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Abukar Hussein Mohamed

Maqaareey2011@gmail.com

Kampala International University

Abdirahman Ali Osobow

Kampala International University

Sleiman Ali Sleyoum

Kampala International University

Mohamud Abdalla Hassan

Kampala International University

Mohamed Ali Ahmed

Kampala International University

DJamila Magan Mohamed

Kampala International University

Melvis Bernis

Kampala International University

Rakia Aboubaker Mohamed

Kampala International University

Jouyriah Adam mohamed

Kampala International University

walyedin elfaky

Kampala International University

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Prevalence Patterns and Factors Associated with Anemia Among Children 1 to 18 Years with TB Attending Hoima Regional Referral Hospital TB Clinic

Authors: Abukar Hussein Mohamed[1], Abdirahman Ali Osobow[1] , Sleiman Ali Sleyoum[1] , Mohamud Abdalla Hassan[1], ,Mohamed Ali Ahmed[1] ,DJamila Magan Mohamed, Melvis Bernis[1],Rakia Abukar Mohamed[1], Jouyriah Adam mohamed[1] ,walyedin elfaky[1]

Department of Pediatrics, faculty of clinical Medicine and Dentistry, Kampala International University, Ishaka – Bushenyi – Uganda , Kampala-Uganda

Corresponding; Abukar Hussein Mohamed, Department of Pediatrics, faculty of clinical Medicine and Dentistry, Kampala International University, Ishaka – Bushenyi – Uganda

Email; Maqaareey2011@gmail.com

Abstract

Background

Anemia is a frequent comorbidity among children with tuberculosis (TB), affecting their growth, immunity, and overall clinical outcomes. However, there is limited data on the prevalence, severity, morphological types and factors associated in Uganda, particularly in regional referral hospitals. This study aimed to evaluate the prevalence, patterns and factors associated with anemia among children 1-18 years with TB attending Hoima Regional Referral Hospital (HRRH) TB clinic.

Methods

This was a hospital-based analytical cross-sectional study. Children aged 1 to 18 years with TB at HRRH were enrolled following informed consent and assent when appropriate. A blood sample was taken for a complete blood count, which was used to determine hemoglobin level, mean corpuscular hemoglobin and mean capsular volume. The presence of anemia as well as the severity was determined based haemoglobin concentration for age and gender in line with WHO guidelines. The morphological type was either normocytic normochromic, microcytic hypochromic or macrocytic based on the mean corpuscular hemoglobin and mean capsular volume. Logistic regression in SPSS was done to determine the significant factors.

Results

Of the 242 study participants, children under five years predominated (60.3%). There were slightly more males (52.1%). Anemia was seen in 147 (60.7%) children. Mild anemia predominated (30.6%), followed by moderate (20.7%) and severe (9.5%). Normocytic normochromic predominated (51.7%), followed by microcytic hypochromic (36.7%) and macrocytic (11.6%). In the multivariable analysis, the odds for anemia were increased by over four times among those with severe stunting (P=0.042), by over three times among those who breastfed for less than 12 months (P=0.022), by over two times among the HIV positive (P=0.002), those who have had TB for ≤2 months (P=0.015) and those with a history of weight loss (P=0.026) and by close to two times for those with moderate stunting (P=0.005).

Conclusion

Of every 10 children, 6 had anemia, indicating that anemia is a major comorbidity among pediatric TB patients. Routine screening for anemia should be incorporated into the management of all children with tuberculosis attending TB clinics with particular attention to children with HIV co-infection, stunting, weight loss, and shorter breastfeeding duration.

Introduction

Tuberculosis (TB) remains an important public health problem, particularly in low- and middle-income countries where children continue to experience substantial morbidity from the disease. Children are especially vulnerable because of their developing immune systems, nutritional requirements, and susceptibility to complications and co-infections [1]. In addition to the direct effects of TB infection, children with TB may develop hematological abnormalities, of which anemia is one of the most common [2]. Anemia can impair oxygen delivery to tissues and may adversely affect growth, immunity, physical functioning, and recovery from illness [3]. Its occurrence in children with TB is therefore an important clinical concern that requires attention during TB management.

The relationship between TB and anemia is complex and multifactorial. Chronic TB infection induces an inflammatory response involving cytokines such as interleukin-6, interleukin-1, and tumor necrosis factor-alpha [4]. These inflammatory pathways increase hepcidin production,

resulting in iron sequestration within macrophages and reduced availability of iron for erythropoiesis [5]. Chronic inflammation may also suppress erythropoietin production and shorten red blood cell survival. In addition, poor dietary intake, malnutrition, micronutrient deficiencies, and co-infections such as HIV may further contribute to the development and severity of anemia among children with TB [6, 7]. Consequently, anemia in TB may present with different morphological patterns, including normocytic normochromic, microcytic hypochromic, and macrocytic anemia, reflecting different underlying mechanisms.

Evidence from different settings indicates that anemia is common among people with TB. A systematic review and meta-analysis reported a pooled anemia prevalence of 61.53% among TB patients, with anemia of chronic disease accounting for a substantial proportion of cases [8]. Similarly, a systematic review focusing on Africa reported a pooled anemia prevalence of approximately 69% among people with TB [9]. Studies among children have also demonstrated considerable variation in prevalence. For example, anemia was reported among 37.9% of children with TB in China [10], while a study among children with pulmonary TB in India reported a prevalence of 75.2% [11]. Differences in age distribution, nutritional status, disease severity, study populations, and geographical settings may partly explain the variation between studies.

In Uganda, evidence on anemia among patients with TB is mainly derived from adult populations. A study conducted at Mulago National Referral Hospital reported anemia in 58.7% of adults with pulmonary TB and identified factors such as low body mass index, HIV co-infection, and other indicators of disease severity as being associated with anemia [12]. However, these findings cannot be directly generalized to children because childhood anemia is influenced by additional factors, including rapid growth, nutritional requirements, breastfeeding practices, and susceptibility to childhood infections. Moreover, there is limited local evidence describing not only the prevalence of anemia but also its severity, morphological patterns, and associated factors among children with TB.

This evidence gap is particularly relevant at Hoima Regional Referral Hospital (HRRH), which serves a large population in the greater Bunyoro region and receives children with TB from

Hoima and surrounding districts. Although children with TB are routinely assessed and managed at the hospital TB clinic, systematic local information on anemia among this population remains limited. Understanding the magnitude and characteristics of anemia is important for identifying children at greater risk and informing appropriate clinical and nutritional interventions.

