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ORIGINAL ARTICLE

Iron Deficiency Anemia Screening in Children Across Indian Prominent Cities

Ranu Singh[1]*, Eileen Canday[2], Shilpa Chadha Thakur[3], Haritha Bathina[4], Prasanthi Suryanarayana[5], Soumyendu Ghosh[6], Aashani Doshi[7], Binu Bhatia[8], Samapti Maity[9]

1 Chief Programme Officer, Community Nutrition Core Group, IAPEN India
2 Head of Nutrition & Dietetics, Sir H.N. Reliance Foundation Hospital, Maharashtra, India
3 Founder & Director, Mindful EatingWshilpa, Senior Consultant, Clinical Nutrition & Dietetics
4 Chief Dietician, Apollo Hospitals, Hyderabad, India
5 Chief Dietitian, Basavatarakam Indo American Cancer Hospital, Telangana, India
6 Senior Consultant Dietitian & Diabetes Educator; Founder & Director, Cognize Nutrition, Member -IAPEN India Community Core Group
7 Clinical Dietician, Sir H.N. Reliance Foundation Hospital, Maharashtra, India
8 Consultant Nutritionist, Treasurer, IAPEN India Delhi Chapter
9 Dietician, SAP Wellness

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* **Corresponding author**.

ranuabhineetsingh@gmail.com

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Abstract

Iron deficiency anemia (IDA) remains a critical public health issue among children under six, adversely impacting growth, cognitive development, and school readiness. This study aimed to estimate the prevalence of anemia among children aged 1–6 years across five major Indian metropolitan cities to generate actionable insights. A cross-sectional screening was conducted between February and May 2025 in Delhi, Kolkata, Mumbai, Hyderabad, and Lucknow. The children aged 1–6 years were screened using the non-invasive Masimo Rad-67^{TM} hemoglobinometer. Anemia was defined as hemoglobin <11 g/dL per WHO standards. A total of 3,395 children were included after obtaining parental consent and applying exclusion criteria. The overall prevalence of anemia was 39.2%, with higher rates in girls (43.5%) and younger children aged 1–4 years (35.2%). The prevalence among children aged 1–6 years was as mentioned, Kolkata (47.1%), Mumbai (42.3%), Delhi (38.1%), Hyderabad (35.5%), and Lucknow (32.7%). Despite better healthcare access in urban settings, city-wise differences were observed, indicating variable risk factors and nutritional environments. Urban childhood anemia prevalence is lower than national averages but still a significant concern, especially in cities like Kolkata. The study emphasizes the need for non invasie anemia screening at point of care to enable localized interventions and improve public health outcomes through more efficient resource allocation and program design.

Keywords: Anemia; Children; Gender disparities; Public health; Hemoglobin Screening

Introduction

Iron deficiency anemia (IDA) is a condition marked by low hemoglobin, smaller and paler red blood cells, due to insufficient iron. Iron is essential for growth and development in fetuses, infants, and children, with its levels regulated through absorption, storage, and recycling processes involving transferrin, enterocytes, macrophages, and the hormone hepcidin. Anemia is the most common blood disorder in children worldwide, affecting about 20.1% of children aged 0-4 and 5.9% aged 5-14 in industrialized countries, but much higher rates of 39% and 48.1%, respectively, in developing countries.[1]

NFHS-5 data shows that anemia impacts all age groups and both genders, but children under five and women aged 15–49 are the most vulnerable.[2] Analysis of NFHS data from 2005 to 2021 (N=419,333) showed a slight decline in severe and moderate anemia among Indian children aged 6–59 months. Between NFHS-3 (2005–06) to NFHS-5 (2019–21), severe anemia in children aged 6–59 months dropped slightly from 2.9% to 2.1%**,** and moderate anemia from 40.4% to 36.7%**.** However, after a decline in NFHS-4, there was an increase in anemia cases in NFHS-5, showing a reversal in the trend.[3,4] According to NFHS-5 (2019– 21), the overall prevalence of anemia among children aged 6–59 months in India is 67.1%**,** indicating a major burden of iron deficiency anemia at the national level. While city-specific data such as for Kolkata**,** Mumbai**,** Delhi**,** Hyderabad, and Lucknow are not separately reported in NFHS-5, their anemia status can be understood from the state-level data. Delhi (as a Union Territory) reported a high prevalence of 69.2%**.** Kolkata, being part of West Bengal, reflects the state's high child anemia prevalence of 69.0%**.** Mumbai**,** located in Maharashtra, showed a slightly lower but still significant prevalence of 68.9%**.** Hyderabad, representing Telangana, reported a prevalence of 70.0%**,** one of the highest among major states. Lucknow, part of Uttar Pradesh, had a prevalence of 66.4%**.** These figures suggest that even in major

