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Original Research Article

Prevalence, Severity, and Morphological Patterns of Anaemia Among Tribal Children and Adolescents in Chhotaudepur District, Gujarat: A Community-Based Cross-Sectional Study

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ABSTRACT

Background: Anaemia disproportionately affects tribal populations in India due to nutritional deficiencies, haemoglobinopathies, and limited healthcare access. Community-level data from tribal districts of Gujarat are lacking.

Aims and Objectives: To assess the prevalence, severity, and morphological patterns of anaemia among tribal children and adolescents in Chhotaudepur district, Gujarat, and to evaluate its association with socio-demographic and anthropometric variables.

Study Design: Community-based cross-sectional study.

Setting: Government residential school, Kawant taluka, Chhotaudepur district, Gujarat, India (February–March 2025).

Materials and Methods: A total of 1,478 tribal participants aged 10–20 years were enrolled. CBC was performed on a Sysmex XP-300 analyser; anaemia was classified by WHO 2011 haemoglobin thresholds (age- and sex-stratified) and morphologically by MCV/MCH. Sickling solubility test (2% sodium metabisulphite) was used for haemoglobinopathy screening.

Statistics: IBM SPSS v25.0; chi-square, Fisher's exact, independent t-test, and Spearman correlation; $p<0.05$ considered significant.

Results: Anaemia prevalence was 60.08% (95% CI: 57.6–62.6%). Among anaemic participants, 63.96% had mild, 33.33% moderate, and 2.70% severe anaemia. Microcytic anaemia was the predominant morphological type (95.27%); no macrocytic anaemia was detected. Sickling solubility test positivity was observed in 10.22% of participants. Anaemia was significantly associated with caste ($p=0.005$) but not with age, sex, below poverty line status, or anthropometric parameters.

Conclusion: Anaemia is highly prevalent among tribal school-going children in Chhotaudepur, with a predominantly microcytic pattern likely due to iron deficiency, as confirmatory iron studies were not performed. Scheduled Tribe membership was the sole significant socio-demographic predictor. Targeted nutritional interventions, iron supplementation, and haemoglobinopathy electrophoresis-based screening are warranted.

Key Words: Anaemia, Adolescent, Tribal Population, Iron Deficiency, Haemoglobinopathies

INTRODUCTION

Anaemia is defined as a haemoglobin concentration below the level required to meet physiological needs.[1] It affects approximately 1.62 billion people globally and remains one of the most prevalent nutritional disorders, particularly among children and adolescents.[2] In India, the burden is substantial: according to the National Family Health Survey (NFHS-5, 2019–21), anaemia affects 67.1% of children, 59.1% of adolescent girls, and 31.1% of adolescent boys.[3,4] Tribal populations are especially vulnerable due to poor nutritional intake, a high prevalence of haemoglobinopathies, infections, and limited healthcare access.

Chhotaudepur district in Gujarat is predominantly inhabited by tribal communities such as Rathwa and Bhil.[5,6] These populations face compounded risks due to socio-economic disadvantage and a higher prevalence of haemoglobinopathies, particularly sickle cell disease. Despite this vulnerability, region-specific community-level data from tribal districts of Gujarat are limited. Therefore, this study was conducted to estimate the prevalence, severity, and morphological patterns of anaemia and to examine its association with socio-demographic and anthropometric factors among tribal school-going children and adolescents in Chhotaudepur district.

MATERIALS AND METHODS

Study Design and Setting

This was a community-based cross-sectional epidemiological study conducted in Kawant taluka of Chhotaudepur district, Gujarat, India, during February and March 2025. The study site was a government-sponsored residential school enrolling students from multiple surrounding villages, providing an efficient sampling frame for the predominantly tribal population.

Ethics and Informed Consent

The study was approved by the Sumandeep Vidyapeeth Institutional Ethics Committee in accordance with the principles of the Declaration of Helsinki (revised 2013). Written informed consent was obtained from parents or legal guardians. Written assent was additionally obtained from adolescents aged ≥12 years; verbal assent was obtained from younger participants. Participant anonymity and data confidentiality were strictly maintained.

Eligibility Criteria

Inclusion criteria: School children aged 10–20 years (Standards VI–XII), permanent residents of Kawant taluka, belonging to tribal communities, providing parental written consent and personal assent, and present on the day of examination.

