Original Article

Prevalence and factors associated with anemia in 6–18 years urban and rural Indian children and adolescents: A multicenter study

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ABSTRACT

Background: Anemia in India is a major public health problem. A better understanding of regional differences in the prevalence of anemia and the association of anemia with growth and quality of life (QOL) among children and adolescents is crucial for providing insights for suitable interventions. **Objectives:** The main objectives were to estimate the prevalence of anemia in rural and urban Indian children and study association of anemia with growth and QOL. **Materials and Methods:** A multicentre, cross-sectional, and observational school-based study (n=13885, July 2016–October 2017) in urban and rural regions of six Indian states (Maharashtra, Gujarat, Tamil Nadu, Punjab, Chhattisgarh, and Assam) was conducted. Anthropometry and hemoglobin (HemoCue) were measured by trained staff. Demographic details, parental-education, QOL, anthropometry, and hemoglobin were recorded using pre-validated and pre-tested questionnaires/standard procedures. Regression analysis was performed to identify predictors of anemia. **Results:** Overall, 26% of the study children were anemic (girls [29%] >than boys [23%]). Gujarat was most affected (37% anemic); rural areas had a higher prevalence of anemia than urban (20%; $p<0.0001$). The prevalence of stunting was higher in anemic children (stunting: 7%, height Z-score <−1=23–26%) than non-anemic (4%; height Z-score <−1=19%) children. Mean QOL score was lower in anemic versus non-anemic (1706±349 vs. 1795±325, $p<0.05$). Maternal education and child's age positively predicted anemia; the odds ratio for children of illiterate mothers to have anemia was higher (β=1.7; confidence interval: 1.4–2.1; $p<0.05$). **Conclusion:** Prevalence of anemia remains a public health problem among children (6–18-years) in India; maternal education is a contributing factor. Compromised growth and QOL are major considerations.

Key words: *Anemia, Education, Growth, Hemoglobin, Indian children, Quality of life*

India is among the countries having the highest prevalence of anemia. Anemia in India is a major public health challenge and is responsible for approximately 1 million deaths annually and is the second leading cause of disability worldwide [1]. Iron deficiency is the leading cause of anemia globally; 33% of school-going children have been reported to be anemic worldwide [2]. The predominant reason for a high prevalence of iron deficiency in children and adolescents is believed to be an increased iron requirement during the growth phase, which is approximately 10 times higher/kg of the body weight as compared to an adult male [3,4]. Children with anemia are reported to be significantly shorter, with lower growth rates in comparison with their age-matched controls [5].

Anemia can also cause impaired cognitive and motor development, weakened immune response, and decreased physical and mental productivity, consequently affecting the quality of life (QOL) [1,2,6,7]. Influence of anemia on QOL has been studied in either adult or geriatric populations or on patients (cancer, AIDS, chronic obstructive pulmonary disease, etc.), where anemia was associated with a reduced QOL [8–12]. However, there is a scarcity of research focusing on the association of anemia with QOL in children and adolescents.

A better understanding of the regional differences in the prevalence of anemia and the association of anemia with growth and QOL among children and adolescents is crucial for providing insights for suitable interventions. The objectives of the present study were to estimate the prevalence of anemia in rural and urban 6–18-year-old Indian children and adolescents from selected centers in India, study the association of anemia with growth parameters and study association of anemia with QOL as measured by Pediatric Quality of Life Inventory (PEDsQL) questionnaire.

MATERIALS AND METHODS

A multicentre, cross-sectional, and observational school-based study was conducted by adopting a multi-stage stratified random sampling procedure. Six Indian states were randomly selected using census data 2011 (http://www.censusindia.gov.in/pca/Searchdata.aspx). From the selected states, one city per state and one nearby village were randomly selected (Maharashtra [Pune, Ranjangaon], Gujarat [Bilimora, Gandevi], Tamil Nadu [Chennai, Urapakkam], Punjab [Mohali, Lalru], Chhattisgarh [Raipur, Kurud], and Assam [Diphu, Manja]). With the help of local investigators, a list of schools (from urban areas and rural areas) was prepared. From the listed schools, one school was selected from each area using a computerized random number sequence method. Of 100 screened schools, 40 schools were finally included for the health check. Written informed consent was obtained from the respective local health authorities, school authorities, and parents before commencing the study. Verbal assent was obtained from all participants. The study has been approved by the institutional ethics committee and has been performed following the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

