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RESEARCH ARTICLE
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EVALUATION OF ANEMIA AND ITS ASSOCIATED FACTORS AMONG CHILDREN AGED 6 MONTHS TO 5 YEARS IN A TERTIARY CARE HOSPITAL: A CROSS-SECTIONAL ANALYTICAL STUDY

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ABSTRACT

Introduction: Childhood anemia remains a critical public health challenge in India, affecting cognitive development, immunity, and mortality. This study evaluated the prevalence of anemia and identified its associated factors among children aged 6 months to 5 years to inform targeted intervention strategies in the Prayagraj region.

Methods: A hospital-based cross-sectional analytical study was conducted at the Department of Pediatrics, Moti Lal Nehru Medical College, Prayagraj, from July 2023 to December 2023. A total of 145 children aged 6-59 months were enrolled through consecutive sampling. Data collection involved structured questionnaires assessing sociodemographic characteristics, nutritional practices, health history, and environmental factors. Hemoglobin estimation was performed using automated hematology analyzer, with anemia defined as hemoglobin <11.0 g/dL per WHO criteria. Anthropometric measurements were recorded using standardized techniques. Bivariate analysis employed chi-square tests and independent t-tests, while multivariable binary logistic regression identified independent predictors of anemia.

Results: The overall prevalence of anemia was 67.6%, with moderate anemia (57.1%) being most common, followed by mild (34.7%) and severe (8.2%). Prevalence was highest among infants aged 6-11 months (82.1%) and rural children (74.2%). Independent predictors of anemia included young age (AOR=3.89, 95% CI: 1.23-12.31), maternal illiteracy (AOR=3.12, 95% CI: 1.14-8.54), low socioeconomic status (AOR=2.78, 95% CI: 1.08-7.15), inadequate dietary diversity (AOR=3.45, 95% CI: 1.48-8.04), insufficient iron-rich food consumption (AOR=2.98, 95% CI: 1.23-7.22), lack of deworming (AOR=2.23, 95% CI: 1.01-4.93), and maternal anemia (AOR=2.67, 95% CI: 1.15-6.19).

Conclusion: Childhood anemia represents a severe public health problem with multifactorial etiology requiring comprehensive interventions addressing nutritional, health, socioeconomic, and environmental determinants for effective control.

Keywords: childhood anemia, nutritional deficiency, dietary diversity, socioeconomic determinants, tertiary care hospital

INTRODUCTION

Anemia represents one of the most significant public health challenges globally, affecting approximately 42% of children under five years of age worldwide. This condition, characterized by inadequate hemoglobin concentration in blood, compromises oxygen delivery to tissues and organs, resulting in far-reaching consequences for child health, development, and survival. The vulnerability of young children to anemia stems from their rapid growth, increased nutritional requirements, dietary inadequacies, and susceptibility to infectious diseases. Among all age groups, children between 6 months and 5 years face the highest risk of developing anemia due to the depletion of fetal iron stores, transition to complementary feeding, and exposure to environmental pathogens (Kassebaum et al., 2014).

The global burden of childhood anemia remains staggering despite decades of public health interventions. The World Health Organization estimates that anemia affects over 273 million children under five years globally, with the highest prevalence concentrated in low- and middle-income countries. South Asia bears a disproportionate burden, accounting for nearly half of the global anemia cases in this age group. The persistence of high anemia rates reflects complex interplay between nutritional deficiencies, infectious diseases, genetic disorders, and socioeconomic determinants that perpetuate this condition across generations (WHO, 2015).

India confronts a particularly severe anemia epidemic among its pediatric population. National Family Health Survey data consistently demonstrates that more than half of Indian children aged 6-59 months suffer from anemia, with prevalence rates ranging from 58.6% to 67.1% across different states. These alarming statistics position India among the countries with the most severe public health significance according to WHO classification criteria. The heterogeneity in anemia prevalence across Indian states reflects diverse dietary patterns, healthcare access, sanitation infrastructure, and socioeconomic development levels (International Institute for Population Sciences, 2017).

Iron deficiency remains the predominant cause of anemia in young children, accounting for approximately 50% of all anemia cases globally. The period from 6 months to 5 years represents a critical window of vulnerability as children exhaust their birth iron stores around 6 months of age and become dependent on dietary iron sources. However, the bioavailability of iron from typical complementary foods in developing countries is often inadequate due to predominance of plant-based diets with high phytate content and low consumption of heme iron sources. Additionally, the high iron requirements during rapid growth phase coincide with dietary transitions that frequently fail to meet nutritional needs (Pasricha et al., 2013).

Beyond iron deficiency, childhood anemia in India has multifactorial etiology encompassing nutritional deficiencies of folate, vitamin B12, and vitamin A, alongside non-nutritional factors. Infectious diseases including malaria, helminthic infections, and chronic inflammatory conditions significantly contribute to anemia burden through multiple mechanisms including blood loss, hemolysis, and inflammation-induced alterations in iron metabolism. The high prevalence of diarrheal diseases and respiratory infections in young children further exacerbates anemia through impaired nutrient absorption and increased nutritional requirements (Suchdev et al., 2012).

The consequences of childhood anemia extend far beyond hematological abnormalities, profoundly impacting multiple dimensions of child health and development. Anemic children demonstrate impaired cognitive development, delayed motor milestones, reduced physical activity, and compromised immune function leading to increased susceptibility to infections. These developmental deficits can persist into later childhood and adolescence, affecting educational achievement and productivity in adulthood. Severe anemia increases mortality risk and contributes to child deaths from common childhood illnesses including pneumonia and diarrhea. The economic implications are substantial, with childhood anemia contributing to reduced human capital formation and perpetuating intergenerational cycles of poverty (Lozoff et al., 2006).

Socioeconomic and demographic factors play crucial roles in determining childhood anemia risk. Children from lower socioeconomic strata, rural areas, and disadvantaged communities consistently demonstrate higher anemia prevalence compared to their more privileged counterparts. Maternal education, household wealth, access to healthcare services, and sanitation facilities emerge as important determinants of childhood anemia in numerous studies. Maternal anemia during pregnancy contributes to inadequate fetal iron stores, predisposing infants to early-onset anemia. Suboptimal infant feeding practices including delayed introduction of complementary foods, inadequate dietary diversity, and early cessation of breastfeeding further compound anemia risk (Ntenda, 2019).

Birth-related factors including prematurity, low birth weight, and multiple pregnancies significantly influence anemia risk in young children. Premature infants have reduced iron endowment due to shortened gestation and face higher iron demands for catch-up growth. Low birth weight children similarly enter extrauterine life with compromised iron stores and increased vulnerability to nutritional deficiencies. The timing of umbilical cord clamping at birth affects neonatal iron status, with delayed clamping providing protective benefits against early childhood anemia (Chaparro&Lonnerdal, 2017).