Exclusion criteria: Acute febrile illness on the day of examination; refusal to participate.

Sample Size

Using the reference anaemia prevalence of 37.3% from Sahoo J et al.,[7] the minimum required sample size was calculated as 1,438 participants (margin of error 2.5%, significance level 5%, two-tailed). The final enrolled sample of 1,478 exceeded this target.

Data Collection

A pretested semi-structured interview schedule was administered by trained field investigators, collecting socio-demographic information (age verified from birth certificates, school records, or Anganwadi registers; sex; religion; caste; below poverty line status; village), a general physical examination, and anthropometric measurements.

Height and weight were measured by standardised protocols; BMI was calculated as weight (kg)/height^2 (m^2). Anthropometric values were classified by centile categories using the Indian Academy of Paediatrics (IAP) 2015 growth charts (Table 1).

Laboratory Methods

Venous blood (3 mL) was collected under aseptic conditions: 2 mL in an EDTA vacutainer for complete blood count (CBC) and sickling solubility testing; 1 mL in a plain vacutainer for ancillary biochemical assessment.

Samples were transported to the hospital laboratory within two hours and processed within four hours. CBC was performed on a Sysmex XP-300 three-part haematology analyser (Sysmex Corporation, Kobe, Japan), providing haemoglobin, WBC count with differential, platelets, PCV, MCV, MCH, MCHC, total RBC, and RDW.

The sodium metabisulphite sickling solubility test was performed as a haemoglobinopathy screening tool. Briefly, a 2% sodium metabisulphite solution was prepared and applied to whole blood under a coverslip; deoxygenation was allowed to proceed for 30 minutes at room temperature. Turbidity of the preparation, indicating sickling of red cells, was defined as a positive result. Haemoglobin electrophoresis for definitive confirmation was not available at the study site.

Definitions

Anaemia was defined and classified using WHO 2011 haemoglobin thresholds stratified by age and sex:[8,9]

children aged 5–11 years (both sexes): Hb <11.5 g/dL (mild 11.0–11.4, moderate 8.0–10.9, severe <8.0 g/dL); females ≥12 years and males 12–14 years: Hb <12.0 g/dL (mild 11.0–11.9, moderate 8.0–10.9, severe <8.0 g/dL); males ≥15 years: Hb <13.0 g/dL (mild 11.0–12.9, moderate 8.0–10.9, severe <8.0 g/dL).

Morphological classification was based on MCV and MCH: microcytic (MCV <80 fL); normocytic normochromic (MCV 80–99 fL, MCH 27–31 pg); macrocytic (MCV ≥100 fL). The primary outcomes were prevalence, severity, and morphological type of anaemia; the secondary outcome was the association of anaemia with socio-demographic and anthropometric variables.

STATISTICS

Data were analysed using IBM SPSS Statistics version 25.0. Continuous variables were expressed as mean ± SD or median (IQR), depending on distribution. Categorical variables were expressed as frequencies and percentages. Group comparisons were performed using the independent samples t-test and Chi-square/Fisher's exact test as appropriate. Spearman's correlation was used to assess relationships between haemoglobin and anthropometric variables. A p-value <0.05 was considered statistically significant. As all analyses were exploratory with no a priori hypotheses, no correction for multiple comparisons was applied.

RESULTS

Total of 1,652 tribal children screened, 174 were excluded (158 not meeting inclusion criteria; 16 declined participation), yielding a final analytic sample of 1,478. The mean age was 14.34 ± 2.02 years; 1,235 (83.56%) were female and 243 (16.44%) males. By religion, 1,475 (99.80%) were Hindu and 3 (0.20%) Muslim. Caste distribution was: ST 1,261 (85.32%), SC 123 (8.32%), OBC 52 (3.52%), and General 42 (2.84%). A total of 1,378 (93.23%) participants were from families below the poverty line. Mean weight was 37.35 ± 7.38 kg, height 149.71 ± 9.63 cm, and BMI 16.85 ± 2.48 kg/m². Full baseline characteristics, including anthropometric classifications, are presented in Table 1.

