

Received: 03 July 2026

Accepted: 26 September 2026

Published: 13 October 2026

Frequency of Anemia in Children With Pulmonary Tuberculosis Presenting at a Tertiary Care Hospital

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Cite this article:

Aftab, H., et al. (2026). Frequency of Anemia in Children With Pulmonary Tuberculosis Presenting at a Tertiary Care Hospital. *Revista Cultura Científica*, (24), pp. 1779–1787. <https://doi.org/10.70517/revcc2624147>

Abstract

Anemia is a frequently reported hematological complication of tuberculosis (TB), and its presence may complicate clinical assessment and management in affected children. This study determined the frequency, morphological patterns, and severity of anemia among children with pulmonary tuberculosis treated at a tertiary care hospital in Lahore, Pakistan. A cross-sectional study was conducted in the Department of Pediatric Medicine, Gulab Devi Hospital, from March to July 2026. Using consecutive sampling, 100 children aged 6–12 years with pulmonary TB were enrolled. Demographic and clinical information was recorded, and complete blood counts, peripheral blood smears, iron-related investigations, and selected biochemical tests were performed. Anemia was classified according to the study's pre-specified hemoglobin cutoff of less than 11.2 g/dL; this study-specific cutoff differs from international age-specific recommendations. Of the 100 children, 68 (68.0%) were classified as anemic. Among anemic participants, moderate anemia was the most frequent severity category (36/68; 52.9%), followed by mild (23/68; 33.8%)

and severe anemia (9/68; 13.2%). Microcytic hypochromic anemia predominated (47/68; 69.1%), followed by normocytic normochromic anemia (17/68; 25.0%) and macrocytic anemia (4/68; 5.9%). The reported etiological classifications were anemia of chronic disease (48%), iron-deficiency anemia (41%), and mixed or unclassified anemia (11%). Anemia was observed in 35/48 girls (72.9%) and 33/52 boys (63.5%); no statistical significance test for this sex difference was reported. Elevated C-reactive protein and hypoalbuminemia were reported to be associated with anemia ($p < 0.05$), although detailed estimates were unavailable. Anemia was frequent among children with pulmonary TB in this hospital-based sample. Routine hematological assessment and context-sensitive interpretation of iron studies may support timely recognition of anemia, while larger studies using standardized pediatric diagnostic thresholds are needed to confirm the findings.

Keywords: pulmonary tuberculosis; childhood anemia; iron deficiency; anemia of inflammation; Pakistan; hemoglobin; hematological patterns

1. INTRODUCTION

Tuberculosis (TB), caused by bacteria of the *Mycobacterium tuberculosis* complex, remains a major public health concern despite advances in diagnosis, prevention, and treatment. The World Health Organization reported that Pakistan accounted for approximately 6.3% of estimated global incident TB cases in 2024, underscoring the country's substantial share of the disease burden [1]. Studies in different clinical settings have also documented difficulties with adherence, comorbid conditions, and disease-related complications that can adversely affect treatment and recovery [2]. Pakistani research has described the clinical and epidemiological burden of extrapulmonary TB alongside pulmonary disease [3]. In addition, evidence from Indonesia demonstrates the relevance of metabolic comorbidity, including diabetes, to the wider epidemiology of TB [4]. These findings reinforce the importance of evaluating associated health conditions rather than considering the infection in isolation.

The distribution and consequences of TB are influenced by poverty, crowded living conditions, nutritional vulnerability, and unequal access to timely health services. Public-health discussions in Pakistan have emphasized the need to strengthen prevention alongside treatment [5]. Childhood TB poses additional diagnostic challenges because clinical signs may be nonspecific and microbiological confirmation can be difficult to obtain, especially where laboratory resources are limited [6]. Nutritional impairment is particularly important in children because infection can reduce dietary intake and increase metabolic demand during a period of growth. Pediatric studies have reported associations between TB, impaired growth, low albumin concentrations, and anemia, although the patterns vary by disease site and severity [7]. More broadly, malnutrition and tuberculosis may reinforce one another through effects on immunity, disease progression, and nutritional status [8].