urban centres, childhood anemia remains a serious concern, reinforcing the need for strengthened nutrition and public health interventions to address nutritional gaps, particularly iron deficiency, in young children.[5] The multi-centric hospital-based study conducted in 2024 in India found a 49.4% prevalence of anemia (95% CI: 47.3–51.5) in children aged 6–

59 months, based on venous blood samples, with microcytic anemia in 67.2% and presumptive iron-deficiency in 55.7%**.**The key risk factors included age <24 months**,** inadequate nutrition**,** poor maternal education, and lack of exclusive breastfeeding for 6 months.[6]

The pathogenesis of iron deficiency anemia (IDA) is multifactorial, involving reduced dietary iron intake, increased physiological demands during rapid growth phases such as infancy and adolescence, acute or chronic blood loss, and intestinal malabsorption caused by conditions like celiac disease, helicobacter pylori infection, and chronic inflammatory bowel disease. Prematurity is a critical factor, as 80% of fetal iron is acquired during the last trimester of pregnancy. Iron deficiency anemia significantly impairs children's growth and overall health by affecting oxygen transport, energy metabolism, and neurological development.[1] Even mild to moderate iron deficiency without anemia can cause fatigue, while severe cases manifest with pallor, fatigue, restless leg syndrome, pica, frequent infections, and cognitive and motor impairments that negatively impact school performance. Iron deficiency during crucial developmental periods leads to lasting deficits in cognitive and psychomotor functions, resulting in poor academic achievement and behavioral problems. The recent rise in anemia prevalence among children aged 6–59 months is attributed to factors such as decreased dietary diversity, inadequate coverage of iron-folic acid supplementation, insufficient improvements in maternal nutrition, and inadequate coverage of iron-folic acid supplementation and deworming programs, further exacerbated by socioeconomic disparities, maternal education levels, and regional differences.[4,7–12]

Both the American Academy of Pediatrics (AAP) and the Indian Academy of Pediatrics (IAP) have established guidelines to promote early detection and management of IDA in children to prevent adverse developmental outcomes. The AAP recommends universal anemia screening at around 12 months of age, including hemoglobin measurement and assessment of risk factors like prematurity, low birth weight, exclusive breastfeeding without iron supplementation, and lead exposure, with additional screenings advised for high-risk children up to age five.[13–15] The IAP follows WHO hemoglobin thresholds and emphasizes treatment based on clinical evaluation and hemogram results, using serum ferritin to confirm

diagnosis. Routine screening targets high-risk groups such as children with poor diet, rapid growth, or recurrent infections. Both organizations highlight early identification and intervention as essential strategies to mitigate the long-term health and cognitive impacts of pediatric anemia and support optimal child growth and development[16].

Despite over fifty years of government efforts to combat anemia through programs such as the National Nutritional Anemia Prophylaxis Programme (NNAPP) initiated in 1970 and more recent strategies like Anemia Mukt Bharat (AMB) under POSHAN Abhiyaan, anemia remains a major public health challenge in India. These initiatives focus on iron and folic acid supplementation, deworming, dietary diversification, and behavior change communication to reduce anemia prevalence[13]. However, the complex and multifactorial nature of childhood anemia demands renewed emphasis on integrated, region-specific approaches and improved implementation of national programs. Although large-scale sur-

veys like the National Family Health Survey (NFHS) provide national and state-level data on childhood anemia, there is a notable lack of city-specific prevalence data in the literature. This gap hampers the development of targeted, context-specific interventions, especially given the diverse socio- economic and nutritional profiles of urban populations. Therefore, this study aims to estimate the prevalence of anemia among children aged 1 to 6 years in selected Indian metropolitan cities to generate reliable, city-level data that can inform more effective public health strategies and policy planning.