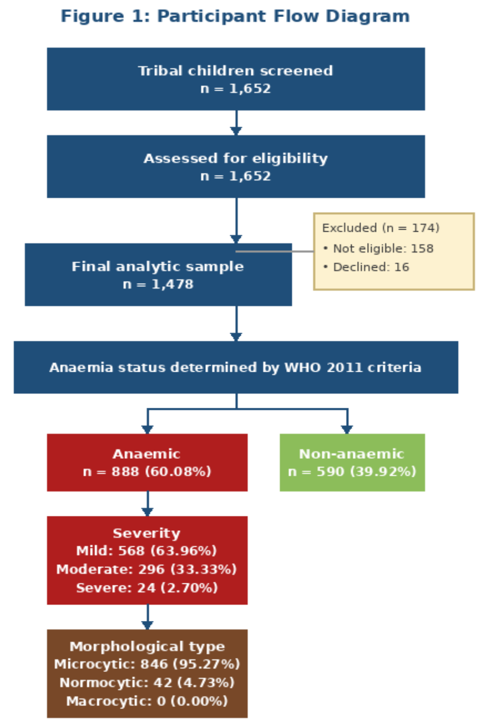

Figure -1: Participant flow diagram.

Table - 1: Socio-Demographic and Anthropometric Characteristics of Study Participants (N=1,478)

Baseline Characteristics	n (%) / Mean ± SD
Age (years)	14.34 ± 2.02
Sex	
Female	1235 (83.56%)
Male	243 (16.44%)
Religion	
Hindu	1475 (99.80%)
Muslim	3 (0.20%)
Caste	
Scheduled Tribe (ST)	1261 (85.32%)
Scheduled Caste (SC)	123 (8.32%)

Other Backward Class (OBC)	52 (3.52%)
General	42 (2.84%)
Below Poverty Line	
Yes	1378 (93.23%)
No	100 (6.77%)
Weight (kg)	37.35 ± 7.38
Height (cm)	149.71 ± 9.63
BMI (kg/m²)	16.85 ± 2.48
Weight Classification (IAP 2015 growth charts)	
Underweight (<3rd centile)	200 (13.53%)
Normal (3rd–97th centile)	1277 (86.40%)
Overweight (>97th centile)	1 (0.07%)
Height Classification (IAP 2015 growth charts)	
Short stature (<3rd centile)	153 (10.35%)
Normal (3rd–97th centile)	1324 (89.58%)
Tall stature (>97th centile)	1 (0.07%)
BMI Classification (IAP 2015 growth charts)	
Undernourished (<5th centile)	211 (14.28%)
Normal (5th–85th centile)	1129 (76.39%)
Overweight (85th–95th centile)	113 (7.65%)
Obese (>95th centile)	25 (1.69%)

BMI = body mass index.

Anthropometric classification based on Indian Academy of Paediatrics (IAP) 2015 growth charts.

Haematological Profile

Descriptive statistics for all haematological parameters are presented in Table 2.

Table - 2: Descriptive Statistics of Haematological Investigations for the Total Cohort (N=1,478)

Haematological Parameter	Median (25th–75th Percentile)
Haemoglobin (g/dL)	11.7 (11.1–12.4)
WBC Count (/µL)	7900 (6800–9300)
Neutrophils (%)	59 (54–64)
Lymphocytes (%)	35 (30–40)
Eosinophils (%)	3 (2–4)
Monocytes (%)	4 (3–5)
Basophils (%)	0 (0–0)
Platelets (×10⁹/L)	3.3 (2.8–3.7)
PCV (%)	37.8 (35.8–39.7)
MCV (fL)	69.3 (66.4–73.6)
MCH (pg)	21.4 (20.4–22.9)
MCHC (g/dL)	30.8 (30.1–31.7)
Total RBC (×10¹²/L)	5.4 (5.1–5.7)
RDW (%)	15.6 (14.8–16.6)

WBC = white blood cell; PCV = packed cell volume; MCV = mean corpuscular volume; MCH = mean corpuscular haemoglobin; MCHC = mean corpuscular haemoglobin concentration; RBC = red blood cell; RDW = red cell distribution width; IQR = interquartile range.