Dietary factors constitute modifiable determinants of childhood anemia amenable to intervention. Exclusive breastfeeding for the first six months followed by timely introduction of iron-rich complementary foods represents the foundation of anemia prevention. However, dietary practices in many Indian communities fall short of these recommendations. Common complementary foods lack adequate iron content and bioavailability, while consumption of iron absorption inhibitors including tea and coffee with meals is prevalent. Inadequate intake of animal-source foods, fruits, and vegetables limits both iron supply and absorption-enhancing factors in children's diets (Gebreegziabiher et al., 2014).

Environmental and hygiene factors significantly influence childhood anemia through their impact on infectious disease burden. Poor sanitation, unsafe water supply, and inadequate hygiene practices increase exposure to enteric pathogens causing diarrhea and parasitic infections. Open defecation and lack of toilet facilities contribute to environmental enteropathy, characterized by chronic intestinal inflammation that impairs nutrient absorption. The widespread practice of open defecation in rural India creates conditions conducive to helminthic infection transmission, particularly hookworm and whipworm species that cause intestinal blood loss and anemia (Ngui et al., 2012).

Healthcare access and utilization patterns influence anemia detection, treatment, and outcomes. Children receiving regular growth monitoring, immunizations, and micronutrient supplementation demonstrate lower anemia prevalence compared to those with limited healthcare exposure. However, healthcare utilization in India remains suboptimal, particularly among marginalized populations. Many anemia cases go undiagnosed until children present with severe symptoms or complications. Inadequate treatment compliance, premature discontinuation of iron supplementation, and lack of follow-up further compromise anemia control efforts (Sunuwar et al., 2020).

Despite numerous government programs aimed at reducing childhood anemia including Integrated Child Development Services, Anemia Mukt Bharat initiative, and Mid-Day Meal scheme, progress remains disappointingly slow. The modest decline in anemia prevalence over recent decades suggests that current strategies require strengthening and better targeting. Understanding the local context-specific factors driving childhood anemia is essential for designing effective interventions tailored to community needs. Tertiary care hospitals, serving as referral centers for complicated cases, provide unique opportunities to study severe anemia and its associated complications while generating evidence to inform public health strategies (Ministry of Health and Family Welfare, 2018).The complex and multifactorial nature of childhood anemia necessitates comprehensive assessment of associated factors to guide targeted interventions. Regional variations in anemia determinants require localized studies to understand area-specific risk factors and inform context-appropriate prevention strategies. The Prayagraj region, with its unique demographic characteristics, healthcare infrastructure, and socioeconomic profile, warrants specific investigation to characterize childhood anemia burden and determinants in this population.The aim of this study was to evaluate the prevalence of anemia and identify associated factors among children aged 6 months to 5 years attending a tertiary care hospital, with specific objectives to assess the severity distribution of anemia, examine sociodemographic determinants, analyze nutritional and dietary factors, investigate birth-related and health-related correlates, and determine the relationship between various risk factors and childhood anemia.

METHODOLOGY

Study Design

This study adopted a hospital-based cross-sectional analytical design.

Study Site

The research was conducted at the Department of Pediatrics, Moti Lal Nehru Medical College, Prayagraj, Uttar Pradesh, India.

Study Duration

The data collection phase of the study extended over a period of six months, commencing in July 2023 to December 2023

Sampling and Sample Size

A consecutive non-probability sampling technique was employed to recruit children attending the pediatric outpatient department and admitted to pediatric wards who met the eligibility criteria. All eligible children presenting during the study period were approached for participation until the desired sample size was achieved. The sample size was calculated using the formula for estimating a single proportion: $n = Z^2 \times P \times (1-P)/d^2$, where Z represents the standard normal variate at 95% confidence level (1.96), P denotes the expected prevalence of anemia (assumed as 60% based on previous Indian studies), and d indicates the absolute precision (7%). Applying these parameters yielded a minimum required sample size of 188 children.

Inclusion and Exclusion Criteria

Children aged 6 months to 5 years (up to 59 months) attending the pediatric outpatient department or admitted to pediatric wards during the study period were included if their parents or legal guardians provided written informed consent for participation. Both male and female children were eligible regardless of their presenting complaints or reasons for hospital visit. Children were excluded from the study if they had received blood transfusion within the preceding three months, as this would artificially alter hemoglobin levels and preclude accurate anemia assessment. Children with known hemoglobinopathies including sickle cell disease and thalassemia were excluded as these conditions have distinct pathophysiology and management approaches requiring separate investigation. Those with chronic kidney disease, liver disease, malignancy, or other chronic systemic illnesses affecting hematopoiesis were excluded to focus on nutritional and infectious etiologies of anemia more relevant to the general pediatric population. Children whose parents declined consent or were unable to provide complete information regarding dietary intake, socioeconomic status, and other relevant variables were also excluded to maintain data completeness and quality.

Data Collection Tools and Techniques

A pre-tested, structured questionnaire was developed and validated through pilot testing on 15 children who were not included in the final study sample. The questionnaire comprised multiple sections capturing sociodemographic characteristics including child's age, gender, birth order, family size, parental education levels, occupation, monthly household income, residence type, and religion. Maternal factors documented included age at child's birth, antenatal care utilization, maternalanemia during pregnancy, and parity. Birth-related information encompassed gestational age, birth weight, mode of delivery, place of delivery, and timing of umbilical cord clamping obtained from available records or maternal recall. Infant feeding practices assessed included breastfeeding duration, age at complementary feeding initiation, dietary diversity, frequency of meals, and consumption patterns of iron-rich foods, fruits, vegetables, and animal-source foods. Health and morbidity data collected included immunization status verified from vaccination cards, history of recent illnesses particularly diarrhea and respiratory infections in the preceding two weeks, deworming history, and use of iron supplementation. Environmental and hygiene factors examined included type of water source, sanitation facilities, hand washing practices, and presence of domestic animals. Face-to-face interviews with mothers or primary caregivers were conducted in a private setting using the local language to ensure comprehension and accurate responses. Each interview lasted approximately 25-30 minutes. Clinical examination included assessment of pallor by examining conjunctival, palmar, and oral mucosa pallor graded as absent, mild, moderate, or severe by trained pediatricians. Anthropometric measurements including weight and height/length were recorded using standardized techniques and calibrated equipment. Weight was measured using a digital weighing scale accurate to 10 grams, while length was measured for children under 2 years using an infantometer and height for older children using a stadiometer, both accurate to 0.1 cm. Venous blood samples (2-3 ml) were collected under aseptic precautions in EDTA vacutainers for complete blood count analysis. Hemoglobin estimation was performed using automated hematology analyzer (Sysmex XN-1000) employing the cyanmethemoglobin method, considered the gold standard for hemoglobin measurement. Additional hematological parameters including red blood cell count, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration were also obtained to characterize anemia morphology.