Methodology

A cross-sectional anemia screening initiative was conducted across five major Indian cities, namely Hyderabad, Lucknow, Kolkata, Mumbai, and Delhi, over a four-month period, from 1st February 2025 to 20th May 2025to assess the prevalence of iron deficiency anemia among children aged 1 to 6 years.

2.1 Screening Procedure

The hemoglobin levels were measured using the Masimo Rad-67^{TM}, a non-invasive, point-of- care hemoglobinometer that allows for real-time monitoring without the need for blood samples, ensuring minimal discomfort. Anemia was defined as a hemoglobin concentration below 11 g/dL, in accordance with WHO standards[17] and as measured by the Rad-67 device.

2.2 Participant Selection Criteria

The participants were children aged between 1 to 6 years selected from community centers, schools, or orphanages. Only the children without any known chronic illnesses or ongoing medical treatment were included in the study. The children younger than 1 year or older than 6 years, as well as those with diagnosed chronic conditions or undergoing any form of medical treatment, were excluded from the screening process.

2.3 Informed Consent

Prior to participation, an informed consent was obtained from parents or legal guardians via a digital Google Form. The presence of a parent or guardian was mandatory during the screening to ensure ethical compliance and procedural transparency.

2.4 Screening Sites

The screening activities were carried out across the five selected cities with a target sample size of approximately 4,000 children. The society appointed trained regional officers and field researchers to conduct the screenings. Prior to the activity, the Masimo technical team conducted training sessions for society staff on the proper use and handling of the Masimo Rad-67 devices.

2.5 Data Management

All the hemoglobin readings and participant data were digitally recorded and stored in a centralized, secure database maintained by the society. The quality control procedures included routine supervision, technical checks, and daily review of collected data to ensure accuracy and completeness. The aim was to document the prevalence of anemia in the selected cohort and to allow for stratified reporting by city, gender and age group.

2.6 Outcome

The study successfully screened 3395 children across five cities. The outcome focused on determining the prevalence and distribution of iron deficiency anemia in this age group, contributing valuable data for public health policy and intervention strategies. The results are intended to inform future programs aimed at anemia prevention and nutritional support for early childhood development in urban India.

Results

The socio-demographic profile of the participants in this study included children aged 1-6 years residing in selected urban cities across India. A balanced representation of both genders was ensured.

The prevalence was expressed as a percentage of anemic children. Out of all 3395 children screened, 1330 were found to be anemic, projecting an overall anemia prevalence of 39.2%based on WHO criteria. The prevalence of anemia was higher in children aged 1– 4years, with 728 out of 1,701 children (42.8%) affected, compared to 602 out of 1,694 children (35.5%)among those aged 4–6 years. Agender-wise analysis revealed that girls had a higher prevalence, with643 out of 1,471 (43.7%) found anemic, compared to 663 out of 1,875boys(35.4%). Among the 49 children whose gender was not recorded, 24(48.9%) were anemic (Table 1).

Table 1. City-wise prevalence of anemia among the study participants

City	Anemia Prevalence
Kolkata	47.1%
Mumbai	42.3%
Delhi	38.1%
Hyderabad	35.5%
Lucknow	32.7%

As per the city-wise findings, Kolkatta reported the highest anemia prevalence with 320 out of 680children (47.1%)

affected, followed by Mumbai with 290 outof 685 (42.3%), Delhi

with 258 out of 677 (38.1%), Hyderabad with 240out of 675 (35.5%), and Lucknow showingthe lowest prevalence with 222out of 678 (32.7%).

resents the age- and gender-wise distribution of anemia among children across five cities. In Mumbai, the prevalence among children aged 1–4 years was 40.2% in boys and 44.3% in girls, with an overall rate of 42.5%; for the 4–6 year group, the rates were 33.2% in boys, 38.3% in girls, and 36.0% in total. In Delhi, it was observed in 36.4% of boys and 41.1% of girls aged 1–4 years (38.7% total), and in 31.8% of boys and 34.7% of girls aged 4– 6 years (33.2% total). In Kolkata, the prevalence in the 1–4 year age group was 46.9% among boys and 48.1% among girls (47.0% total), while in the 4–6 year age group, it was 36.1% in

boys, 42.4% in girls, and 39.3% overall. In Lucknow, 34.4% of boys and 36.9% of girls aged 1–4 years were affected (35.6% total), and among those aged 4–6 years, 32.3% of boys and 35.6% of girls had IDA (34.0% total). In Hyderabad, the prevalence was 35.7% in boys and 36.7% in girls aged 1–4 years (36.2% total), and 32.1% in boys and 32.2% in girls aged 4–6 years (32.2% total). These findings indicate a substantial burden of anemia among preschool- aged children across urban India, aligning more closely with national estimates from NFHS5, while also highlighting variations by gender, age group, and city.