Therefore, this study was conducted to determine the prevalence, severity, morphological patterns, and factors associated with anemia among children aged 1–18 years with TB attending the TB clinic at Hoima Regional Referral Hospital. The findings are expected to contribute context-specific evidence for improving the comprehensive management of children with TB in Uganda.

Methods

Study design and setting

A hospital-based analytical cross-sectional study was conducted at HRRH, Uganda. The hospital is located in Hoima Municipality, approximately 200 km northwest of Kampala, and has a bed capacity of 267 beds. It serves a catchment population of more than 3.5 million people across approximately 10 districts. The TB clinic is located within the outpatient department and manages patients diagnosed with TB at the hospital as well as those referred from lower-level health facilities for initiation of treatment. Children with TB are managed through the general TB clinic, while those requiring admission are admitted to the paediatric ward. Routine investigations, including complete blood count and peripheral blood smear, are performed in the hospital's central laboratory.

Study population and eligibility criteria

The target population comprised all children aged 1–18 years with TB within the catchment area of HRRH. The accessible population consisted of children aged 1–18 years with TB attending the HRRH TB clinic. Study participants were children aged 1–18 years with TB who attended the TB clinic during the study period and fulfilled the eligibility criteria.

Children aged 1–18 years with TB who presented to HRRH during the study period were eligible if their caregivers provided informed consent and children aged 8 years and above provided

assent. Children receiving hematinics, those with a history of blood transfusion within the preceding three months, critically ill children requiring emergency care, and children with chronic conditions such as sickle cell disease were excluded.

Sample size and sampling

The sample size was determined using the Kish-Leslie formula. An estimated prevalence of 82.7% reported by Ahmed and Yusuf (2024) was used, giving a minimum sample size of 220 participants [13]. By factoring in the non response, a total of 242 eligible children were enrolled in the study. Participants were recruited from children presenting to the TB clinic during the study period and meeting the eligibility criteria.

Data collection and measurements

Data were collected using a structured questionnaire administered to the caregivers of eligible children. Information collected included socio-demographic characteristics, clinical characteristics, TB-related factors, co-infections, nutritional status, breastfeeding history, and history of weight loss. Clinical information was obtained from the participants, caregivers, and medical records as applicable.

A blood sample was collected from each participant and analyzed in the hospital central laboratory using a complete blood count. Hemoglobin concentration was used to determine the presence and severity of anemia, while red blood cell indices, including mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), were used to determine the morphological pattern of anemia.

Anthropometric measurements were obtained for assessment of nutritional status. Weight and height were measured twice and the average of the two measurements was recorded.

Definition and classification of anemia

Anemia was defined according to age- and sex-specific hemoglobin thresholds based on World Health Organization (WHO) guidelines. Severity was categorized as mild, moderate, or severe according to the applicable age and sex-specific hemoglobin cut-offs. For children aged 1–<2

years, anemia was defined as hemoglobin below 10.5 g/dL; for those aged 2–<5 years, below 11.0 g/dL; for those aged 5–<12 years, below 11.5 g/dL; and for those aged 12–<15 years, below 12.0 g/dL. Among those aged 15–<18 years, the threshold was 12.0 g/dL for females and 13.0 g/dL for males.

Anemia was classified morphologically as normocytic normochromic, microcytic hypochromic, or macrocytic based on the red blood cell indices, particularly MCV, MCH, MCHC, and hematocrit.

Data quality control and management

Eligibility criteria were strictly followed throughout participant recruitment. Completed questionnaires were checked daily for completeness and consistency. Weight and height measurements were taken twice and averaged. Routine laboratory quality-control procedures were followed, and one sample for every 30 samples analyzed was sent to Lancet Laboratories for external quality control.

Completed questionnaires were securely stored under lock and key. Electronic data were entered and stored on password-protected computers and subsequently exported to IBM SPSS Statistics version 26 for analysis.

Statistical analysis

Data were analyzed using SPSS version 26. Descriptive statistics were used to summarize participant characteristics using frequencies and percentages. The prevalence of anemia was calculated as the proportion of children who met the age- and sex-specific WHO criteria for anemia. The severity of anemia was summarized according to mild, moderate, and severe categories. Morphological patterns were summarized using the proportions of normocytic normochromic, microcytic hypochromic, and macrocytic anemia.

For factors associated with anemia, bivariable analysis was conducted using cross-tabulations, with crude odds ratios (ORs), 95% confidence intervals (CIs), and chi-square *p*-values reported. Variables with $p < 0.20$ at bivariable analysis, together with variables considered biologically

plausible, were entered into a multivariable binary logistic regression model. Backward stepwise regression was used to obtain the final model. Variables with $p < 0.05$ in the final model were considered statistically significant. Multicollinearity was assessed using the variance inflation factor, with a cut-off of 5. Confounding was assessed by comparing crude and adjusted effect estimates, with a change of 10% or more considered evidence of confounding. Effect modification was assessed by examining homogeneity of effects across strata.