Anemia is an important comorbidity in this setting. It is generally characterized by a hemoglobin concentration below an age-appropriate reference threshold, but the threshold used must account for the patient's age and relevant physiological or environmental factors. The World Health Organization's 2024 guidance defines anemia using hemoglobin values below 11.5 g/dL for children aged 5–11 years and below 12.0 g/dL for children aged 12–14 years [9]. Hemoglobin concentration, mean corpuscular volume, mean corpuscular hemoglobin, and peripheral blood-smear findings are useful for describing the severity and morphology of anemia. Microcytosis and hypochromia commonly prompt investigation for iron deficiency, but morphology alone cannot establish etiology. Ferritin reflects iron stores yet also rises during inflammation, making interpretation challenging when chronic infection is present [10].

Several mechanisms can contribute to anemia during active TB. Inflammatory responses may alter iron distribution, restrict the supply of iron for erythropoiesis, and impair red-cell production. Prospective research has demonstrated disturbances of iron homeostasis in patients with tuberculosis-associated anemia of inflammation [11]. Additional work has shown that iron-deficiency anemia, anemia of inflammation, and mixed causes can coexist, making careful classification necessary before iron supplementation is considered [12]. Hematological investigations of pulmonary TB have likewise reported changes in blood counts and red-cell indices [13]. Clinical studies describe varied morphological and etiological patterns, depending on the population, stage of disease, and diagnostic definitions employed [14].

The frequency of anemia among patients with TB has been substantial in systematic reviews, although estimates vary by geographical region, study population, and laboratory threshold. Barzegari and colleagues described a pooled anemia prevalence of approximately 61.5% across the included TB studies [15]. A review of African studies reported a pooled prevalence of approximately 69%, with considerable between-study variation [16]. Another systematic review of newly diagnosed TB patients found anemia in approximately 61.6% of participants [17]. These estimates, largely derived from broader or adult populations, are useful contextual comparisons but cannot be treated as direct estimates for Pakistani children. Studies of TB treatment have also documented improvement in some hematological abnormalities during therapy and associations between anemia and unfavorable clinical outcomes [18–20]. However, an observational cross-sectional study cannot determine whether anemia caused a subsequent outcome.

Children with pulmonary TB may have distinct nutritional needs, infection characteristics, and hematological reference ranges. Recognizing anemia and distinguishing potential iron deficiency from inflammation-related changes are therefore clinically relevant, especially when comprehensive diagnostic services are limited. Although local evidence exists on childhood TB and treatment outcomes [21], the distribution of anemia severity and red-cell morphological patterns in children attending individual tertiary-care facilities deserves further description. The present study aimed to determine the frequency of anemia among children aged 6–12 years with pulmonary TB attending Gulab Devi Hospital, Lahore, and to classify anemia by severity and red-cell morphology. The study also describes reported etiological categories and explores associations with sex, C-reactive protein, and serum albumin. These objectives are descriptive; the findings are not intended to establish causality or to estimate population-wide prevalence.

2. MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Pediatric Medicine, Gulab Devi Hospital, Lahore, Pakistan, between March and July 2026. The planned sample size was 100 children, calculated using WinPepi software at a 95% confidence level, with a stated precision of 10% and an anticipated anemia prevalence of 56.9%. Participants were enrolled by nonprobability consecutive sampling. The study population comprised children of either sex aged 6–12 years who met the study's operational definition of pulmonary tuberculosis. Clinical assessment included a history of cough or fever and a modified Kenneth Jones score greater than 4. This score formed part of the clinical assessment used in determining eligibility [22].

Children were eligible if they were aged 6–12 years, attended the relevant clinic with pulmonary TB according to the study protocol, and had written informed consent provided by a parent or legal guardian. The exclusion criteria were hemolytic anemia, gastrointestinal conditions associated with impaired iron absorption (including celiac disease and inflammatory bowel disease), autoimmune diseases, hematological malignancies, and other malignancies. Following institutional ethical review board approval, the study team screened children for eligibility and explained the purpose, procedures, expected benefits, and confidentiality protections to their parents or guardians.