From the selected schools, all children (aged 6–18 years) from whom consent and assent were obtained were examined by a pediatrician to rule out any pre-existing health ailments such as hemoglobinopathies or other chronic disorders. Data on children with weight or height below or above five standard deviations (SD) were excluded (117) as data entry errors and two children were diagnosed with type 1 diabetes mellitus while screening and were excluded from the analysis [13].

Data were collected from July 2016 to October 2017 with a team of pediatricians, pediatric phlebotomists, auxologists, and nutritionists. The same set of height and weight measuring equipment was used and was calibrated periodically. HemoCue and cuvettes from the same manufacturer were used to assess hemoglobin (Hb) in all children at all sites. Participating staff received training and re-training about study protocols at each center. Information on school location, fee structure, and child's date of birth was obtained from the school records.

Height and weight were measured in all participating children using portable stadiometer to the nearest millimeter (Seca Portable stadiometer, 20–205 cm, Hamburg Germany) and weight to the nearest 100 g with the help of an electronic scale (Seca 876 Flat scale, Seca GmbH & Co. kg, Hamburg, Germany) using standard protocols. Body mass index (BMI) was computed using the formula weight (kg)/height (m^2). Using Indian reference data [14], Z-scores for height, weight, and BMI were computed.

The manufacturer's protocol was used to calibrate HemoCue cuvettes before the data collection from each center. The inter-assay coefficient of variation (CV) was <0.8% and intra-assay CV was <0.9%. Before testing the Hb concentration, every child was informed about the procedure of measurement. The procedure was done after he/she was comfortable about the testing. The chosen finger was first cleaned with a spirit swab (70% ethyl alcohol) and then pricked with sterile single-use safety lancet. After discarding the first drop, the next drop was used to measure Hb using the cuvettes provided by the manufacturer. Readings were recorded in the pro forma.

Anemia was classified as per the World Health Organisation (WHO) recommendations [7]. Classification for children (5–11 years): (i) Within reference range (Hb ≥11.5 g/dl), (ii) mildly anemic (Hb=11.0–11.49 g/dl), (iii) moderately anemic (Hb=8.0–10.9 g/dl), and (iv) severely anemic (Hb <8.0 g/dl). Classification for boys (12–14 years) and girls (12 years and above): (i) Within reference range (Hb ≥12.0 g/dl), (ii) mildly anemic (Hb=11.0–11.9 g/dl), (iii) moderately anemic (Hb=8.0–10.9 g/dl), and (iv) severely anemic (Hb <8.0 g/dl). Classification for boys above 15 years: (i) Within reference range (Hb ≥13.0 g/dl), (ii) mildly anemic (Hb=11.0–12.9 g/dl), (iii) moderately anemic (Hb=8.0–10.9 g/dl), and (iv) severely anemic (Hb <8.0 g/dl).

QOL was assessed using Paediatric QOL Inventory™ (PedsQL™ 4.0 Copyright© 1998) [15,16]. The questionnaire composed of 23 items consisted of 4 dimensions: Physical (8 questions), emotional (5 questions), social (5 questions), and school functioning (5 questions). Every item was scaled based on a 5-point Likert scale from 0 (never) to 4 (Almost always). The scores were further transformed on a scale from 0 to 100. A total score was generated by summing up all the items over the number of items answered on all scales. A higher score indicated better QOL. If more than 50% of questions were not answered, the record was excluded from the analysis. QOL was measured in all the children except (i) boys above 15 years from Maharashtra (children had examinations) and (ii) Gujarat (all children).

Demographic details such as socioeconomic status and parental education were obtained using a standardized and validated questionnaire from Kuppuswamy scales [17].