Ethical considerations

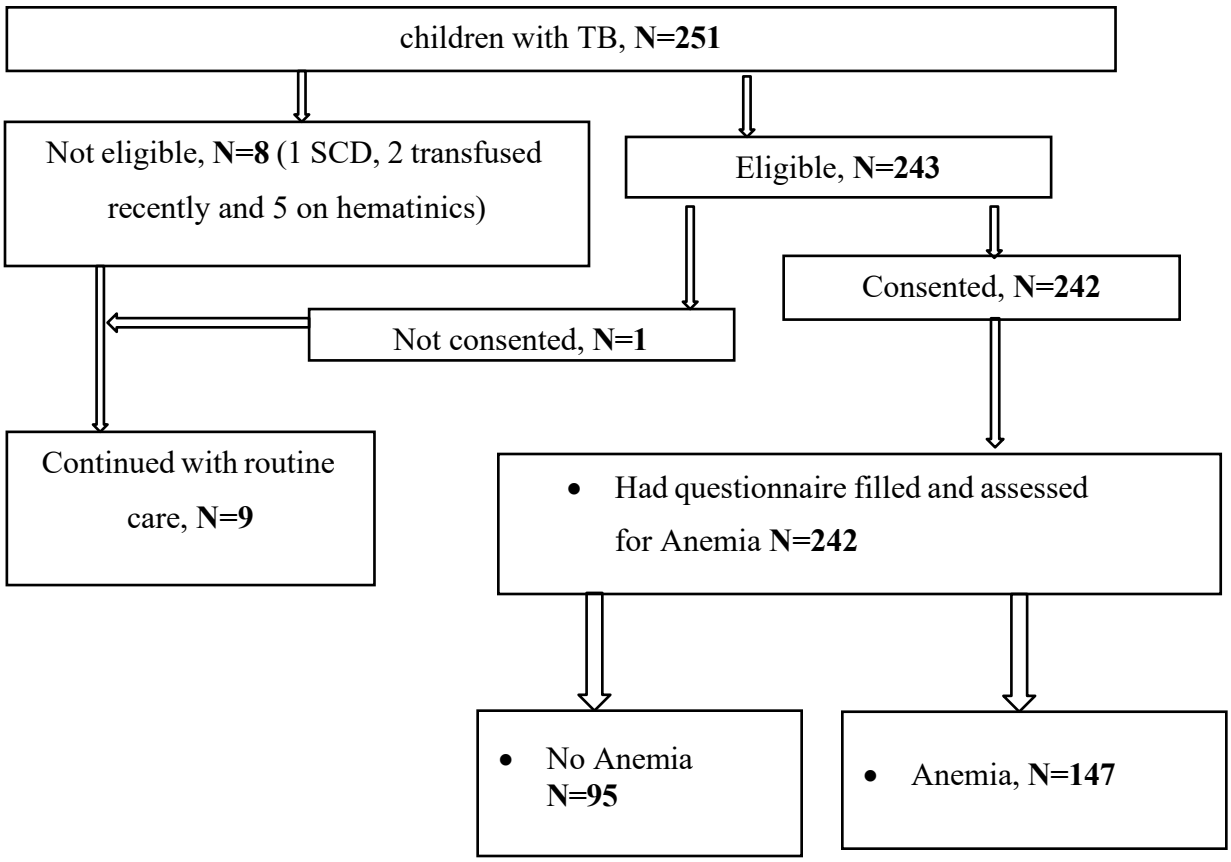
Ethical approval was obtained from the Kampala International University Research Ethics Committee (KIU-REC-2026-140), and the study was registered with the Uganda National Council for Science and Technology through the REC. Permission to conduct the study was obtained from the Medical Director and the TB clinic in-charge at HRRH. Written informed consent was obtained from caregivers after explaining the study in English or the local language, Runyoro. Assent was obtained from children aged 8 years and above. Participation was voluntary, and participants were free to decline participation or withdraw at any time without affecting the care they received.

Standard infection-prevention procedures, including hand hygiene, appropriate use of personal protective equipment, safe disposal of medical waste, sterilization, and environmental hygiene, were followed during the study. Participant confidentiality and privacy were maintained throughout data collection and management.

Results

Overview

In the course of the study period, 251 children with TB were seen at the study centre. Of these, two had been transfused in preceding three months, one had sickle cell disease, while five were taking hematinics. Of the eligible 243, one could not consent, leaving 242 that were enrolled as shown in Figure 2 below.



Characteristics of the study participants

In this study that enrolled 242 study participants, children under five years of age predominated accounting for close to two thirds 146 (60.3%) of the study participants. There were slightly more males 126 (52.1%) than females 116 (47.9%). Close to two thirds 158 (65.3%) were from rural areas. Only 23 (9.5%) . The details of the baseline characteristics are shown in table 1 below.

Table 1: Social demographic characteristics of study participants

Characteristic	Frequency	Percentage
Age child (years)		
1-<5	146	60.3
5-<12	41	16.9
12-<18	55	22.7
Sex		
Male	126	52.1
Female	116	47.9
School status		
Pre-School	74	30.6
School Going	168	69.4
Residence		
Rural	158	65.3
Urban/peri urban	84	34.7
Family income (UGX/month)		
<200,000	122	50.4
200,000-500,000	93	38.4
>500,000	27	11.2
Age caretaker (years)		
20-44	154	63.6
45-59	49	20.2
60+	39	16.1
Education caretaker		
None	124	51.2
Primary	48	19.8
Secondary/Tertiary	70	28.9
Occupation caretaker		
Employed	60	24.8
Business	54	22.3
Peasant	98	40.5
Un employment	30	12.4
House hold size		
≤5	132	54.5
>5	110	45.5

BF=Breast feeding, EBF=Exclusive breastfeeding.

Almost two thirds 149 (61.6%) had been with TB for over 2 months. Pulmonary tuberculosis was the predominant type 220 (90.9%). In this study, 147(60.7%) had a normal weight for height, 155 (64.0%) had a normal height for age while 124(51.2%) had a normal weight for age, with the rest showing some degree of undernutrition. A history of weight loss was reported in 199 (82.2%), fever in 158(65.3%), night sweats in 89 (36.8%) while hemoptysis was only reported in 14 (5.8%). The details of the baseline characteristics are shown in table 2 below.

Table 2: Clinical characteristics of study participants

Characteristic	Frequency	Percentage TB duration
≤2 months	93	38.4
>2 months	149	61.6
TB type		
Pulmonary	220	90.9
Extra pulmonary	22	9.1
Malaria		
Negative	223	92.1
Positive	19	7.9
HIV		
Negative	124	51.2
Positive	118	48.8
Intestinal parasites		
Absent	188	77.7
Present	54	22.3
Diarrhea		
No	191	78.9
Yes	51	21.1
Wasting		
No wasting	147	60.7
Moderate	72	29.8
Severe	23	9.5
Stunting		
No stunting	155	64.0
Moderate	67	27.7
Severe	20	8.3
Underweight		
No underweight	124	51.2
Moderate	91	37.6
Severe	27	11.2
Immunization status		
Up to date	232	95.9
Not up to date	10	4.1
Weight loss history		
No	43	17.8
Yes	199	82.2
Fever history		
No	84	34.7
Yes	158	65.3
Night sweats history		
No	153	63.2
Yes	89	36.8
Hemoptysis history		
No	228	94.2
Yes	14	5.8

Of the 242 study participants, anemia was seen in 147, representing a prevalence of 60.7% with a 95% confidence interval of 54.5-66.5% as shown in figure 3 below.

Figure 3: Prevalence of anemia among children aged 1-18 years with TB at HRRH.