The median haemoglobin for the entire cohort was 11.7 g/dL (IQR 11.1–12.4). Notably, the median MCV (69.3 fL; normal ≥80 fL) and median MCH (21.4 pg; normal ≥27 pg) were both below the lower limits of normal for age, indicating a predominantly microcytic and hypochromic haematological pattern across the cohort, even before anaemia classification.

Prevalence and Severity of Anaemia

Of 1,478 children, 888 (60.08%; 95% CI: 57.6–62.6%) were anaemic and 590 (39.92%) were non-anaemic. Among the 888 anaemic children, severity distribution was: mild 568 (63.96%), moderate 296 (33.33%), and severe 24 (2.70%). Sickling solubility test positivity was detected in 151 (10.22%) of all participants, representing a screening estimate only, as confirmatory haemoglobin electrophoresis was not available at the study site. Of the 151-sickling solubility test-positive participants, 97 (64.2%) were also anaemic, compared with 791 (59.5%) of the 1,327-sickling solubility test-negative participants; this difference was not statistically significant (p=0.237). These data are summarised in Table 3.

Table - 3: Prevalence, Severity, and Morphological Type of Anaemia in the Study Population (N=1,478).

Category	n	% (95% CI)
Total children studied	1478	100.00
Anaemia Status		
Anaemic	888	60.08 (95% CI: 57.6–62.6)
Non-anaemic	590	39.92
Severity of Anaemia (among 888 anaemic)		
Mild	568	63.96
Moderate	296	33.33
Severe	24	2.70
Morphological Type (among 888 anaemic)		
Microcytic (MCV <80 fL)	846	95.27
Normocytic normochromic	42	4.73
Macrocytic (MCV ≥100 fL)	0	0.00
Sickling Solubility Test Positive (of N=1478)		
Positive	151	10.22

95% CI calculated using the Wilson score method. MCV = mean corpuscular volume. Macrocytic anaemia (MCV ≥100 fL) was not observed in this cohort.

Morphological Type of Anaemia

Of the 888 anaemic children, 846 (95.27%) had microcytic anaemia (MCV <80 fL), 42 (4.73%) had normocytic normochromic anaemia, and no macrocytic anaemia (MCV ≥100 fL) was identified. Iron deficiency is the most probable aetiological contributor; however, iron studies (serum ferritin, serum iron, TIBC) and peripheral blood film examination were not done.

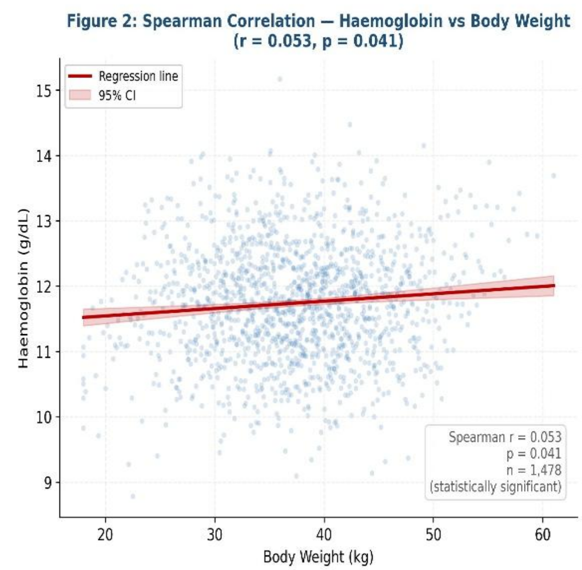

Figure – 2: Spearman's Correlation Between Haemoglobin Concentration and Body Weight

Figure – 2 shows the Scatter plot with regression line depicting Spearman's correlation between haemoglobin concentration (g/dL) and body weight (kg)in 1,478 study participants (r=0.053, p=0.041). A statistically significant but weak positive correlation is observed.

Figure 3 shows Scatter plot with regression line depicting Spearman's correlation between haemoglobin concentration (g/dL) and height (cm) in 1,478 study participants (r=0.066, p=0.012). A statistically significant weak positive correlation is observed.