Data were categorized as per age, state, region, and gender. Data were analyzed using SPSS 25.0 for Windows (SPSS Inc., Chicago, USA). The normality of all the outcome variables that is anthropometric parameters, QOL scores, and Hb concentrations was tested. Depending on the normality of the variables, parametric or non-parametric tests were applied. Binary logistic regression analysis was performed to identify the risk factors for anemia; significance level was set at $p<0.05$. Anemia was selected as the dependent variable and age, socioeconomic class, BMI, and maternal education were selected as the independent variables.

RESULTS

A total of 13,885 healthy children and adolescents (6339 girls) in the age group of 6–18 years were studied. Tables 1 and 2 summarize the descriptive characteristics (mean±SD) of the study population stratified by gender, urban/rural residence, and age. Based on the growth rates, boys were classified as 6–12 years (Group A), 13–15 years (Group B), and 16–18 years (Group C), and girls as 6–9 years (Group A), 10–14 years (Group B), and 15–18 years (Group C) [18].

Rural regions showed a higher prevalence of anemia in most of the states. On comparing the interstate prevalence (both regions combined), Gujarat (Hb within reference range: 63%, mild anemia: 21%, moderate to severe anemia: 16%) was the most affected state with the highest prevalence of anemia, followed by Punjab, Assam, Tamil Nadu, Maharashtra, and Chhattisgarh.