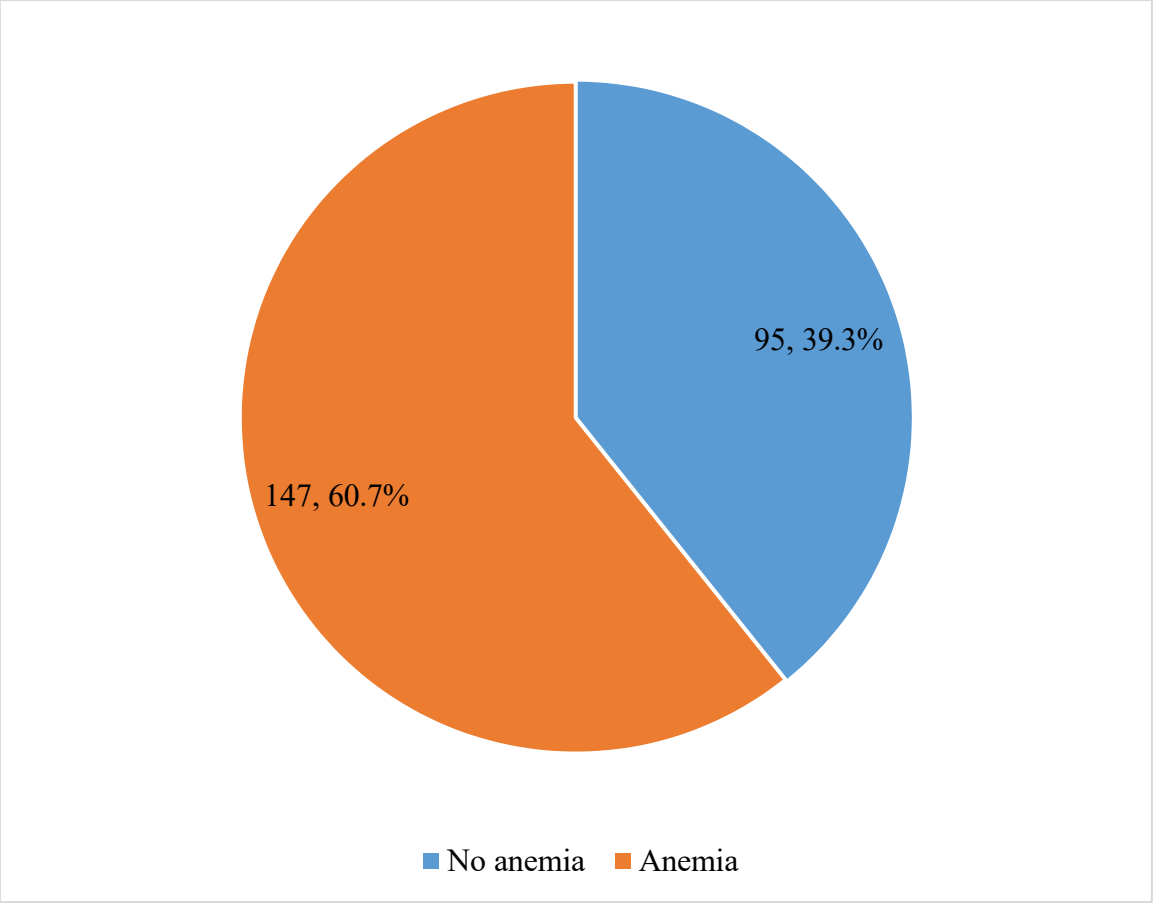


figure 3 :Prevalence of anemia among children aged 1-18 years with TB at HRRH

Severity of anemia among children aged 1-18 years with TB at HRRH.

Of the 242 study participants, mild anemia predominated and was seen in 74 (30.6%, CI=24.8-36.4%), followed by moderate anemia seen in 50 (20.7%, CI=15.7-26.0%) and lastly severe anemia seen in 23 (9.5%, CI=6.2-13.2%) as detailed in figure 4 below.

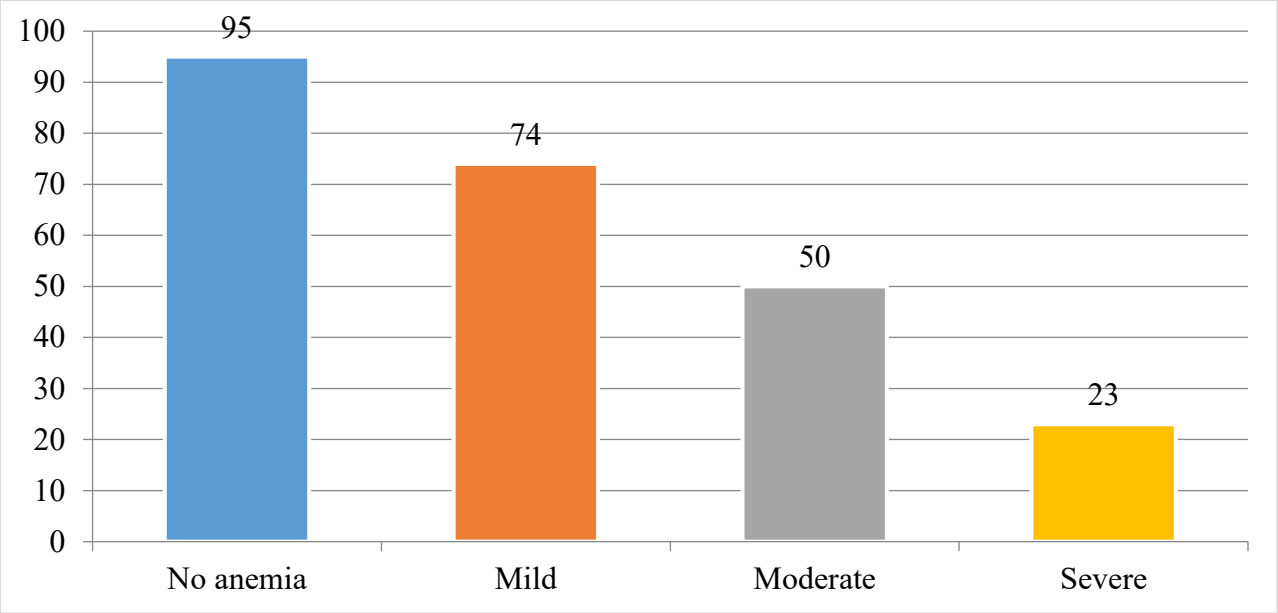


Figure 4: Severity of anemia among children aged 1-18 years with TB at HRRH.

Morphological patterns of anemia among children aged 1-18 years with TB at HRRH.