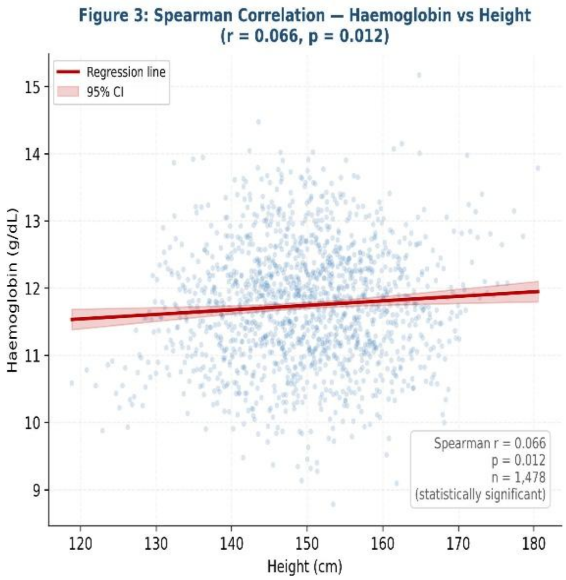

Figure – 3: Spearman's Correlation Between Haemoglobin Concentration and Height

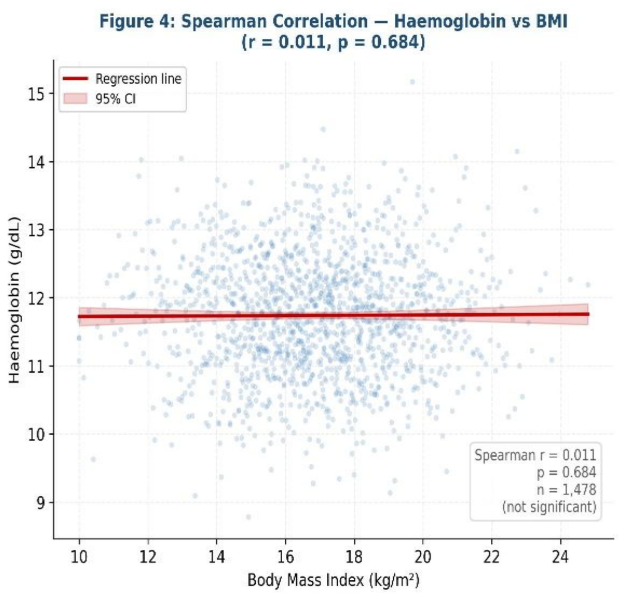

Figure -4: Spearman's Correlation Between Haemoglobin Concentration and Body Mass Index

Figure 4 shows Scatter plot with regression line depicting Spearman's correlation between haemoglobin concentration (g/dL) and body mass index (BMI; kg/m²) in 1,478 study participants (r=0.011, p=0.684). No statistically significant correlation is observed.

Association of Anaemia with Socio-Demographic and Anthropometric Factors Full association data are presented in Table 4.

Sex (p=0.197), age (p=0.278), religion (p=0.280), below poverty line status (p=0.283), weight percentile (p=0.072), height percentile (p=0.395), and BMI percentile (p=0.270) were not significantly associated with anaemia. Caste was the sole significant predictor (p=0.005): anaemia prevalence was highest among ST children (87.95% of anaemic vs 81.36% of non-anaemic). A weak but statistically significant positive correlation was found between haemoglobin and weight (Spearman r=0.053, p=0.041) and height (r=0.066, p=0.012), but not with BMI (r=0.011, p=0.684).

DISCUSSION

This large community-based cross-sectional study of 1,478 tribal school-going children and adolescents in Chhotaudepur district, Gujarat, found an anaemia prevalence of 60.08% (95% CI: 57.6–62.6%), highlighting a substantial public health burden. The observed prevalence is higher than several published reports from tribal populations across India. Sahoo J et al.[7] documented 37.3% anaemia in 953 tribal adolescent school students in Odisha, while Dolai TK et al.[10] reported 46.34% in 1,010 tribal children in West Bengal, and Kumar SV et al.[11] found 28% in 384 Yanadi tribal schoolboys in Andhra Pradesh. In contrast, Sreedhar T et al.[12] reported 66.1% in 1,000 tribal children in Andhra Pradesh — closely concordant with our findings. A systematic review by Daniel RA et al.[13] reported a pooled anaemia prevalence of 65.7% in Indian adolescent girls, with tribal adolescent girls specifically at 63.8%. The higher rates in our cohort compared with some reports likely reflect geographic, dietary, and haemoglobinopathy differences, as well as methodological variation in age cut-offs and diagnostic criteria.