Table 1: Demographic characteristic of urban and rural boys from 6 Indian states

Group type	Variables	Maharashtra	Gujarat	Tamil Nadu	Punjab	Chhattisgarh	Assam
Group A (6–12 year) Urban	n	415	438	218	148	360	321
	Age (years)	8.4±1.8	8.5±2.1	8.5±2.0	9.3±1.8	9.2±1.1	8.8±1.7
	SDS height	−0.08±0.9[g,p,a,†]	−0.54±0.9[m,t,c. †]	−0.06±1.0[g,p,a]	−0.42±1.0[m,t, †]	−0.04±0.9[g,p,a,†]	−0.38±0.9[m,t,c,†]
	SDS weight	−0.35±1.2[g,t,c,†]	−0.61±1.0[m,t,c, †]	−0.16±1.2[m,g,p]	−0.51±0.9[t,c, †]	−0.02±1.0[m,g,p,a,v]	−0.37±1.1[c,†]
	SDS BMI	−0.5±1.2[t,c,a,†]	−0.53±1.1[t,c,†]	−0.23±1.2[m,g]	−0.44±0.9[c, †]	−0.05±1.1[m,g,p,†]	−0.3±1.0[m]
	Hb (g/dl)	13.0±1.1[g,t,p,a,†]	12.2±1.1[m,t,c,a]	12.4±1.1[m,g,c,†]	12.1±1.3[m,c,a]	13.0±1.1[g,t,p,a,†]	12.5±1.2[m,g,p,c,†]
	QOL score	2013±241[†]	NA	1798±333[†]	1737±308[†]	1865±282	2262±52[†]
Group A (6–12 year) rural	n	717	245	452	19	141	213
	Age (years)	8.5±1.6	8.7±2.0	8.5±2.0	9.3±1.8	9.4±1.7	8.8±2.1
	SDS height	−0.85±0.9[t,p,c,†]	−0.83±0.9[t,p,c]	−0.03±0.9[m,g,p,c,a]	−1.15±0.9[m,g,t,a]	−1.21±1.1[m,g,t,a]	−0.67±1.1[t,p,c]
	SDS weight	−1.28±0.9[t,a,†]	−1.17±0.9[t,a]	−0.22±1.1[m,g,p,c,a]	−1.28±0.9[t,a]	−1.39±0.9[t,a]	−0.61±0.9[m,g,t,p,c]
	SDS BMI	−1.23±1.1[t,a,†]	−1.09±1.1[t,a]	−0.36±1.2[m,g,p,c]	−0.98±0.8[t,a]	−1.09±0.8[t,a]	−0.42±0.8[m,g,p,c]
	Hb (g/dl)	12.3±1.3[g,a,†]	12.0±1.2[m]	12.2±1.2[†]	12.5±1.6	11.9±1.2	12.0±1.6[m]
	QOL score	1994±210	NA	1637±369	1484±370	1692±315	1770±210
Group B (13–15 year) urban	n	336	132	433	249	352	139
	Age (years)	13.6±1.0	13.6±1.1	14.1±1.1	14.1±1.2	13.7±1.2	13.4±1.1
	SDS height	0.2±1.0[g,p,a,†]	−0.46±1.0[m,t,p,c,†]	0.08±0.9[g]	−0.03±1.1[m,g,†]	0.04±0.9[g,†]	−0.17±1.1[m,†]
	SDS weight	0.07±1.0[g,p,a,†]	−0.37±1.1[m,t,c,†]	0.09±1.1[g,p,a]	−0.26±1.0[m,t,c,†]	0.18±1.1[g,p,a,†]	−0.24±0.9[m,t,c,†]
	SDS BMI	−0.07±1.1[p,c,†]	−0.26±1.1[c,†]	0.04±1.1[p]	−0.31±0.9[m,t,c,†]	0.16±1.1[m,g,p,a,†]	−0.23±0.9[c]
	Hb (g/dl)	13.8±1.4[g,t,p,a,†]	12.8±1.3[m,t,p,c]	13.5±1.5[m,g,c]	13.3±1.7[m,g,c]	13.9±1.3[g,t,p,a,†]	13.2±1.6[m,c]
	QOL score	2033±229[†]	NA	1793±377	1763±322[†]	1808±295[†]	2073±159[†]
Group B (13–15 year) rural	n	133	350	239	154	213	303
	Age (years)	13.4±1.1	14.0±1.0	13.8±1.2	14.2±1.2	14.1±1.1	13.9±1.1
	SDS height	−0.94±0.9[t,p]	−0.72±1.1[t,c]	0.09±0.9[m,g,p,c,a]	−0.51±1.1[m,t,c]	−1.02±0.9[g,t,p,a]	−0.71±1.1[t,c]
	SDS weight	−1.25±1.0[t,p,a]	−1.02±1.1[t,p,a]	0.02±1.0[m,g,p,c,a]	−0.75±0.9[m,g,t,c]	−1.23±0.9[t,p,a]	−0.59±0.9[m,g,t,c]
	SDS BMI	−1.17±1.3[g,t,p,a]	−0.89±1.0[m,t,p,a]	−0.06±1.1[m,g,p,c,a]	−0.65±0.8[m,g,t,c,a]	−0.98±0.8[t,p,a]	−0.33±0.7[m,g,t,p,c]
	Hb (g/dl)	12.6±1.6[t]	12.6±1.4[t]	13.3±1.3[m,g,c]	13.0±1.5[c]	12.6±1.5[t,p]	12.9±1.6[m,g]
	QOL score	1916±221	NA	1744±252	1506±370	1598±325	1723±340
Group C (16–18 year) urban	n	NA	12	128	144	22	35
	Age (years)	NA	17.2±0.7[c]	16.6±0.5[p,a]	17.2±1.0[t,c]	16.2±0.2[g,p,a]	17.4±1.0[t,c]
	SDS height	NA	−0.22±1.1	0.02±0.8[p]	−0.35±1.1[t]	−0.21±1.1[†]	−0.36±0.8[†]
	SDS weight	NA	0.22±1.6[†]	0.08±1.1[p,a]	−0.39±1.2[t]	0.04±1.2[†]	−0.63±0.5
	SDS BMI	NA	0.17±1.2[†]	−0.04±1.2	−0.37±1.1[†]	0.09±1.2[†]	−0.6±0.6
	Hb (g/dl)	NA	13.6±1.3[a]	14.4±1.3[a]	14.4±1.7[a]	14.5±1.6	15.3±1.5[g,t,p,†]
	QOL score	NA	NA	NA	1692±304	1925±202[†]	2063±159
Group C (16–18 year) rural	n	10	81	34	56	110	74
	Age (years)	16.4±0.3	16.7±0.5	16.4±0.5	17.3±0.8	17.5±1.2	16.9±0.8
	SDS height	−0.85±0.6	−0.56±0.9[c,a]	−0.06±1.2[c,a]	−0.31±0.9[c,a]	−0.97±0.9[g,t,a]	−1.04±0.9[g,t,p]
	SDS weight	−0.95±0.6[t]	−0.88±0.9[t]	0.33±1.1[m,g,p,c,a]	−0.64±0.9[t,c]	−1.14±0.7[t,p,a]	−0.71±0.9[t,c]
	SDS BMI	−0.66±0.7[t]	−0.78±0.9[t,a]	0.32±1.2[m,g,p,c,a]	−0.69±0.9[t,a]	−0.86±0.7[t,a]	−0.31±0.7[g,t,p,c]
	Hb (g/dl)	13.5±2.3	13.7±1.7	14.2±1.8	14.0±1.9	14.2±1.6	13.8±1.7
	QOL score	1925±248	NA	NA	1729±366	1589±306	1906±287