Of the 147 participants that were found to have anemia, normocytic normochromic predominated seen in 76 (51.7%, CI=44.2-59.9%), followed by microcytic hypochromic in 54 (36.7%, CI=29.3-45.6%) and lastly macrocytic in 17 (11.6%, CI= 6.8-17.0%) as detailed in figure 5 below.

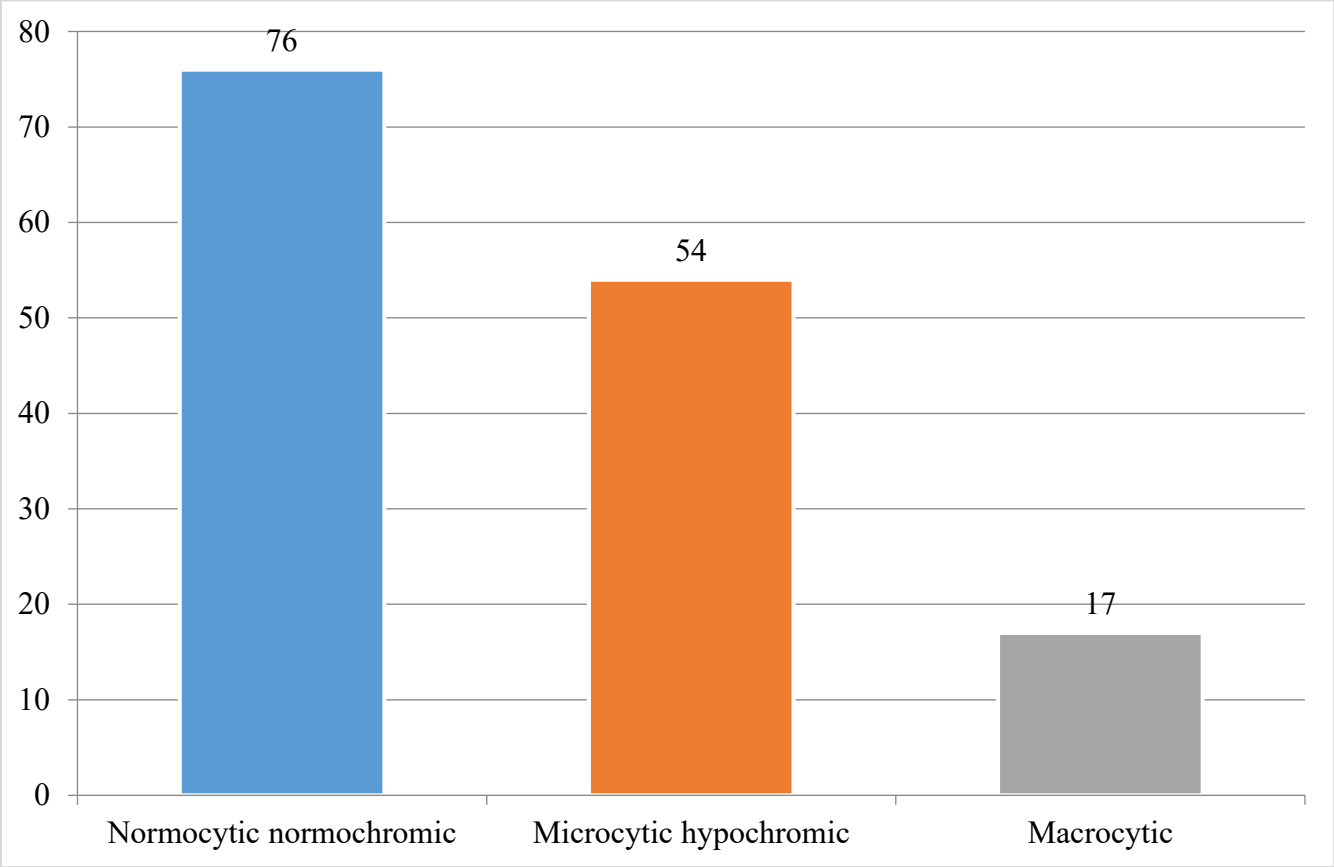


Figure 5: Morphological patterns of anemia among children aged 1-18 years with TB at HRRH

Factors associated with anemia among children aged 1-18 years with TB at HRRH. The social demographic variables considered for multivariable analysis (P<0.2) were: age category of child, school status, residence and breast-feeding duration, as detailed in table 4 below.

Table 4: Bivariable analysis of social demographic factors associated with anemia among children aged 1-18 years with TB at HRRH.

Bivariable analysis of social demographic factors associated with anemia among children aged 1-18 years with TB at HRRH.

Characteristic	No anemia, N=95	Anemia, N=147	Bivariable analysis		
			cOR	95% CI	P value
Age child (years)					
1-<5	47(49.5)	99(67.3)	2.528	1.341-4.766	**0.004**
5-<12	18(18.9)	23(15.6)	1.533	0.680-3.460	0.303
12-<18	30(31.6)	25(17.0)	Ref		
Sex					
Male	46(48.4)	80(54.4)	1.272	0.758-2.133	0.362
Female	49(51.6)	67(45.6)	Ref		
School status					
Pre-School	34(35.8)	40(27.2)	Ref		
School Going	61(64.2)	107(72.8)	1.491	0.856-2.597	**0.158**
Residence					
Rural	54(56.8)	104(70.7)	1.836	1.071-3.150	**0.027**
Urban/peri urban	41(43.2)	43(29.3)	Ref		
Family income (UGX/month)					
<200,000	47(49.5)	75(51.0)	1.277	0.550-2.963	0.570
200,000-500,000	36(37.9)	57(38.8)	1.267	0.533-3.012	0.593
>500,000	12(12.6)	15(10.2)	Ref		
Age caretaker					
20-44	58(61.1)	96(65.3)	1.034	0.502-2.131	0.927
45-59	22(23.2)	27(18.4)	0.767	0.326-1.806	0.544
60+	15(15.8)	24(16.3)	Ref		
Education					
None	54(56.8)	70(47.6)	0.864	0.476-1.568	0.631
Primary	13(13.7)	35(23.8)	1.795	0.810-3.979	0.250
Secondary/Tertiary	28(29.5)	42(28.6)	Ref		
Occupation					
Employed	24(25.3)	36(24.5)	Ref		
Business	26(27.4)	28(19.0)	0.718	0.342-1.509	0.382
Peasant	36(37.9)	62(42.2)	1.148	0.593-2.221	0.682
Un employment	9(9.5)	21(14.3)	1.556	0.610-3.967	0.355
House hold size					
≤5	50(52.6)	82(55.8)	1.135	0.676-1.906	0.631
>5	45(47.4)	65(44.2)	Ref		

cOR= Crude odds ratio, CI= Confidence interval, BF=Breast feeding, EBF=Exclusive breastfeeding.