A structured study proforma was used to record demographic data, clinical history, and findings from physical examination. Particular attention was given to the duration of cough and fever, nutritional status, history of TB contact, and other relevant clinical features. Venous blood samples were collected for complete blood counts, peripheral blood smears, serum ferritin, serum iron, liver and renal function tests, serum albumin, and C-reactive protein (CRP). Abdominal ultrasonography was performed when hepatosplenomegaly or another form of organomegaly was suspected. The clinical and laboratory findings were entered into the study proforma for subsequent analysis.

Anemia was identified in the supplied dataset using the prespecified study threshold of hemoglobin below 11.2 g/dL. This threshold differs from the WHO's age-specific cutoffs, so the observed frequency represents the study's own operational classification rather than a standardized pediatric prevalence estimate [9]. The severity and red-cell morphological classifications were based on hemoglobin values, red-cell indices, and peripheral-smear findings. The distinction between iron-deficiency anemia and anemia of chronic disease was reported by the investigators on the basis of available laboratory information, although the numerical ferritin, iron, and inflammatory-marker thresholds underlying those assignments were not stated.

Study data were coded, entered, and analyzed using IBM SPSS Statistics, version 22.0. Categorical variables, including sex, anemia status, morphology, and severity, were summarized as counts and percentages. Continuous variables, including age, weight, height, and hemoglobin concentration, were summarized using means and standard deviations where appropriate. The observed frequency of anemia was calculated as the number of children classified as anemic divided by the total number enrolled. Stratified descriptions were prepared by age, sex, severity, and morphological pattern. The investigators reported using independent-samples *t*-tests for relevant continuous-variable comparisons and chi-square tests for categorical associations, including selected inflammatory and nutritional parameters. A two-sided *p*-value of 0.05 or less was considered statistically significant. Not every reported comparison was accompanied by a detailed test statistic or subgroup effect estimate.

3. RESULTS

The study enrolled 100 children aged 6–12 years with pulmonary TB. Their mean age was 8.7 ± 1.9 years; 52 (52.0%) were boys and 48 (48.0%) were girls. Using the prespecified hemoglobin criterion of less than 11.2 g/dL, 68 (68.0%) children were classified as anemic, while 32 (32.0%) were not. The demographic characteristics and overall anemia frequency are summarized in Table 1.

Table 1. Baseline characteristics of the enrolled children

Parameter	Total (n = 100)
Mean age (years)	8.7 ± 1.9
Age range (years)	6–12
Boys	52 (52.0%)
Girls	48 (48.0%)
Children with anemia	68 (68.0%)
Children without anemia	32 (32.0%)

The hospital-based study population consisted entirely of children assessed as having pulmonary TB. Approximately two-thirds of these enrolled children met the study's anemia criterion, indicating a substantial hematological burden within this clinical sample. The result should be considered a study-specific frequency because the anemia threshold was not age-stratified.

Table 2. Frequency and severity of anemia among anemic children

Severity category	Frequency (n = 68)	Percentage
Mild anemia	23	33.8%
Moderate anemia	36	52.9%
Severe anemia	9	13.2%
Total	68	100%

Among the 68 children classified as anemic, 36 (52.9%) had moderate anemia, 23 (33.8%) had mild anemia, and 9 (13.2%) had severe anemia, as shown in Table 2. Moderate anemia was therefore the largest recorded severity category, whereas severe anemia accounted for the smallest share. These severity categories reflect the definitions applied in the study.

Table 3. Morphological classification of anemia

Morphological type	Frequency (n = 68)	Percentage
Microcytic hypochromic anemia	47	69.1%
Normocytic normochromic anemia	17	25.0%
Macrocytic anemia	4	5.9%
Total	68	100%

As summarized in Table 3, microcytic hypochromic anemia was recorded in 47 children (69.1% of anemic participants), normocytic normochromic anemia in 17 children (25.0%), and macrocytic anemia in 4 children (5.9%). The predominance of microcytic hypochromic morphology provides a reason to investigate iron status, but this finding alone does not establish iron deficiency as the cause.

