observed in the present study between leukocytosis and age groups ($p = 0.005$). A study from Northwest Ethiopia also recorded significant differences between leukocytosis and age groups [14]. In malnourished children, immune dysfunction and increased susceptibility to infections exacerbate age-related differences, with certain age groups exhibiting more pronounced leukocytosis depending on the prevalence and severity of infections [1].

The current data revealed a significant difference between lymphocytosis and residence ($p=0.017$). There was no study that either agreed or disagreed with our finding**.** Therefore, it was presented as the first finding among malnourished children. The geographical region serves as a proxy for a specific set of environmental

exposures. Higher lymphocyte counts are not caused by the location itself but by factors present in that location, namely, industrial chemicals that chronically stimulate or damage the immune systems of the resident population [42].

On the other hand, these results showed no statistically significant differences between low WBC parameters and socio-demographic characteristics and other risk factors among those malnourished children. However, several other studies revealed statistically significant differences between high WBC parameters with variable [14,23]. Malnutrition exerts a significant physiological impact on hematopoiesis and immune cell production, particularly by suppressing bone marrow activity and causing thymic atrophy. These biological effects often outweigh socio-demographic influences, leading to consistently low WBC, neutrophil, and lymphocyte counts regardless of external variables [9].

The present study had different limitations, including the small sample size, where some significant associations require a larger sample size; the cross-sectional study design that cannot establish the causes of abnormal hematology among children who had micronutrient deficiency; and the status of the bone marrow, spleen, and liver of those children, as well as deficiencies in micronutrients such as iron, transferrin, folate, and vitamin B12, which were not evaluated.

CONCLUSION

Acute malnutrition remains a significant global health challenge among children under five years old, with notable sex disparities, as females were more affected. Additionally, blood analysis demonstrated alterations in white blood cell counts, including leukocytosis, neutropenia, and lymphocytosis among malnourished children. A clear association was observed between leukocytosis and age groups and between lymphocytosis and residence. In contrast, there were not statistically significant differences between abnormal WBC parameters and acute malnutrition, or between low WBC parameters and socio-demographic characteristics and other risk factors.

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Author's Contributions

ANMG and RS, supervision, revision, and final editing of the manuscript. ANMG analysis of results, preparing of tables and figures. BQMA writing of introduction and methodology and discussion of results. RS and BQMA, collection of data and samples from all family members, and testing of samples. All authors arranged the referencing style, reading, and making the final revision of the manuscript.

Conflict of Interest

The author declare that there is no conflict of interest.

Funding

Not applicable.

Data Availability

Raw data are available upon a reasonable request.

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