The clinical variables considered for multivariable analysis (P<0.2) were: duration of tuberculosis, type of tuberculosis, HIV status, wasting, stunting, underweight, history of weight loss and history of haemoptysis as detailed in table 5 below.

Table 5: Bivariable analysis of clinical factors associated with anemia among children aged 1-18 years with TB at HRRH.

Characteristic	No anemia, N=95	Anemia, N=147	Bivariable analysis		
			cOR	95% CI	P value
TB duration					
≤2 months	27(28.4)	66(44.9)	2.052	1.182-3.563	**0.011**
>2 months	68(71.6)	81(55.1)	Ref		
TB type					
Pulmonary	83(87.4)	137(93.2)	1.981	0.820-4.787	**0.129**
Extra pulmonary	12(12.6)	10(6.8)	Ref		
Malaria					
Negative	87(91.6)	136(92.5)	Ref		
Positive	8(8.4)	11(7.5)	0.880	0.340-2.274	0.791
HIV					
Negative	62(65.3)	62(42.2)	Ref		
Positive	33(34.7)	85(57.8)	2.576	1.510-4.395	**0.001**
Intestinal parasites					
Albescent	70(73.7)	118(80.3)	Ref		
Present	25(26.3)	29(19.7)	0.688	0.373-1.268	0.231
Diarrhea					
No	72(75.8)	119(81.0)	Ref		
Yes	23(24.2)	28(19.0)	0.737	0.395-1.375	0.337
Wasting					
No wasting	63(66.3)	84(57.1)	Ref		
Moderate	26(27.4)	46(31.3)	1.327	0.742-2.373	0.340
Severe	6(6.3)	17(11.6)	2.125	0.792-5.698	**0.134**
Stunting					
No stunting	71(74.7)	84(57.1)	Ref		
Moderate	21(22.1)	46(31.3)	1.851	1.011-3.391	**0.046**
Severe	3(3.2)	17(11.6)	4.790	1.349-17.011	**0.015**
Underweight					
No underweight	56(58.9)	68(46.3)	Ref		
Moderate	33(34.7)	58(39.5)	1.447	0.831-2.521	**0.191**
Severe	6(6.3)	21(14.3)	2.882	1.089-7.632	**0.033**
Immunization					
Up to date	90(94.7)	142(96.6)	Ref		
Not up to date	5(5.3)	5(3.4)	0.634	0.178-2.251	0.481
Weight loss					
No	24(25.3)	19(12.9)	Ref		
Yes	71(74.7)	128(87.1)	2.277	1.167-4.442	**0.016**
Fever history					
Yes	63(66.3)	95(64.6)	0.928	0.539-1.598	0.787
No	32(33.7)	52(35.4)	Ref		
Night sweats					

No	64(67.4)	89(60.5)	Ref		
Yes	31(32.6)	58(39.5)	1.345	0.783-2.312	0.283
Hemoptysis					
No	92(96.8)	136(92.5)	Ref		
Yes	3(3.2)	11(7.5)	2.480	0.673-9.135	**0.172**

cOR= Crude odds ratio, CI= Confidence interval, TB=Tuberculosis, HIV=Human immunodeficiency virus.

In the multivariable analysis, the independent factors associated with anemia among children aged 1-18 years with TB at HRRH for duration < 6 months and (aOR=3.149, CI=1.844-8.521, P=0.022) for duration of 6-12 months, duration of TB≤2 months (aOR=2.048, CI=1.123-5.025, P=0.015), being HIV positive (aOR=2.061, CI=1.352-4.876, P=0.002), stunting with (aOR=1.699, CI=1.158-5.362, P=0.005) for moderate stunting and (aOR=4.020, CI=1.851-15.376, P=0.042) for severe as well as a history of weight loss (aOR=2.211, CI=1.124-4.530, P=0.026). The odds for anemia among children with TB were increased by over four times among those with severe stunting, by over three times among those who breastfed for less than 12 months, by over two times among the HIV positive, those who have had TB for ≤2 months and those with a history of weight loss and by close to two times for those with moderate stunting as detailed in table 6 below.

Table 6: Multivariable analysis of factors associated with anemia among children aged 1-18 years with TB at HRRH

Characteristic	Bivariable analysis			Multivariable analysis		
	cOR	**95% CI**	**P value**	**aOR**	**95% CI**	**P value**
Age child (years)						
1-<5	2.528	1.341-4.766	0.004	1.389	0.673-2.868	0.374
5-<12	1.533	0.680-3.460	0.303	1.244	0.488-3.171	0.647
12-<18	Ref					
School status						
Pre-School	Ref					
School Going	1.491	0.856-2.597	0.158	1.548	0.746-3.209	0.241
Residence						
Rural	1.836	1.071-3.150	0.027	1.188	0.594-2.377	0.626
Urban/peri urban	Ref					
TB duration						
≤2 months	**2.052**	**1.182-3.563**	**0.011**	**2.048**	**1.123-5.025**	**0.015**
>2 months	Ref					
TB type						
Pulmonary	1.981	0.820-4.787	0.129	1.702	0.152-3.247	0.651
Extra pulmonary	Ref					
HIV						
Negative	Ref					
Positive	**2.576**	**1.510-4.395**	**0.001**	**2.061**	**1.352-4.876**	**0.002**
Wasting						
No wasting	Ref					
Moderate	1.327	0.742-2.373	0.340	1.026	0.455-2.316	0.950
Severe	2.125	0.792-5.698	0.134	3.096	0.966-9.925	0.057
Stunting						
No stunting	Ref					
Moderate	**1.851**	**1.011-3.391**	**0.046**	**1.699**	**1.158-5.362**	**0.005**
Severe	**4.790**	**1.349-17.011**	**0.015**	**4.020**	**1.851-15.376**	**0.042**
Underweight						
No underweight	Ref					
Moderate	1.447	0.831-2.521	0.191	1.215	0.618-2.386	0.572
Severe	2.882	1.089-7.632	0.033	1.338	0.440-4.068	0.608
Weight loss history						
No	Ref					
Yes	**2.277**	**1.167-4.442**	**0.016**	**2.211**	**1.124-4.530**	**0.026**
Hemoptysis history						
No	Ref					
Yes	2.480	0.673-9.135	0.172	2.176	0.408-11.590	0.362

cOR= Crude odds ratio, aOR= adjusted odds ratio, CI= Confidence interval, BF=Breast feeding, TB=Tuberculosis, HIV=Human immunodeficiency virus.