Data Management and Statistical Analysis

All collected data were coded, entered, and stored in Microsoft Excel spreadsheets. The dataset was then imported into R software for comprehensive statistical analysis. Descriptive statistics were computed for all variables, with categorical data presented as frequencies and percentages, while continuous variables were expressed as means with standard deviations or medians with interquartile ranges depending on distribution normality assessed through Shapiro-Wilk test and visual inspection of histograms. Bivariate analysis was conducted to examine associations between anemia status and various potential risk factors using appropriate statistical tests. Chi-square test or Fisher's exact test was employed for categorical variables, while independent samples t-test or Mann-Whitney U test was utilized for continuous variables depending on data distribution. Variables demonstrating significant association ($p<0.05$) in bivariate analysis were entered into multivariable binary logistic regression model to identify independent predictors of anemia while controlling for potential confounders. The logistic regression model employed backward elimination method, with results presented as adjusted odds ratios with 95% confidence intervals. Model fitness was evaluated using Hosmer-Lemeshow goodness-of-fit test. Statistical significance was determined at p-value less than 0.05 for all analyses. Subgroup analyses were performed to examine anemia patterns across different age categories, socioeconomic strata, and residential backgrounds.

Ethical Considerations

The study protocol received approval from the Institutional Ethics Committee of Moti Lal Nehru Medical College, Prayagraj prior to study initiation. The research was conducted in accordance with the Declaration of Helsinki principles and Indian Council of Medical Research ethical guidelines for biomedical research involving human participants. Written informed consent was obtained from parents or legal guardians of all participating children after providing detailed information about study objectives, procedures, potential risks and benefits, and their right to refuse participation or withdraw at any stage without affecting their child's medical care.

RESULTS

Table 1: Sociodemographic Characteristics of Study Participants (N=145)

Characteristics	Category	Frequency (n)	Percentage (%)
Age Group	6-11 months	28	19.3
	12-23 months	42	29
	24-35 months	38	26.2
	36-59 months	37	25.5
Gender	Male	78	53.8
	Female	67	46.2
Residence	Urban	56	38.6
	Rural	89	61.4
Birth Order	First	64	44.1
	Second	52	35.9
	Third or more	29	20
Mother's Education	Illiterate	34	23.4
	Primary (1-5 years)	43	29.7
	Secondary (6-10 years)	48	33.1
	Higher Secondary & above	20	13.8
Father's Education	Illiterate	21	14.5
	Primary (1-5 years)	38	26.2
	Secondary (6-10 years)	56	38.6
	Higher Secondary & above	30	20.7
Socioeconomic Status (Monthly Income)	Lower (< ₹10,000)	67	46.2
	Middle (₹10,000-30,000)	58	40
	Upper (> ₹30,000)	20	13.8
Family Type	Nuclear	82	56.6
	Joint	63	43.4
Religion	Hindu	112	77.2
	Muslim	28	19.3
	Others	5	3.5