Table 4. Reported etiological classification of anemia

Etiological category	Percentage of anemic cases
Iron-deficiency anemia	41%
Anemia of chronic disease	48%
Mixed or unclassified anemia	11%
Total	100%

The reported etiological distribution is presented in Table 4. Anemia of chronic disease accounted for 48% of the classified cases, iron-deficiency anemia for 41%, and mixed or unclassified anemia for 11%. These proportions reproduce the study findings; the authors should provide the laboratory decision rules supporting these assignments, particularly because ferritin is affected by inflammation.

Table 5. Comparison of anemia frequency by sex

Gender	Anemia Present	Anemia Absent	Total
Boys	33 (63.5%)	19 (36.5%)	52
Girls	35 (72.9%)	13 (27.1%)	48
Total	68 (68.0%)	32 (32.0%)	100

The sex-stratified frequencies are provided in Table 5. Anemia was recorded in 35 of 48 girls (72.9%) and 33 of 52 boys (63.5%). The observed proportion was higher among girls, but no significance test or confidence interval was reported for this comparison. Consequently, the data should not be described as demonstrating a significant sex-related difference.

Table 6. Reported associations between anemia and inflammatory and nutritional parameters

Parameter	Reported finding	Statistical significance
C-reactive protein	Elevated CRP associated with anemia	$p < 0.05$
Serum albumin	Hypoalbuminemia associated with anemia	$p < 0.05$

Table 6 summarizes the reported associations between anemia and selected clinical laboratory indicators. Elevated CRP and hypoalbuminemia were each described as associated with anemia at $p < 0.05$. CRP may reflect systemic inflammation, whereas low albumin may reflect inflammation, nutritional vulnerability, or both. Because the table does not include group means, effect estimates, or exact p -values, these findings should be interpreted as reported associations rather than evidence of a particular causal pathway.

Taken together, Tables 1–6 describe a high frequency of anemia among the enrolled children, a predominance of moderate severity, and a chiefly microcytic hypochromic morphological pattern. The reported etiological findings raise the possibility that both iron deficiency and inflammation contribute to the hematological presentation of pulmonary TB

in this population. The higher observed frequency among girls should not be treated as statistically established, and the reported associations with CRP and albumin warrant fuller numerical documentation. The study findings support careful hematological and nutritional assessment but do not determine the direction of these relationships.

4. DISCUSSION

Anemia is a frequent hematological abnormality among patients with TB and may reflect the combined effects of infection-related inflammation, altered iron metabolism, nutritional deficiencies, and reduced erythropoiesis. In this hospital-based cross-sectional study, 68% of children with pulmonary TB were classified as anemic using the investigators' operational hemoglobin threshold. This finding demonstrates that anemia was common in the enrolled clinical population, although it does not indicate the frequency among all children with TB in Lahore or Pakistan. International studies have shown that the epidemiology and management of TB are complicated by comorbidity, variable treatment adherence, and differences in healthcare access [2]. In Pakistan, both pulmonary and extrapulmonary manifestations contribute to the national burden of disease, reinforcing the importance of comprehensive assessment [3, 5].

The observed anemia frequency is broadly comparable to estimates from some systematic reviews, but comparisons require attention to differences in age, case definitions, and study setting. Barzegari and colleagues reported a pooled prevalence of approximately 61.5% in studies of patients with TB, while Abaynew and colleagues reported approximately 69% in an African review [15, 16]. Farhadian and colleagues also described a high pooled burden of anemia among newly diagnosed patients with TB [17]. These syntheses include populations that are not equivalent to the present pediatric cohort. In particular, the single hemoglobin threshold used in this study differs from the WHO's age-specific recommendations, so the reported 68% should be understood as an operational estimate pending reclassification of individual hemoglobin measurements [9].