Discussion

This study set out to evaluate the prevalence, patterns and factors associated with anemia among children aged 1-18 years with TB attending Hoima Regional Referral Hospital (HRRH) TB clinic. The findings indicate that close to two thirds (60.7%) of the participants had some degree of anemia, predominated by the mild and moderate forms, with morphology being mainly normocytic normochromic or microcytic hypochromic. The findings all indicated that breast feeding duration, HIV status, nutritional status and weight loss had a significant association with the observed anemia burden. This study highlights a high burden of anemia, but also highlight the areas that can be focused on in combating this high burden as detailed in the following subsections.

This study found that the prevalence of anemia among children aged 1–18 years with tuberculosis attending Hoima Regional Referral Hospital was 60.7% (95% CI: 54.5–66.5%). This finding demonstrates that anemia is a major comorbidity among children with tuberculosis in this setting. The high prevalence implies that a substantial proportion of pediatric TB patients present with impaired oxygen-carrying capacity, which may worsen growth, immunity, cognitive development, and overall treatment outcomes. The findings support the understanding that tuberculosis contributes significantly to hematological abnormalities through chronic inflammation, nutritional deficiencies, impaired erythropoiesis, and iron sequestration mediated by inflammatory cytokines [14].

The prevalence observed in this study is comparable to findings from a systematic review by Barzegari [8], which reported a pooled anemia prevalence of 61.53% among tuberculosis patients. Similarly, the present findings are close to those reported by Baluku in Uganda, who documented a prevalence of 58.7% among adults with pulmonary tuberculosis at Mulago National Referral Hospital [12]. The similarity between the findings may suggest that tuberculosis contributes substantially to anemia regardless of age group, especially in high-burden settings such as Uganda where malnutrition, chronic infections, and socioeconomic deprivation are common.

The findings are also comparable to reports from Brazil by Mendonc where 61.2% of TB

patients had anemia, and from India where Leon reported that 63% of newly diagnosed pulmonary TB patients were anemic at baseline [14, 15]. These similarities across geographically different populations strengthen the evidence that anemia is a common manifestation of tuberculosis worldwide.

However, the prevalence in this study was lower than the 69% pooled prevalence reported in Africa by Abaynew [9], the 75.2% reported in India by Selvan & Nagesh [11], the 71% in Guinea by Kuotu [16] and the 82.7% reported in Somalia by Ahmed [13]. The lower prevalence in the current study could be attributed to differences in study populations, nutritional status, disease severity, socioeconomic conditions, and HIV prevalence. Some studies included multidrug-resistant TB patients or severely ill participants [17], who are more likely to develop severe inflammatory responses and nutritional deficiencies that increase the risk of anemia [18].

On the other hand, the prevalence in this study was higher than the 37.9% reported among children with TB in China by Han [10] and the 35.5% reported in South Africa [19]. The higher prevalence in the current study may reflect the greater burden of malnutrition, HIV co-infection, delayed healthcare seeking, and poverty commonly experienced in low-resource settings such as Uganda. Additionally, most participants in the present study were from rural areas and low-income households, which may predispose them to poor nutrition and delayed TB diagnosis.

The findings of this study add important evidence to pediatric TB care in Uganda because few previous studies have specifically focused on anemia among children with TB. The study therefore bridges an important knowledge gap by providing local and age-specific data that can guide routine hematological screening and management in pediatric TB clinics.

The present study found that mild anemia was the most common severity category, affecting 30.6% of participants, followed by moderate anemia (20.7%) and severe anemia (9.5%). These findings suggest that although anemia is highly prevalent among children with tuberculosis, the

majority of cases occur in the milder forms. This pattern may indicate that many children are diagnosed before progression to life-threatening anemia, although a substantial proportion still

had moderate to severe disease requiring urgent intervention.

The predominance of mild anemia is consistent with findings from a meta-analysis by Barzegari [8], who reported pooled prevalences of 35.67% for mild anemia, 31.19% for moderate anemia, and 11.61% for severe anemia among TB patients. Similar findings were reported in Nepal [20] where mild anemia predominated as well as Ethiopia where 5.7% had severe anemia, 15.7% had moderate anemia and 29.9% had mild anemia [21].

The agreement between these studies may indicate that anemia of chronic disease associated with TB often initially manifests as mild reductions in hemoglobin before worsening with prolonged disease or nutritional deterioration [22]. Mild anemia may predominate because chronic inflammatory processes gradually impair erythropoiesis and iron metabolism over time rather than causing sudden severe reductions in hemoglobin levels [22]. This indicates that early diagnosis and intervention have the potential to avert the severe forms that are associated with morbidity and mortality.

However, the current findings differ from those reported in Ethiopia, where mild and moderate anemia occurred at nearly equal proportions [23]. The difference may be explained by variations in age categories, nutritional status, healthcare access, and coexisting infections. The Ethiopian study focused on younger children under five years, who are biologically more vulnerable to recurrent infections and nutritional deficiencies, factors that may increase anemia severity. Similarly, Dhanashri in India reported a much higher burden of moderate anemia among HIV-positive children with TB [24]. This discrepancy may be because HIV infection worsens immune suppression, increases chronic inflammation, and contributes to bone marrow suppression, thereby increasing anemia severity [25].

The presence of severe anemia in 9.5% of participants in the present study is clinically important because severe anemia is associated with impaired tissue oxygenation, delayed recovery, poor treatment outcomes, and increased mortality risk among children with tuberculosis [26].
This finding highlights the importance of routine hemoglobin assessment and timely management of anemia during TB treatment.

The findings contribute to clinical practice by emphasizing that not all anemia among children with TB is severe at presentation. Early identification of mild and moderate anemia offers an opportunity for nutritional support, treatment of underlying causes, and prevention of progression to severe anemia.

This study found that normocytic normochromic anemia was the predominant morphological pattern, accounting for 51.7% of anemia cases, followed by microcytic hypochromic anemia (36.7%) and macrocytic anemia (11.6%). The predominance of normocytic normochromic anemia suggests that anemia of chronic disease was the commonest mechanism underlying anemia among children with TB in this setting.