The present prevalence is strikingly consistent with Gujarat state NFHS-5 estimates of 65% anaemia in women and 80% in young children,[4,5] confirming that the tribal population of Chhotaudepur mirrors state-level trends. No directly comparable large-scale tribal anaemia survey exists from Gujarat's Chhotaudepur district, underscoring the novelty and regional public health importance of this study.

Table - 4: Association of Anaemia with Socio-Demographic and Anthropometric Variables.

Characteristic	Anaemic (n=888)	Non-anaemic (n=590)	Total (N=1478)	p Value	Test
Sex					
Female	751 (84.57%)	484 (82.03%)	1235 (83.56%)	0.197	†
Male	137 (15.43%)	106 (17.97%)	243 (16.44%)		
Age (years)					
Mean ± SD	14.39 ± 2.03	14.28 ± 2.03	14.34 ± 2.02	0.278	‡
Religion					
Hindu	885 (99.66%)	590 (100%)	1475 (99.80%)	0.280	*
Muslim	3 (0.34%)	0 (0%)	3 (0.20%)		
Caste					
ST	781 (87.95%)	480 (81.36%)	1261 (85.32%)	0.005	†
SC	63 (7.09%)	60 (10.17%)	123 (8.32%)		
OBC	25 (2.82%)	27 (4.58%)	52 (3.52%)		
General	19 (2.14%)	23 (3.90%)	42 (2.84%)		
Below Poverty Line					
Yes	833 (93.81%)	545 (92.37%)	1378 (93.23%)	0.283	†
No	55 (6.19%)	45 (7.63%)	100 (6.77%)		
Weight percentile (IAP 2015)					
Underweight (<3rd)	131 (14.75%)	69 (11.69%)	200 (13.53%)	0.072	*
Normal (3rd–97th)	757 (85.25%)	520 (88.14%)	1277 (86.40%)		
Overweight (>97th)	0 (0%)	1 (0.17%)	1 (0.07%)		
Height percentile (IAP 2015)					
Short stature (<3rd)	98 (11.04%)	55 (9.32%)	153 (10.35%)	0.395	*
Normal (3rd–97th)	789 (88.85%)	535 (90.68%)	1324 (89.58%)		
Tall stature (>97th)	1 (0.11%)	0 (0%)	1 (0.07%)		
BMI percentile (IAP 2015)					
Undernourished (<5th)	129 (14.53%)	82 (13.90%)	211 (14.28%)	0.270	*
Normal (5th–85th)	636 (71.62%)	493 (83.60%)	1129 (76.39%)		
Overweight (85th–95th)	98 (11.04%)	15 (2.54%)	113 (7.65%)		
Obese (>95th)	25 (2.82%)	—	25 (1.69%)		

*‡ Independent samples t-test; † Chi-square test; * Fisher's exact test. Statistical significance: p<0.05.*
ST = Scheduled Tribe; SC = Scheduled Caste; OBC = Other Backward Class; BPL = below poverty line;
BMI = body mass index. Anthropometric classification based on IAP 2015 growth charts.
No correction for multiple comparisons was applied (exploratory analysis).

The severity distribution — mild 63.96%, moderate 33.33%, severe 2.70% — is broadly comparable with Sahoo J et al.[7] (mild 53.5%, moderate 43.7%, severe 2.8%). The combined burden of mild and moderate anaemia, affecting over 96% of anaemic children, carries important consequences for cognitive development, academic performance, physical growth, and immune function.

Microcytic anaemia accounted for 95.27% of all anaemia cases, consistent with findings from Dolai TK et al.[10] (microcytosis in 81.68%) and Sreedhar T et al.[12] (80.31% microcytic hypochromic anaemia). This pattern, driven by inadequate dietary iron intake and poor bioavailability from predominantly cereal-based tribal diets, supports iron deficiency as the likely principal aetiological factor, although this could not be confirmed biochemically. The complete absence of macrocytic anaemia may reflect traditional dietary practices of the Rathwa and related communities of eastern Gujarat that include non-vegetarian items, reducing the risk of vitamin B12 and folate deficiency — though a formal dietary survey was not conducted. By contrast, Ashok C et al.[14] found macrocytic anaemia in 18% of a tribal paediatric cohort in Jharkhand, reflecting substantial regional dietary heterogeneity.