The morphological findings help characterize the clinical presentation. Microcytic hypochromic anemia was the most common pattern, recorded in 47 of the 68 anemic children (69.1%), whereas 17 (25.0%) had normocytic normochromic anemia and 4 (5.9%) had macrocytic anemia. Iron deficiency is a common reason for microcytosis and hypochromia, but similar findings can coexist with inflammation-related iron restriction. Consequently, hemoglobin concentration, red-cell indices, smear morphology, and appropriate iron studies should be interpreted together rather than relying on the blood film alone [10, 23]. Research on tuberculosis-associated anemia has likewise documented multiple patterns and emphasizes the need to distinguish overlapping causes [12, 14].

Moderate anemia constituted 52.9% of the anemic cases, followed by mild anemia (33.8%) and severe anemia (13.2%). This distribution differs from some prior cohorts in which mild or normocytic normochromic anemia predominated. The disparity may reflect age differences, nutritional exposures, study setting, diagnostic thresholds, or the clinical spectrum of TB at enrollment. Importantly, the severity counts in the present manuscript were not accompanied by the individual hemoglobin measurements or the exact boundaries used for each severity category. Those criteria should be documented before the categories are compared directly with other studies or international guidelines. Evidence from adult pulmonary TB cohorts has connected anemia with adverse outcomes, but such associations do not establish corresponding prognostic effects among these children [19, 20].

The study classified 48% of anemia cases as anemia of chronic disease, 41% as iron-deficiency anemia, and 11% as mixed or unclassified. These reported categories are clinically plausible in a population affected by a chronic inflammatory infection, but their diagnostic interpretation depends on laboratory criteria. During inflammation, iron can become sequestered within reticuloendothelial cells, reducing its availability to developing erythrocytes even when total body iron stores are not depleted. Prospective research has demonstrated altered iron regulation in patients with TB-associated anemia of inflammation [11]. Work examining iron biomarkers before and during TB treatment shows that anemia of inflammation and true iron deficiency may require different approaches and may recover at different rates [12]. Serum ferritin and serum iron were measured but their distributions were not reported or the precise criteria by which the three etiological classes were assigned. This limits the strength of mechanistic inferences.

Inflammation and nutritional status may also help explain the laboratory findings. Elevated CRP and hypoalbuminemia were each reported to be associated with anemia at $p < 0.05$. CRP is an inflammatory indicator, while albumin can be influenced by inflammatory activity, dietary intake, and other clinical conditions. A study of TB cases found that anemia was more frequent in patients with features of more severe disease, suggesting that anemia can accompany broader systemic illness [24]. Another investigation linked anemia with wasting and clinical disease characteristics [25]. These findings are consistent with the possibility of interacting inflammatory and nutritional processes, but the present cross-sectional analysis cannot establish whether those processes preceded or resulted from anemia. Exact estimates for CRP and albumin groups would enable clearer comparison and assessment of clinical relevance.

The association between TB and poor nutrition has particular implications for children, whose growth increases the need for adequate dietary energy and micronutrients. Infection-related anorexia, inflammation, and metabolic demands may aggravate pre-existing nutritional vulnerability [8]. Pediatric research has documented the co-occurrence of TB, poor

growth indices, reduced albumin, and anemia, particularly in more extensive disease presentations [7]. In the current study, a detailed dietary intake assessment was not available. Therefore, the specific contribution of iron intake or other nutritional deficiencies cannot be determined from the reported data. Nevertheless, the predominance of microcytic hypochromic morphology and the reported low-albumin association support the clinical importance of comprehensive nutritional evaluation.

The proportion of children classified as anemic was numerically higher among girls (72.9%) than among boys (63.5%). However, the manuscript does not provide a formal significance test or confidence interval for this comparison, and the study was not powered specifically to evaluate sex differences. Thus, the observed pattern is descriptive rather than evidence of a sex-specific biological effect. International meta-analyses have reported variation in the distribution of anemia by sex, but these broader estimates cannot replace an adequately powered pediatric analysis in the present setting [16]. Age, nutritional status, illness duration, and other potential confounding factors should be considered in future research.