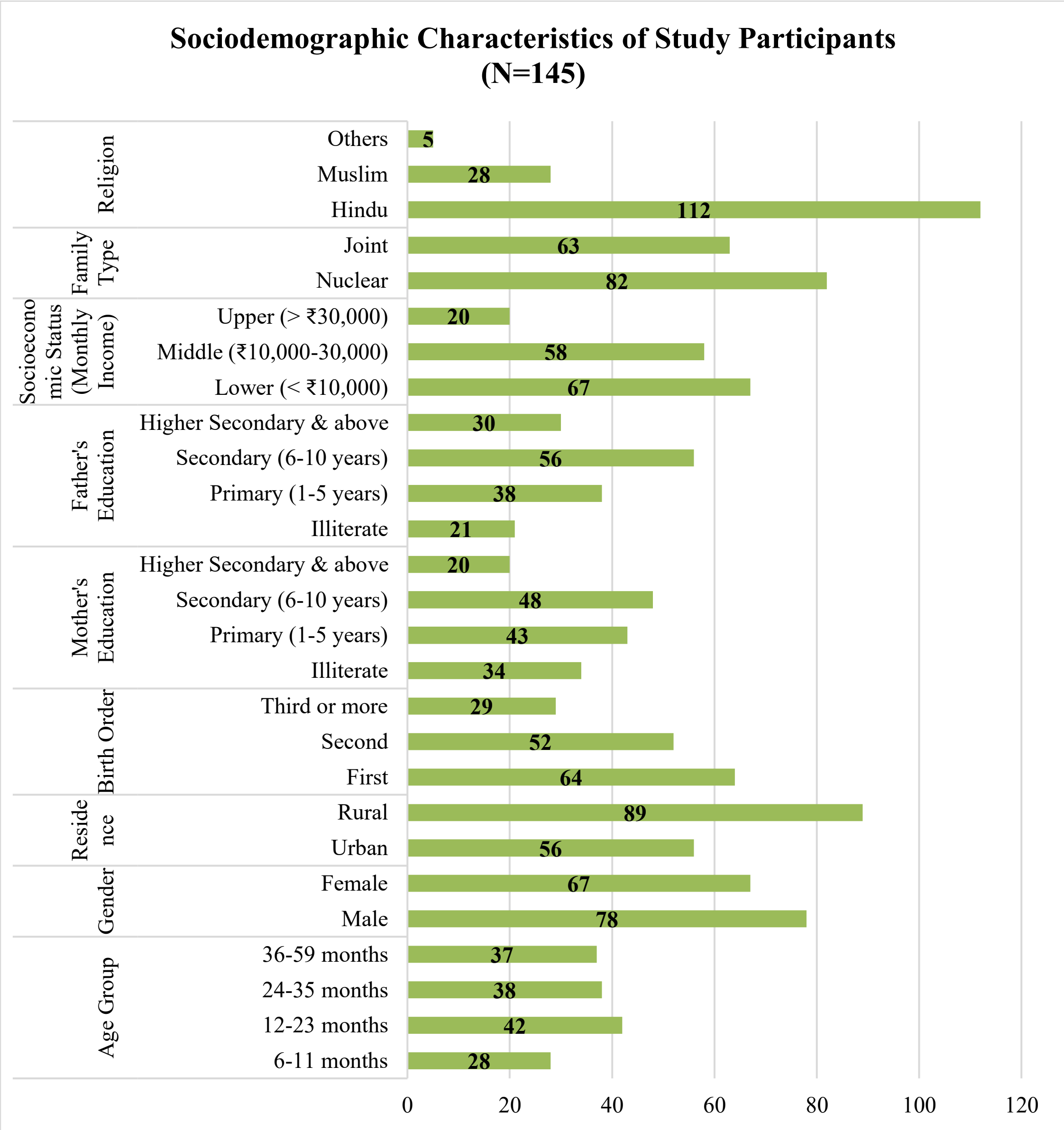

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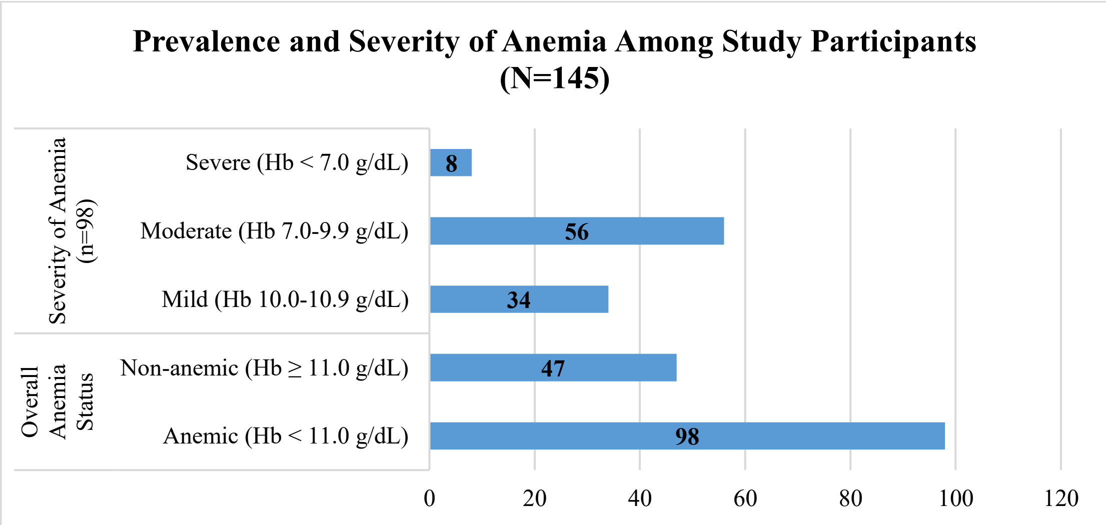
Table 2: Prevalence and Severity of Anemia Among Study Participants (N=145)

Anemia Classification		**Frequency (n)**	**Percentage (%)**	**Mean Hb (g/dL) ± SD**
Overall Anemia Status	Anemic (Hb< 11.0 g/dL)	98	67.6	9.24 ± 1.38
	Non-anemic (Hb ≥ 11.0 g/dL)	47	32.4	11.87 ± 0.64
Severity of Anemia (n=98)	Mild (Hb 10.0-10.9 g/dL)	34	34.7	10.42 ± 0.28
	Moderate (Hb 7.0-9.9 g/dL)	56	57.1	8.64 ± 0.82
	Severe (Hb< 7.0 g/dL)	8	8.2	6.23 ± 0.58
Age-specific	6-11 months	23/28	82.1	8.96 ± 1.42

Prevalence	12-23 months	32/42	76.2	9.12 ± 1.35
	24-35 months	24/38	63.2	9.38 ± 1.41
	36-59 months	19/37	51.4	9.67 ± 1.28
Gender-specific Prevalence	Male	51/78	65.4	9.34 ± 1.43
	Female	47/67	70.1	9.12 ± 1.31
Residence-specific Prevalence	Urban	32/56	57.1	9.67 ± 1.28
	Rural	66/89	74.2	8.98 ± 1.39

Note: Hb = Hemoglobin; SD = Standard Deviation; Anemia classification based on WHO criteria



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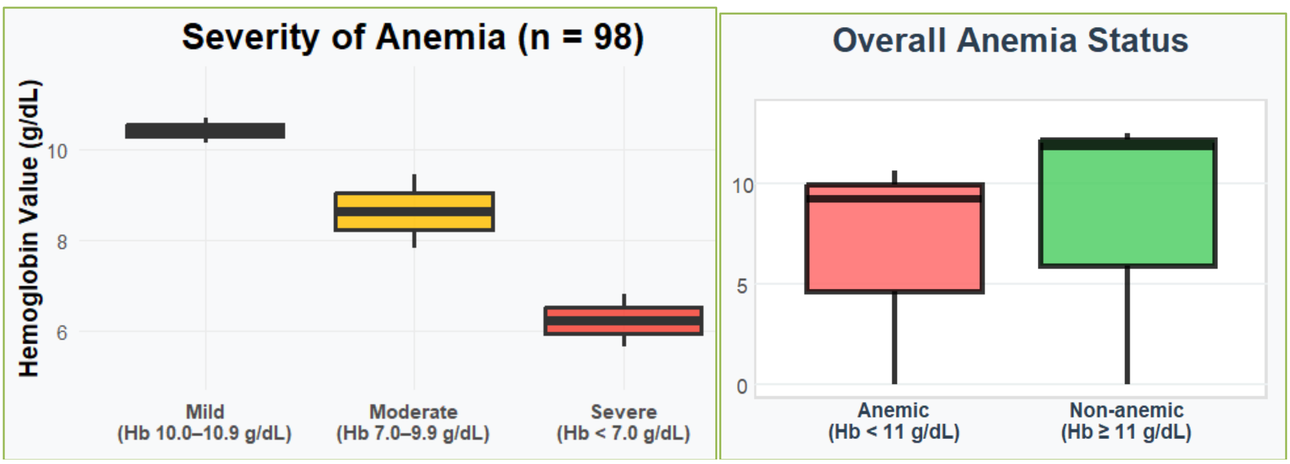