Hb: Hemoglobin, SDS for height, weight, and BMI were calculated as per IAP 2015 reference growth charts. Quality of life (QOL) scores are absolute scores calculated as per PEDsQL scale. Interstate significances are provided as follows: If significantly different (when p<0.05) m=Maharashtra, g=Gujarat, t=Tamil Nadu, p= Punjab, c=Chhattisgarh, a=Assam. [†]Significantly different from age group matched rural boys

To study the influence of anemia on growth, we examined the prevalence of anemia across different height for age Z score (HAZ) categories that are stunting (HAZ <−2), mild stunting (HAZ <−1), and height within the reference range (HAZ >−1). We found that stunting was less prevalent in children and adolescents with Hb concentrations within the reference range and it increased with the severity of anemia.

To assess the association of malnutrition with the prevalence of anemia, we examined the prevalence of anemia across BMI categories. In children and adolescents who were underweight (BAZ <−2SDS), 28% children were below the reference range of Hb, and in the overweight category (BAZ >2SDS), 23% were below the reference range of Hb indicating that anemia

Table 2: Demographic characteristics of urban and rural girls from 6 Indian states as per age groups

Group type	Variables	Maharashtra	Gujarat	Tamil Nadu	Punjab	Chhattisgarh	Assam
Group A (6–9 year) urban	n	209	286	108	51	133	223
	Age (year)	7.6±1.3	7.6±1.3	7.6±1.4	8.0±1.3	8.1±0.6	8.0±1.2
	SDS height	−0.09±0.9[g,p,a, †]	−0.44±0.9[m,t,a,†]	0.04±0.9[g,p,a]	−0.47±0.9[m,t,c,†]	−0.06±1.1[g,p,a,†]	−0.46±0.8[m,t,c,†]
	SDS weight	−0.36±1.1[t,c,†]	−0.44±1.1[t,c,†]	−0.14±1.1[m,g,p,a]	−0.57±0.9[t,c,†]	−0.07±1.1[m,g,p,a,†]	−0.51±0.9[t,c,†]
	SDS BMI	−0.51±1.2[t,c,†]	−0.35±1.3[†]	−0.26±1.2[m]	−0.49±0.9[†]	−0.19±1.2[m,†]	−0.43±1.0[†]
	Hb (g/dl)	12.8±1.1[g,t,p,a,†]	12.0±1.2[m,c,a]	11.9±1.2[m,c,a]	11.9±1.3[m,c,a]	12.9±1.1[g,t,p,a,†]	12.4±1.2[m,g,t,p,c,†]
	QOL score	NA	NA	2086±270[†]	1617±38	2138±18	NA
Group A (6–9 year) rural	n	495	99	366	2	34	156
	Age (year)	7.8±1.2	7.7±1.5	7.4±1.3	8.3±1.2	7.9±1.4	7.8±1.5
	SDS height	−0.64±0.9[t,c]	−0.77±0.8[t]	−0.06±0.9[m,g,p,c,a]	−0.88±0.9[t]	−1.03±0.8[m,t]	−0.83±1[t]
	SDS weight	−1.14±0.9[t]	−1.06±0.9[t]	−0.23±1.1[m,g,p,c,a]	−1.17±0.9[t]	−1.05±0.8[t]	−1±0.9[t]
	SDS BMI	−1.22±1.1[g,t,c,a]	−0.95±1.1[m,t]	−0.32±1.2[m,g,p,c,a]	−1.03±0.9[t]	−0.71±0.8[m,t]	−0.79±0.9[m,t]
	Hb (g/dl)	12.2±1.3[t]	11.8±1.3	12.0±1.3[m]	12.2±0.1	12.2±1.0	12.1±1.2