The significant association of Scheduled Tribe membership with anaemia (p=0.005) likely reflects compounding effects of nutritional deficiencies, genetic predisposition to haemoglobinopathies, reduced healthcare access, and community-level socioeconomic disadvantage. The absence of a significant association with the BPL poverty indicator reflects near-uniform poverty status in this cohort (93.23% BPL), which drastically reduces statistical power to detect between-group differences. The absence of significant anthropometric associations may indicate that anaemia is driven primarily by micronutrient deficiency and haemoglobinopathies rather than by overall caloric deprivation — consistent with findings from comparable tribal populations.[3,10]

The sickling solubility test positivity rate of 10.22% is clinically significant and argues strongly for inclusion of haemoglobin electrophoresis as a routine component of tribal health surveys in this region. The weak but significant positive correlations of haemoglobin with weight (r=0.053, p=0.041) and height (r=0.066, p=0.012), in the absence of a significant correlation with BMI (r=0.011, p=0.684), suggest that lean body mass and somatic growth may have marginal positive effects on haemoglobin levels. These correlations are of low clinical magnitude and must be interpreted as exploratory findings.

Study Limitations

The cross-sectional design precludes causal inference. The study was conducted at a single residential school in one taluka, limiting generalisability. Detailed dietary intake assessment, menstrual history, worm infestation history, and prior iron supplementation were not recorded. Iron studies (serum ferritin, serum iron, TIBC) and peripheral blood film examination were unavailable. Sickling solubility test-positive cases could not be confirmed by haemoglobin electrophoresis, as this facility was not available at the study site. The predominantly female composition (83.56%; only 243 boys, 16.44%) reflects residential school enrolment patterns and may limit representativeness for male tribal adolescents; as national data indicate a markedly lower anaemia burden in adolescent boys than girls (31.1% vs 59.1%), the small male subgroup in this study was likely underpowered to detect sex-specific associations, and the findings on anaemia prevalence and its correlates may not be generalisable to boys. No correction for multiple comparisons was applied across seven statistical tests; results should be treated as hypothesis-generating. Despite these limitations, the large sample size, standardised laboratory methodology, and WHO-based age- and sex-stratified diagnostic criteria represent methodological strengths.

CONCLUSIONS

Anaemia affects 60.08% (95% CI: 57.6–62.6%) of tribal school-going children and adolescents in Chhotaudepur district, Gujarat, with microcytic anaemia accounting for

95.27% of cases, suggestive of a predominantly nutritional iron deficiency aetiology. Scheduled Tribe community membership was the sole significant socio-demographic predictor of anaemia. The 10.22% sickling solubility test positivity signals a substantial, incompletely characterised haemoglobinopathy burden requiring electrophoresis-based confirmation. These findings call for tribe-targeted, multi-pronged interventions: strengthening of the Weekly Iron and Folic Acid Supplementation (WIFS) programme, community-level dietary iron education, school-based haemoglobin electrophoresis screening, and de-worming initiatives. Multi-centre studies across tribal districts of Gujarat are needed to generate state-representative estimates and inform policy.

What was already known before this study
• Anaemia is highly prevalent among Indian tribal populations, driven by nutritional deficiencies, haemoglobinopathies, and socioeconomic disadvantage. • National surveys (NFHS-5) document approximately 65% anaemia in Gujarat women and 80% in children under five, but tribal-specific district-level data are lacking. • Microcytic, iron-deficiency anaemia is the predominant morphological pattern in most Indian paediatric anaemia surveys.
What this study adds
• This is among the largest single-site community-based haematological surveys from a tribal district of western India, enrolling 1,478 children with standardised WHO age- and sex-stratified classification. • Anaemia prevalence in Chhotaudepur tribal school-going children is 60.08%, with microcytic anaemia accounting for 95.27% of cases, suggesting iron deficiency as the dominant aetiology. • Scheduled Tribe membership is the sole significant socio-demographic predictor; poverty, sex, age, and anthropometric indicators were not independently associated. • A sickling solubility test positivity rate of 10.22% identifies a substantial haemoglobinopathy burden warranting electrophoresis-based confirmation in future surveys.

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