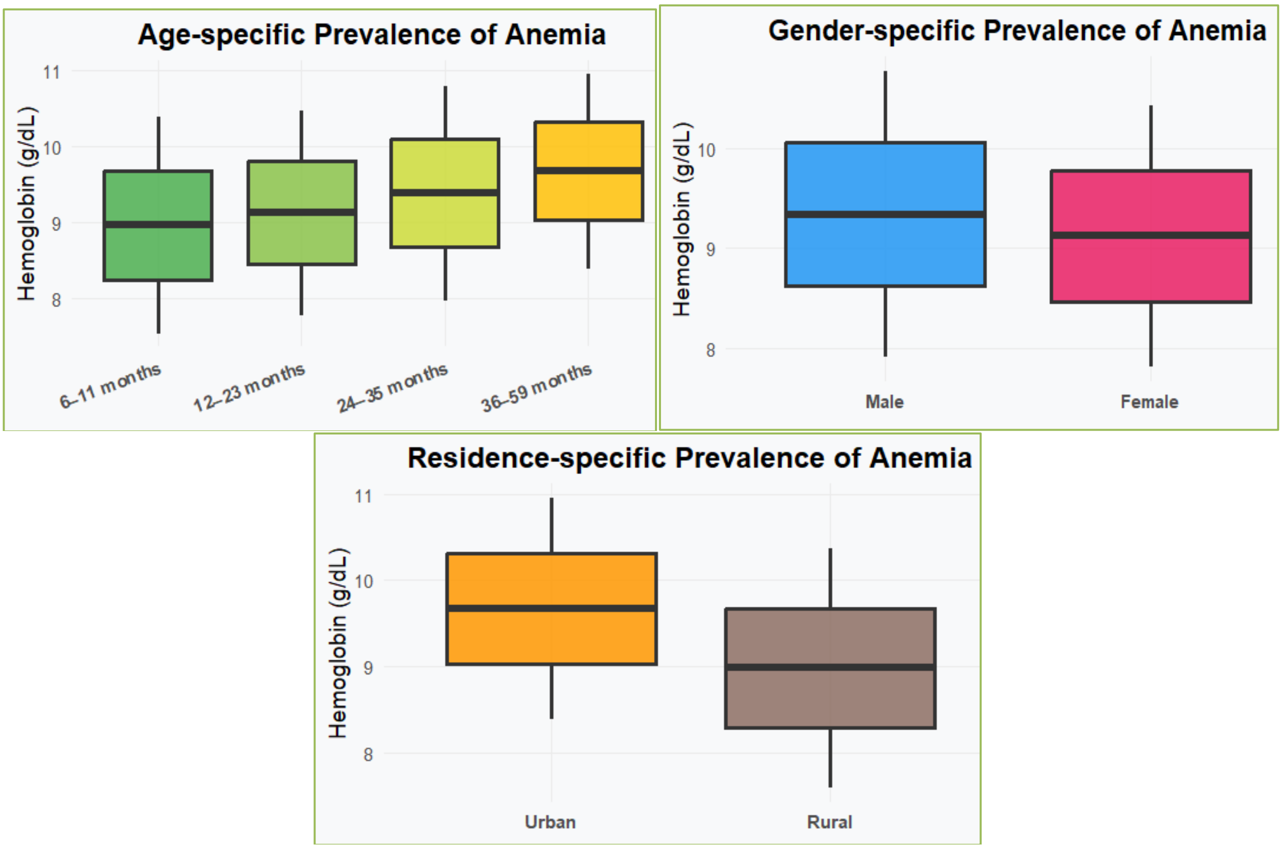

Fig: 2(ii)

Table 3: Association Between Nutritional Factors and Anemia Status (N=145)

Nutritional Variables		Anemic n=98 (%)	Non-anemic n=47 (%)	χ² value	p-value	OR (95% CI)
Breastfeeding Duration	< 6 months	45 (45.9)	8 (17.0)	12.34	<0.001	4.23 (1.82-9.84)
	≥ 6 months	53 (54.1)	39 (83.0)			Ref
Age at Complementary Feeding	< 6 months	38 (38.8)	7 (14.9)	14.56	0.001	3.67 (1.52-8.86)
	6-7 months	43 (43.9)	28 (59.6)			Ref
	> 7 months	17 (17.3)	12 (25.5)			0.92 (0.39-2.18)
Dietary Diversity Score	Low (< 4 food groups)	72 (73.5)	18 (38.3)	18.76	<0.001	4.48 (2.17-9.24)
	Adequate (≥ 4 food groups)	26 (26.5)	29 (61.7)			Ref
Iron-rich Food Consumption	Inadequate (< 3 times/week)	81 (82.7)	24 (51.1)	16.89	<0.001	4.56 (2.15-9.67)
	Adequate (≥ 3 times/week)	17 (17.3)	23 (48.9)			Ref

Animal-source Food Intake	No/Rarely	68 (69.4)	19 (40.4)	11.98	0.001	3.34 (1.65-6.76)
	Regular (≥ 2 times/week)	30 (30.6)	28 (59.6)			Ref
Fruit & Vegetable Intake	Inadequate (< daily)	76 (77.6)	22 (46.8)	14.67	<0.001	3.98 (1.93-8.21)
	Adequate (daily)	22 (22.4)	25 (53.2)			Ref
Nutritional Status (WHZ)	Underweight (< -2 SD)	48 (49.0)	11 (23.4)	9.45	0.002	3.14 (1.47-6.71)
	Normal (≥ -2 SD)	50 (51.0)	36 (76.6)			Ref
Iron Supplementation	Not received	73 (74.5)	21 (44.7)	13.24	<0.001	3.62 (1.76-7.45)
	Received	25 (25.5)	26 (55.3)			Ref

Note: OR = Odds Ratio; CI = Confidence Interval; Ref = Reference category; WHZ = Weight-for-Height Z-score