	QOL score	1990±445	NA	1756±249	1650±71	2225±106	2135±239
Group B (10–14 year) urban	n	379	148	343	137	417	232
	Age (year)	12.3±1.4	12.3±1.4	12.7±1.4	12.8±1.5	12.2±1.4	12.3±1.4
	SDS height	0.16±0.9[g,p,a,†]	−0.17±0.8[m,c,†]	0.08±0.9[p,a]	−0.46±1.1[m,t,c]	0.10±0.9[g,p,a,†]	−0.19±0.9[m,t,c,†]
	SDS weight	−0.01±1.1[g,p,†]	−0.41±1.0[m,t,c,†]	−0.05±1.1[g,p]	−0.66±0.9[m,t,c,a]	0.14±1.2[g,p,a,†]	−0.18±1.0[p,c,†]
	SDS BMI	−0.11±1.2[g,p,†]	−0.42±1.1[m,c,†]	−0.11±1.2[p]	−0.56±0.9[m,t,c,a]	0.11±1.2[g,p,†]	−0.13±1.1[p]
	Hb (g/dl)	13.2±1.0[g,t,p,a, †]	12.0±1.2[m,t,c,a]	12.5±1.2[m,g,p,c]	11.8±1.6[m,t,c,a]	12.9±1.2[m,g,t,p,†]	12.7±1.2[m,g,p,†]
	QOL score	2000±247[†]	NA	1659±351	1509±280[†]	1875±273	2108±157[†]
Group B (10–14 year) rural	n	227	377	268	95	152	351
	Age (year)	12.1±1.4	13.2±1.4	12.6±1.3	12.7±1.4	13.0±1.4	12.9±1.3
	SDS height	−0.82±0.9[g,†]	−0.66±0.9[t,c]	0.08±0.9[m,g,p,c,a]	−0.62±0.9[t,c]	−0.92±0.9[g,t,p,a]	−0.64±0.9[t,c]
	SDS weight	−1.32±0.9[g,t,p,c,a,†]	−1.02±1.0[m,t,a]	0.05±1.1[m,g,p,c,a]	−0.86±0.9[m,t,a]	−0.9±0.9[m,t,a]	−0.46±0.9[m,g,t,p,c]
	SDS BMI	−1.23±0.9[g,t,p,c,a,†]	−0.9±1.0[m,t,c,a]	0.02±1.2[m,g,p,c,a]	−0.72±0.9[m,t,a]	−0.61±0.9[m,g,t,a]	−0.22±0.9[m,g,t,p,c]
	Hb (g/dl)	12.3±1.6[g,†]	11.8±1.4[m,t,c,a]	12.4±1.3[g]	12.0±1.7[c]	12.5±1.2[g,p]	12.3±1.3[g]
	QOL score	1900±255[†]	NA	1674±283	1687±338	1508±240	1715±353
Group C (15–18 year) urban	n	51	33	181	146	111	65
	Age (year)	15.4±0.3	16.3±1.0	16.1±0.1	16.8±1.2	15.6±0.4	16.43±1.1
	SDS height	0.22±0.9[p,a,†]	−0.33±0.8[†]	0.13±0.9[p,a]	−0.8±1[m,t,c,†]	−0.16±0.9[m,t,†]	−0.44±0.9[m,t,†]
	SDS weight	0.19±0.9[g,p,†]	−0.66±1.1[m,t,c]	0.02±1.2[g,p,†]	−0.92±0.8[m,t,c,a]	0.11±1.1[g,p,†]	−0.29±1.0[p]
	SDS BMI	0.1±1[g,p,†]	−0.59±1.2[m,c]	−0.05±1.2[p,†]	−0.64±0.9[m,t,c,a]	0.2±1.2[g,p,†]	−0.11±0.9[p]
	Hb (g/dl)	13.2±1.3	12.3±1.3	12.2±1.4	11.7±1.8	12.7±1.3	12.7±1.4[†]
	QOL score	1700±288	NA	2229±190[†]	1583±338	1766±260[†]	2025±238[†]
Group C (15−18 year) rural	n	8	199	118	73	49	137
	Age (y)	16.0±0.9	16.1±0.7	15.7±0.6	16.9±1.1	16.9±1.3	16.2±0.9
	SDS height	−0.86±1.1[t]	−0.71±1.0[t]	0.22±0.9[m,g,p,c,a]	−0.47±1[t,c,a]	−0.86±0.9[t,p]	−0.9±0.9[t,p]
	SDS weight	−1.27±1.1[t]	−0.95±1.0[t]	0.34±1.1[m,g,p,c,a]	−0.78±1.0[t,a]	−0.95±0.8[t,a]	−0.42±0.8[g,t,p,c]
	SDS BMI	−1±0.9[t,a]	−0.73±1.1[t,a]	0.28±1.2[m,g,p,c]	−0.65±1.0[t]	−0.65±0.8[t]	−0.04±0.8[m,g,p,c]
	Hb (g/dl)	13.1±1.2	11.9±1.4[c]	11.9±1.6	12.0±1.6	12.7±1.8[g]	12.0±1.5
	QOL score	2092±14	NA	1740±238	1655±304	1423±207	1625±397