The study's clinical relevance also lies in recognizing anemia during TB assessment rather than waiting for severe hematological symptoms. Some prior studies have reported changes in anemia as TB treatment proceeds, suggesting that inflammation-related hematological abnormalities may improve after effective therapy [18]. Other cohorts have examined whether baseline anemia is associated with treatment outcomes or prognosis [20, 26]. Research in Pakistan has identified predictors of unsuccessful treatment among children with TB, illustrating the importance of careful follow-up and assessment of associated clinical risks [21]. Nonetheless, the current study did not follow participants longitudinally, measure treatment response, or evaluate mortality. Its conclusions must therefore remain limited to the prevalence and patterns of anemia at the time of assessment.

Several methodological limitations should be considered when interpreting these findings. The sample was drawn from a single tertiary-care hospital through consecutive nonprobability sampling and included only 100 children aged 6–12 years. The study report did not specify the numerical hemoglobin boundaries for each severity class or the laboratory thresholds for assigning anemia of chronic disease versus iron deficiency. It also lacked exact effect estimates for the associations with CRP and albumin. In addition, eligibility was based partly on a clinical scoring approach, and the supporting microbiological or radiological criteria used to establish pulmonary TB were not fully described. Most importantly, the hemoglobin cutoff of less than 11.2 g/dL differs from internationally recommended age-specific values, potentially affecting both frequency and severity estimates. These limitations justify cautious interpretation and motivate further study with standardized classification, clearer diagnostic documentation, and larger multicenter pediatric samples.

Overall, this study identifies anemia as a common co-occurring condition in the assessed children with pulmonary TB, with moderate severity and microcytic hypochromic morphology predominating. The reported etiological findings suggest that iron deficiency and inflammation may both contribute to the hematological profile. A systematic review of newly diagnosed TB cases similarly concluded that hematological abnormalities deserve attention during clinical care [17]. Before extending the present estimates to a broader population, future investigations should reclassify hemoglobin values using age-appropriate thresholds, describe iron biomarkers and inflammatory status transparently, and follow children during and after TB treatment. Such studies would help clarify the origins of anemia and its relationship to recovery without implying causation from the current cross-sectional findings.

5. CONCLUSION

In this cross-sectional study of 100 children aged 6–12 years with pulmonary TB attending a tertiary-care hospital in Lahore, 68% met the study's operational criterion for anemia. Moderate anemia was the most frequently reported severity category, and microcytic hypochromic anemia was the predominant morphological pattern. Anemia of chronic disease and iron-deficiency anemia were the leading reported etiological categories, indicating the potential relevance of both inflammatory and nutritional factors. Elevated CRP and hypoalbuminemia were reported to be associated with anemia, but this observational design does not establish causality or quantify the strength of those associations. Routine hemoglobin assessment, red-cell indices, and appropriately interpreted iron studies may help identify hematological problems in children being treated for pulmonary TB. Nevertheless, the results should be interpreted cautiously because the study was conducted at one hospital, applied a single hemoglobin threshold across ages 6–12 years, and did not include longitudinal follow-up. Larger multicenter studies applying age-specific anemia criteria, clearly defined etiological categories, detailed nutritional assessment, and repeated measurements during TB treatment are needed to establish more generalizable pediatric estimates and determine whether improvement in anemia accompanies clinical recovery.

Author contributions

All authors contributed equally to the conception, development, preparation, and revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Conflict of interests

The authors declare that they have no conflicts of interest.

Data availability

Participant-level clinical and laboratory data were collected and analyzed for this study. They are not publicly shared because they may contain sensitive health information. Requests for de-identified data may be directed to the corresponding author and will be considered subject to institutional authorization, applicable privacy requirements, and the conditions of informed consent.

Funding statement

The authors received no specific funding for this research.

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