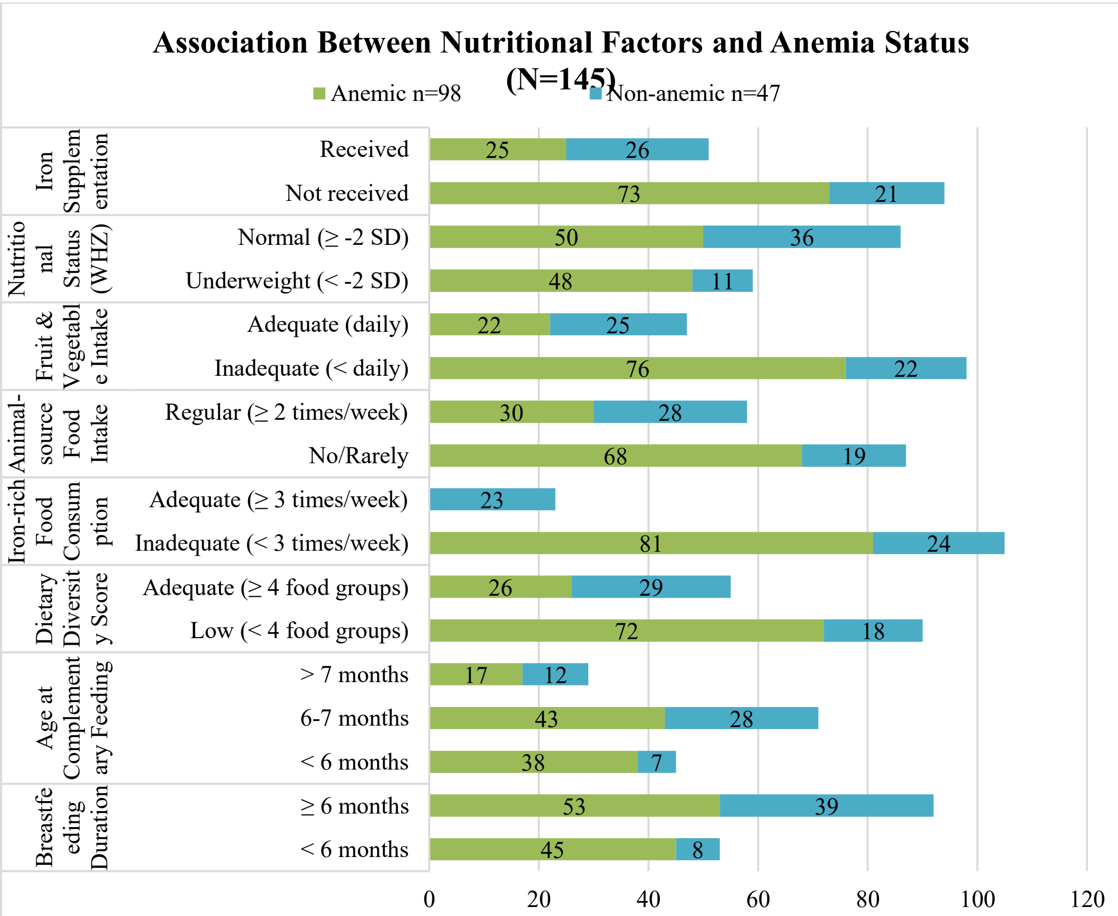

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Table 4: Association Between Health-Related Factors and Anemia Status (N=145)

Health Variables		**Anemic n=98 (%)**	**Non-anemic n=47 (%)**	**χ^2 value**	**p-value**	**OR (95% CI)**
Birth Weight	Low (< 2.5 kg)	42 (42.9)	8 (17.0)	10.12	0.001	3.67 (1.58-8.52)
	Normal (≥ 2.5 kg)	56 (57.1)	39 (83.0)			Ref
Gestational Age	Preterm (< 37 weeks)	28 (28.6)	5 (10.6)	6.34	0.012	3.36 (1.22-9.28)
	Term (≥ 37 weeks)	70 (71.4)	42 (89.4)			Ref
Recent Illness (past 2 weeks)	Diarrhea	38 (38.8)	8 (17.0)	7.56	0.006	3.08 (1.33-7.13)
	Respiratory infection	34 (34.7)	12 (25.5)	1.34	0.247	1.55 (0.73-3.31)
	No illness	26 (26.5)	27 (57.5)			Ref
Deworming History	Not done	67 (68.4)	19 (40.4)	11.02	0.001	3.18 (1.59-6.35)
	Done (past 6 months)	31 (31.6)	28 (59.6)			Ref
Immunization Status	Incomplete	45 (45.9)	10 (21.3)	9.12	0.003	3.14 (1.46-6.76)
	Complete	53 (54.1)	37 (78.7)			Ref
Maternal Anemia	Present	62 (63.3)	15 (31.9)	13.89	<0.001	3.67 (1.79-7.52)
	Absent	36 (36.7)	32 (68.1)			Ref
Sanitation Facility	Open defecation/shared	71 (72.4)	22 (46.8)	9.78	0.002	2.98 (1.48-6.01)
	Own toilet	27 (27.6)	25 (53.2)			Ref
Water Source	Unsafe (well/pond)	56 (57.1)	16 (34.0)	7.56	0.006	2.58 (1.28-5.21)
	Safe (tap/handpump)	42 (42.9)	31 (66.0)			Ref

Note: OR = Odds Ratio; CI = Confidence Interval; Ref = Reference category

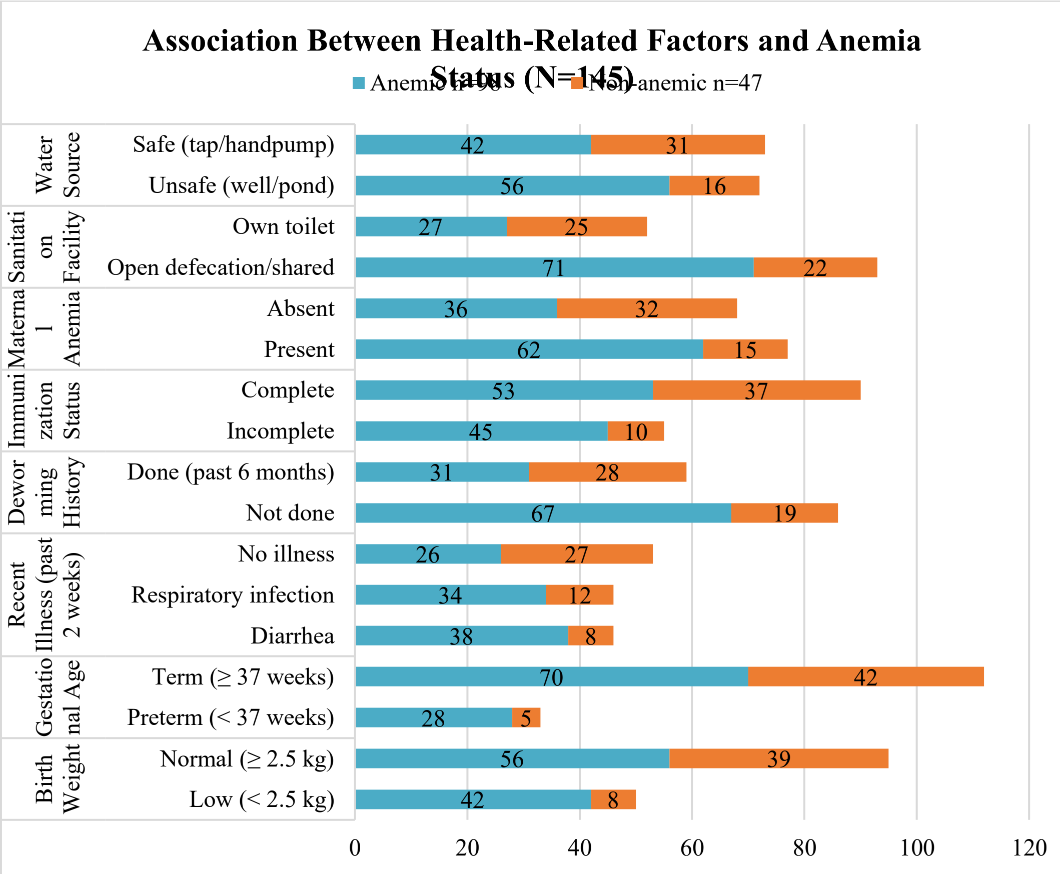

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Table 5: Multivariable Logistic Regression Analysis of Factors Associated with Anemia (N=145)