Hb: Hemoglobin; SDS for height, weight, and BMI are calculated as per IAP 2015 reference growth charts. Quality of life (QOL) scores are absolute scores calculated as per PEDsQL scale. Interstate significances are provided as follows: If significantly different (when p<0.05) m=Maharashtra, g=Gujarat, t=Tamil Nadu, p=Punjab, c=Chhattisgarh, a=Assam. [†] Significantly different from age group matched rural girls

was prevalent at both the ends of the spectrum that is in the underweight and the overweight.

To determine the influence of maternal education on the prevalence of anemia, we compared the prevalence of moderate to severe anemia with maternal education level categories that are at least 15 years or more, <15 years, and illiterate. The results revealed a higher prevalence of moderate to severe anemia ($p<0.05$) in children belonging to illiterate mothers as compared to the children of educated mothers.

Comparing the total QOL scores in boys from urban and rural regions, we found a significant difference in all the states (except Gujarat, from where the scores were not available) in Group A as well as in Group B (Tables 1 and 2). For girls, the urban and rural regions of Maharashtra, Punjab, and Assam (for Group B) and Tamil Nadu, Chhattisgarh, and Assam (for Group C) showed a significant difference in QOL scores ($p<0.05$).

We also assessed the QOL (based on the QOL scores) in relation to the prevalence of anemia. The results indicate that children and adolescents with Hb concentrations within the reference range had the highest QOL score as compared to those suffering from mild and moderate to severe anemia. Severely anemic children and adolescents showed significantly lower QOL.

Maternal education and age were significant predictors of anemia ($p<0.001$) (Table 3). As compared to the highly educated mothers (graduate and above), mother's having education below graduation and illiterate mothers were more likely to have children suffering from anemia. The risk of anemia also increased with age in children.

DISCUSSION

In the present study, 26% of the study children were anemic with girls showing a higher prevalence of anemia than boys in adolescent years. Gujarat was the most affected state (37% anemic). Rural regions of most states showed a higher prevalence of anemia. Growth was also affected as revealed by a higher prevalence of stunting in children with anemia. Maternal education and age of the child were significant predictors of anemia. The risk of anemia increased with child's age. According to the prevalence cutoff values for public health significance (WHO), the prevalence of anemia in Gujarat, Punjab, Assam, and Tamil Nadu may be regarded as a moderate public health problem, while that in Maharashtra and Chhattisgarh were a mild public health problem (prevalence cutoff values of anemia for public health significance as recommended by WHO: Severe: 40% or higher; moderate: 20.0–39.9%; and mild: 5.0–19.9%) [7].

Our study revealed that 29% girls and 23% boys suffered from anemia. The prevalence of anemia increased with age with an increased incidence observed in girls, representing the probable influence of puberty on iron deficiency. These results are in concordance with the national family health survey (NFHS)-3 and the National Nutrition Monitoring Bureau Survey reports that suggested a widespread prevalence of anemia in all age groups with 56% adolescent girls (15–19 years) and 30% adolescent boys (15–19 years) being anemic [1]. A study from Gujarat has also reported similar observation, although it focused on adolescents (10–14 years) residing only in Gujarat [19].