These findings are consistent with studies from India [27], Brazil [15]and Nepal [28]all of which identified normocytic normochromic anemia as the predominant pattern among TB patients. Similarly, a meta analysis [8] reported that anemia of chronic disease accounted for nearly half of anemia cases among TB patients globally.

The predominance of normocytic normochromic anemia may be explained by chronic inflammatory responses induced by tuberculosis infection [22]. Pro-inflammatory cytokines such as interleukin-6 stimulate hepcidin production, which traps iron within macrophages and reduces iron availability for erythropoiesis despite adequate body iron stores [27]. Chronic inflammation also suppresses erythropoietin production and shortens red blood cell survival, resulting in normocytic normochromic anemia [15].

Microcytic hypochromic anemia was the second most common pattern observed in this study. This finding may suggest coexistence of iron deficiency anemia among many children with TB.

Iron deficiency may result from poor nutritional intake, chronic inflammation, parasitic infections and recurrent illness [29]. Similar findings were reported by Han in China, where microcytic hypochromic anemia predominated among anemic children with TB [10].

Macrocytic anemia accounted for 11.6% of anemia cases in the present study. Macrocytic anemia may reflect folate or vitamin B12 deficiencies, which are common among chronically ill and malnourished children. Similar observations were reported in South Africa, where macrocytosis was associated with folate deficiency [30].

The findings of this study add value to pediatric TB care by demonstrating that anemia among children with tuberculosis is heterogeneous in morphology and therefore may require individualized management approaches. Identifying the dominant morphological patterns can help clinicians determine the likely underlying mechanisms and select appropriate interventions such as iron supplementation, nutritional rehabilitation, or management of chronic inflammation.

This study identified breastfeeding duration less than 12 months, duration of TB for ≤2 months, HIV positivity, stunting, and history of weight loss as independent factors associated with anemia among children with tuberculosis. Children who were breastfed for less than 12 months had significantly higher odds of anemia compared to those breastfed for longer durations. Breastfeeding provides essential nutrients, immunological protection, and improved resistance against infections during early childhood [15]. Early cessation of breastfeeding may predispose children to nutritional deficiencies, recurrent infections, and impaired growth, thereby increasing susceptibility to anemia [5]. Also, cow's milk and other complementary foods can also be low in iron quantity and bioavailability. Similar findings were reported by Hailu who found that early cessation of breastfeeding predicted anemia among children [31].

Participants who had been with tuberculosis for at most two months had odds of anemia increased by over two times. These participants are usually in the intensive phase of TB treatment, and have just initiated the TB treatment. This is possibly because during the intensive phase, the patients have high bacterial loads, severe chronic inflammation, and malnutrition. The combinations of high bacterial loads, severe chronic inflammation, and malnutrition suppress red blood cell production [32].

HIV-positive children were more than twice as likely to have anemia compared to HIV-negative children. This finding is biologically plausible because HIV contributes to chronic inflammation,

opportunistic infections, nutritional deficiencies, and bone marrow suppression, all of which impair erythropoiesis [25]. Similar associations between HIV infection and anemia among TB patients were reported by Baluku [12]. The coexistence of TB and HIV may further amplify inflammatory responses and worsen hematological abnormalities [6].

Stunting was independently associated with anemia, with severely stunted children having over four times higher odds of anemia. Stunting reflects chronic malnutrition and prolonged nutritional deprivation, which impair hemoglobin synthesis and immune function [19]. Malnourished children are also more susceptible to recurrent infections that worsen anemia (Aynalem et al., 2022). The findings are consistent with previous evidence linking chronic undernutrition to anemia among children in low-resource settings [31].

History of weight loss was also independently associated with anemia. Weight loss is often an indicator of severe or prolonged tuberculosis disease, poor nutritional status, and increased metabolic demand. Chronic inflammation and catabolic states associated with TB may reduce appetite, impair nutrient absorption, and suppress erythropoiesis, thereby contributing to anemia [14].

Although age below five years, rural residence, pulmonary TB, severe underweight, and hemoptysis were associated with anemia at bivariable analysis, they did not retain significance after multivariable adjustment. This suggests that the effects of these variables may have been mediated through nutritional status, HIV infection, or other confounding factors. The findings of this study are important for clinical practice because they identify high-risk groups that require closer monitoring for anemia during TB care.

Strengths and limitations of the Study

The study assessed multiple dimensions of anemia including prevalence, severity, morphological patterns, and associated factors, thereby providing a comprehensive understanding of anemia among children with TB. The analytical cross-sectional design limited the ability to establish causal relationships between the identified factors and anemia. The study was hospital-based and

conducted at a single regional referral hospital, which may limit generalizability of the findings to children with TB in other settings or communities. Recall bias may have occurred for variables obtained through caregiver interviews such as breastfeeding duration and history of weight loss.

Conclusions

According to our findings, 6 of every 10 children aged 1–18 years with tuberculosis had anemia, indicating that anemia is a major comorbidity among pediatric TB patients. Mild anemia was the most common severity category, although a substantial proportion of children had moderate and severe anemia requiring clinical attention. Normocytic normochromic anemia was the predominant morphological pattern, suggesting that anemia of chronic disease is the leading mechanism of anemia among children with tuberculosis in this setting. Independent factors associated with anemia included shorter breastfeeding duration, having had TB for ≤2 months, HIV co-infection, stunting, and history of weight loss. These findings emphasize the important contribution of chronic inflammation, malnutrition, and immunosuppression to the development of anemia among children with TB.

Declarations

Ethics approval

Ethical approval for the study was obtained from the Kampala International University Research Ethics Committee (KIU-REC-2026-140), and the study was registered with the Uganda National Council for Science and Technology. The research was conducted in accordance with the approved study protocol, applicable institutional and national research ethics guidelines, and the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from the caregivers of all participating children, and assent was obtained from children aged 8 years and above. Participation was voluntary, and confidentiality and privacy were maintained throughout the study.

Informed consent

Written informed consent was obtained from all the caregivers of the children. Participation was entirely voluntary. Participants were free to decline or withdraw at any time without penalty. Confidentiality of all responses was strictly maintained.

Consent for publication

Not applicable, as no identifying information or images of participants are included in this manuscript.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

Clinical trial:

Clinical trial not applicable

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Authors' contributions

All authors equally contributed to development of this manuscript.

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