Independent Variables		Adjusted OR	95% CI	p-value	β Coefficient
Age Group	6-11 months	3.89	1.23-12.31	0.021	1.358
	12-23 months	2.67	1.05-6.79	0.039	0.982
	24-35 months	1.78	0.72-4.41	0.212	0.577
	36-59 months	Ref	-	-	-
Residence	Rural	1.89	0.76-4.69	0.167	0.636
	Urban	Ref	-	-	-
Mother's Education	Illiterate	3.12	1.14-8.54	0.027	1.138
	Primary	2.45	1.02-5.89	0.045	0.896
	Secondary & above	Ref	-	-	-
Socioeconomic Status	Lower class	2.78	1.08-7.15	0.034	1.023
	Middle class	1.67	0.71-3.93	0.241	0.513
	Upper class	Ref	-	-	-

Low Birth Weight	Yes	2.34	0.89-6.15	0.085	0.85
	No	Ref	-	-	-
Dietary Diversity Score	Low (< 4 food groups)	3.45	1.48-8.04	0.004	1.238
	Adequate (≥ 4 food groups)	Ref	-	-	-
Iron-rich Food Consumption	Inadequate	2.98	1.23-7.22	0.015	1.092
	Adequate	Ref	-	-	-
Recent Diarrheal Illness	Yes	2.45	0.96-6.25	0.061	0.896
	No	Ref	-	-	-
Deworming Status	Not done	2.23	1.01-4.93	0.048	0.801
	Done	Ref	-	-	-
Maternal Anemia	Present	2.67	1.15-6.19	0.022	0.982
	Absent	Ref	-	-	-
Sanitation Facility	Open defecation/shared	1.98	0.87-4.51	0.104	0.683
	Own toilet	Ref	-	-	-

Note: OR = Odds Ratio; CI = Confidence Interval; Ref = Reference category; Model χ^2 = 67.84, p<0.001; Hosmer-Lemeshow test: χ^2 = 8.23, p=0.412; Nagelkerke R^2 = 0.524

DISCUSSION

The present study revealed an overall anemia prevalence of 67.6% among children aged 6 months to 5 years attending a tertiary care hospital in Prayagraj, which classifies as a severe public health problem according to WHO criteria. This finding aligns closely with national estimates from the National Family Health Survey-4, which reported anemia prevalence of 58.6% among children under five years in India (International Institute for Population Sciences, 2017). The slightly higher prevalence observed in our study compared to national figures may be attributed to the hospital-based study design, which inherently captures children seeking healthcare for various ailments, potentially including those with higher anemia risk. Similar hospital-based studies conducted by Kuziga et al. (2017) in Uganda reported 61.8% prevalence, while Gebreegziabiher et al. (2014) documented 56.6% prevalence in Ethiopia, suggesting that childhood anemia remains a persistent challenge across developing nations irrespective of geographic location.

The severity distribution in our study showed that moderate anemia constituted the largest proportion (57.1%), followed by mild anemia (34.7%) and severe anemia (8.2%). This pattern is consistent with findings from a multi-country analysis by Kassebaum et al. (2014), who observed that moderate anemia represents the most common severity grade in pediatric populations. The presence of 8.2% severe anemia cases is concerning and exceeds the 3-5% typically reported in community-based studies, reinforcing the notion that hospital settings capture more severe cases requiring medical attention. The mean hemoglobin concentration of 9.24±1.38 g/dL among anemic children falls well below the WHO threshold, indicating substantial iron deficiency and potential developmental implications for this vulnerable population.

Age-stratified analysis demonstrated a declining trend in anemia prevalence with increasing age, from 82.1% in infants aged 6-11 months to 51.4% in children aged 36-59 months. This inverse relationship between age and anemia prevalence has been consistently documented in previous research. Pasricha et al. (2010) reported similar age-related patterns in rural India, attributing the high prevalence in younger infants to depletion of fetal iron stores around 6 months, inadequate dietary iron from complementary foods, and rapid growth requirements. The physiological vulnerability of younger children is compounded by suboptimal feeding practices during the complementary feeding period, as evidenced by our dietary assessment data. As children grow older, improved dietary diversity and reduced growth velocity contribute to lower anemia risk, explaining the declining prevalence observed in older age groups (Lozoff et al., 2006).

Our study identified several sociodemographic factors significantly associated with childhood anemia. Rural residence emerged as an important predictor, with 74.2% of rural children affected compared to 57.1% of urban children. This rural-urban disparity has been extensively documented in the literature and reflects differential access to healthcare services, nutritional resources, and health information. A systematic review by Balarajan et al. (2011) across 23 developing countries confirmed higher anemia rates in rural areas, attributing this to limited healthcare infrastructure, predominance of agriculture-based livelihoods with seasonal food insecurity, and higher infection burden. In the Indian context, rural areas face additional challenges including limited availability of fortified foods, inadequate cold chain facilities for maintaining food quality, and cultural dietary restrictions that limit consumption of bioavailable iron sources.

Maternal education emerged as a significant protective factor against childhood anemia in multivariable analysis. Children of illiterate mothers had 3.12 times higher odds of anemia compared to those whose mothers had secondary or higher education. This finding corroborates extensive literature establishing maternal education as a critical determinant of child health outcomes. Educated mothers demonstrate better health-seeking behavior, improved infant feeding practices, enhanced understanding of nutrition principles, and greater autonomy in household decision-making regarding food purchases and healthcare utilization (Sunuwar et al., 2020). The pathways through which maternal education influences childhood anemia are multifaceted, operating through improved antenatal care utilization, optimal breastfeeding practices, timely introduction of complementary foods, and prompt recognition and treatment of childhood illnesses.

Socioeconomic status showed a strong gradient relationship with anemia, with children from lower-income households (monthly income <₹10,000) having 2.78 times higher odds of anemia compared to upper-income families. Economic constraints limit household purchasing power for nutritious foods, particularly animal-source foods rich in bioavailable heme iron. Poverty also correlates with inadequate housing conditions, poor sanitation, and limited access to healthcare services, creating a syndemic of nutritional deficiency and infectious diseases that collectively contribute to anemia. A study by Korenromp et al. (2005) demonstrated that socioeconomic gradients in childhood anemia persist even after controlling for other risk factors, suggesting that poverty operates through multiple direct and indirect pathways to increase anemia vulnerability.