Table 3: Binary logistic regression analysis for prediction of anemia

Independent variables	B (SE)†/OR (95% CI)	Significance (p-value)
Maternal education		
Illiterate	1.7 (1.4–2.1)	0.0001
Below graduation	1.36 (1.2–1.6)	0.015
Highly educated mothers (graduate and above)	Reference	
Socioeconomic class		
LSEC	0.959 (0.84–1.1)	0.539
USEC	Reference	
Age (years)†	0.04 (0.009)	0.0001
BMI (kg/m²)†	−0.014 (0.008)	0.101

†Continuous variables results are stated as B (SE); SE: Standard error, for categorical variables – OR: Odds ratio, CI: Confidence interval, LSEC: Lower socioeconomic class, USEC: Upper socioeconomic class. Level of significance indicated if p<0.05

Our results indicated an increased prevalence of stunting and wasting with increasing severity of anemia. In line with these results, Awasthi *et al.* (2003) [20] reported a lower concentration of Hb in underweight and stunted children and Soliman *et al.* (2009) [5,21] reported a significant correlation of growth velocity with serum ferritin concentrations in children; however, both the studies focused on children <5 years of age. Our findings highlighted the association of anemia with growth aligns with the fact that adolescence is a time of pubertal development along with a growth spurt, and hence an increased amount of iron is required for the synthesis of Hb for the expanding blood volume, myoglobin for the increasing muscle mass, and iron-containing enzymes necessary for growth [4]. Given an increased daily iron requirement in adolescence [4], failing to meet the same may serve as a predominant contributing factor responsible for reduced growth.

The level of maternal education was inversely associated with the occurrence of anemia in both urban and rural regions. Children of illiterate mothers were 1.7 times higher risk of anemia than children with more educated mothers. In accordance with our results, Choi *et al*. have also reported a similar relationship in Korean children [22]. The possible reason for such a relationship may be that higher education exposes an individual to factors determining health such as the selection of micronutrient-rich diet (e.g., green leafy vegetables), the significance of improved sanitation, and supporting several nutrition-specific interventions necessary for better health-related QOL.

Our study revealed anemic children and adolescents had a lower QOL and these results are in accordance with the study by Strauss *et al*. that suggested an improvement in the QOL of anemic patients when administered intravenous iron [12]. Similar findings have also been reported by Wouters *et al.* (2019), although in older individuals, in whom anemia was associated with a decreased health-related QOL [11]. The compromised QOL as observed in our study may be due to the undiagnosed/untreated anemia resulting in an increased risk of infections, delayed motor or cognitive development in children, decreased work performance, and depression.

Our study along with past research suggests that the progress in reducing anemia has been slow and thus studies on the prevalence of anemia and factors explaining the same are critical. To the best of our knowledge, no such data on Indian children and adolescents have been published till date. Furthermore, the national prevalence of anemia in the age group 10–14 years is unknown as they were not included in NFHS. We assume that the higher prevalence of anemia in rural children is due to the higher level of parental illiteracy, household food insecurity, and poor compliance by children to government programs such as iron-folic acid supplementation programs. Our study strengthens similar observations from previous studies [23–25]; although, we have not reported data on household food security in this study.

Our study had a few limitations. It did not include the etiology of anemia that is iron deficiency, infectious diseases (such as the intestinal parasites, malaria, tuberculosis, and HIV), chronic inflammation, or inherited hemoglobinopathies. Moreover, we have also not reported the differences in the nutritional factors (dietary intake of iron, folic acid, and phytate) or sanitation practices that may be associated with the prevalence of anemia in our study population. Nonetheless, we have studied a large population of children and adolescents belonging to a wide age group and have also explored factors associated with anemia.

CONCLUSION

Maternal education may be one of the major contributing factors for the higher prevalence of anemia, which in turn affects their overall QOL. More research into preventable causes can lead to effective solutions to control and prevent anemia and improve the growth and QOL of Indian children and adolescents.

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