Dietary diversity emerged as the strongest independent predictor of anemia in our multivariable model, with children consuming fewer than four food groups daily having 3.45 times higher odds of being anemic. This finding underscores the critical importance of diversified complementary feeding for meeting micronutrient requirements in young children. Monotonous diets dominated by cereals and starches, common in resource-poor settings, fail to provide adequate quantities and bioavailable forms of iron, folate, vitamin B12, and other essential nutrients for erythropoiesis. The work of Arimond and Ruel (2004) established dietary diversity as a valid proxy indicator for micronutrient adequacy in children's diets across diverse cultural contexts. Our findings reinforce recommendations to promote consumption of multiple food groups including animal-source foods, legumes, fruits, and vegetables to enhance overall nutritional quality and micronutrient density of children's diets.

Inadequate consumption of iron-rich foods (less than three times weekly) was associated with nearly three-fold increased anemia odds. This relationship has been well-established in nutritional epidemiology, though the causality is bidirectional. Plant-based diets, while providing non-heme iron, suffer from lower bioavailability due to presence of absorption inhibitors including phytates, tannins, and calcium. Furthermore, common dietary practices such as consuming tea with meals, which is prevalent in Indian households, significantly impair iron absorption through polyphenol chelation. Kennedy et al. (2007) demonstrated that even modest increases in animal-source food consumption dramatically improve iron status in young children, with small quantities of meat, fish, or poultry enhancing absorption of non-heme iron from plant sources through the "meat factor" effect.

The suboptimal duration of exclusive breastfeeding and early or delayed introduction of complementary foods observed in our study population represents a missed opportunity for anemia prevention. Children who were breastfed for less than six months had 4.23 times higher odds of anemia. Breast milk, though relatively low in iron content, provides iron with exceptionally high bioavailability (approximately 50% absorption) compared to complementary foods. Additionally, exclusive breastfeeding protects against gastrointestinal infections that impair iron absorption and increase iron losses. The timing of complementary feeding initiation is equally critical; early introduction (before 6 months) exposes infants to contaminated foods and reduces breast milk intake, while delayed introduction (after 7 months) creates a nutritional gap as breast milk alone becomes insufficient to meet iron requirements (Chaparro&Lonnerdal, 2017).

Low birth weight emerged as a significant risk factor for childhood anemia, with affected children having 2.34 times higher odds of anemia, though this did not reach statistical significance in the multivariable model ($p=0.085$). The biological plausibility of this association is well-established; low birth weight infants have reduced iron endowment due to interrupted placental iron transfer during the third trimester, when most fetal iron accumulation occurs. Additionally, these infants often experience postnatal complications requiring repeated blood sampling and have increased iron demands for catch-up growth. Rao and Georgieff (2007) demonstrated that low birth weight children enter infancy with 50-75% lower iron stores compared to normal birth weight counterparts, predisposing them to early-onset iron deficiency unless appropriate supplementation is provided.

Recent diarrheal illness showed a strong association with anemia in bivariate analysis, with affected children having 3.08 times higher odds of being anemic. Diarrhea contributes to anemia through multiple mechanisms including direct intestinal blood loss, malabsorption of nutrients, increased intestinal permeability, inflammatory cytokine production that alters iron metabolism, and reduced dietary intake during illness. The bidirectional relationship between diarrhea and anemia creates a vicious cycle wherein anemic children have compromised immunity predisposing them to infections, while recurrent infections exacerbate anemia. Ngure et al. (2014) demonstrated that environmental enteropathy, a subclinical intestinal inflammation condition resulting from chronic fecal pathogen exposure, independently predicts childhood anemia even in the absence of clinical diarrhea episodes.

The protective effect of deworming observed in our study aligns with established evidence regarding helminthic infections and anemia. Children who had not received deworming medication in the past six months had 2.23 times higher odds of anemia. Intestinal helminths, particularly hookworm, contribute to anemia through chronic intestinal blood loss, with a single hookworm causing approximately 0.03 mL blood loss daily. In endemic areas, polyparasitism is common, with children harboring multiple helminth species simultaneously. The World Health Organization recommends periodic deworming for all children in endemic areas regardless of individual infection status, a strategy proven cost-effective for anemia control (Ngui et al., 2012).

Maternal anemia emerged as an independent predictor of childhood anemia with 2.67-fold increased odds. This association reflects both genetic susceptibility and shared environmental risk factors including dietary patterns, socioeconomic status, and healthcare access. Maternal iron deficiency during pregnancy limits placental iron transfer, resulting in reduced fetal iron stores. Furthermore, anemic mothers are more likely to deliver preterm or low birth weight infants, both of which predispose to childhood anemia. The intergenerational transmission of anemia underscores the importance of preconception and prenatal interventions to break the cycle of iron deficiency across generations (Black et al., 2013).

Poor sanitation and unsafe water sources showed significant associations with anemia in bivariate analysis. Open defecation and lack of improved sanitation facilities increase environmental contamination with enteric pathogens and helminth eggs, elevating infection risk. The recent focus on environmental enteropathy has highlighted how chronic exposure to fecal contamination, even without clinical illness, triggers systemic inflammation that disrupts iron homeostasis through hepcidinupregulation, which blocks intestinal iron absorption and sequests iron in macrophages. Cumming and Cairncross (2016) demonstrated strong correlations between sanitation coverage and childhood anemia at population level, suggesting that sanitation improvements may contribute to anemia control beyond their effects on reducing clinical infections.

The findings from this study have important programmatic implications for childhood anemia control efforts in India. The identification of multiple modifiable risk factors suggests that comprehensive, multi-sectoral interventions are required rather than single-nutrient supplementation approaches. Nutrition education targeting maternal dietary diversity, promotion of iron-rich foods, optimal infant feeding practices, and addressing broader social determinants including maternal education and household economic security should be prioritized. Integration of anemia screening and management into existing child health programs including immunization services and Integrated Child Development Services could improve coverage and treatment adherence.

CONCLUSION

This study revealed that childhood anemia remains highly prevalent (67.6%) with moderate severity predominating among children attending a tertiary care hospital in Prayagraj. Multiple interconnected factors including young age, rural residence, maternal illiteracy, poverty, inadequate dietary diversity, poor consumption of iron-rich foods, low birth weight, lack of deworming, maternal anemia, and inadequate sanitation significantly contribute to anemia burden. The multifactorial etiology necessitates comprehensive interventions addressing nutritional, health, and socioeconomic determinants simultaneously to achieve meaningful reductions in childhood anemia prevalence and associated developmental consequences.

RECOMMENDATIONS

Strengthening nutrition education programs targeting mothers on optimal infant feeding practices, dietary diversification, and iron-rich food consumption should be prioritized. Integration of routine anemia screening into child health services with prompt treatment and follow-up is essential. Periodic deworming, improved sanitation access, and maternal anemia control through preconception and prenatal interventions require scaling up. Socioeconomic support programs addressing poverty and enhancing maternal education will provide enabling environments for sustainable anemia reduction among vulnerable children populations.

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