Table 2. Age- and gender-wise distribution of anemia among the study participants in different cities

City	Age group	Boys (%)	Girls (%)	Total (%)
Mumbai	1-4	40.2	44.3	42.5
	4-6	33.2	38.3	36.0
Delhi	1-4	36.4	41.1	38.7
	4-6	31.8	34.7	33.2
Kolkata	1-4	46.9	48.1	47.0
	4-6	36.1	42.4	39.3
Lucknow	1-4	34.4	36.9	35.6
	4-6	32.3	35.6	34.0
Hyder-abad	1-4	35.7	36.7	36.2
	4-6	32.1	32.2	32.2
Average		36.2	41.4	38.8

Discussion

In this cross-sectional survey of 3,395 children aged 1–6 years acrossfive major Indian cities, 1,330 children (39.2%) were found to be anemic. Prevalence was higher in girls than boys. City-wise anemia prevalence was highest in Kolkatta (47.1%), followed by Mumbai (42.3%), Delhi (38.1%), Hyderabad (35.5%), and lowest in Lucknow (32.7%).

A global meta-analysis revealed that the pooled prevalence of IDA and iron deficiency among under-5 children was 16.42% and 17.95%, respectively, with higher risk in children under 2 years, those from large families, or born to anemic mothers. The burden was notably higher in Asia and Africa.[18] A recent meta-analysis of 157 studies across India found anemia prevalence to be highest among toddlers under 3 years (69%), especially in the Eastern region (87%), and among preschoolers aged 3–5 years (64%), peaking at 85% in Central India. School-going children had a lower overall prevalence of 51.2%, with the highest rates in the North-Eastern region (83.9%).[19] Based on the Comprehensive National Nutrition Survey (2016–2018) in India, 40.5% of children aged 12–59 months were anemic, and 30% had anemia with micronutrient deficiencies (iron, folic acid, or vitamin B12). The key risk factors included younger age, maternal education level, inadequate antenatal IFA intake, illness, and poor hygiene practices.[20] In India, inadequate dietary iron intake contributes to IDA, but state-wise disparities reveal other contributing factors. For example, despite higher iron intake in Gujarat, anemia prevalence was higher than in Kerala, suggesting that factors like vitamin A deficiency may also play a key role—an insight particularly relevant for understanding and preventing IDA in children.[21]Children are among the most vulnerable groups affected by iron deficiency anemia, with recent data from the National Family Health Survey (NFHS) showing a sharp rise in prevalence—from 35.7% in 2016 to 68.4% in 2019. States like Haryana (71%), Jharkhand (69.9%), and Madhya Pradesh (68.9%), Bihar at 63.5%, and Uttar Pradesh at 63.5% reported particularly high rates, reflecting a growing public health concern.[22] In Nagla Chandi Village, Uttar Pradesh, 36% of boys and 44% of girls aged 6–59 months were found to be anemic, with a high proportion also underweight. The key contributing factors included poor diet, lack of iron-folic acid supplements, and inadequate hygiene and childcare services.[23]

Most large-scale health surveys and national data sources, including NFHS, provide anemia prevalence at the state, national, and city level. The NFHS-5 reports anemia prevalence for children aged 6–59 months (under 5 years), whereas our study included children up to 6 years of age. This slight extension in the age range is relevant because anemia prevalence tends to decline as children grow older and begin to consume a more diverse diet. Including older children (5–6 years) in the sample may contribute to the similar or lower overall trend of anemia prevalence observed in our findings compared to NFHS-5 data, which focuses on a younger, more nutritionally vulnerable age group.

The present study focused on urban populations in five metropolitan cities, where the majority of the participants belonged to varied income households with better access to healthcare, nutrition, and education. In contrast, the NFHS-5 data represent entire state populations, including a substantial proportion of children from rural and low-income backgrounds. This socio-demographic difference is a key factor influencing the lower anemia prevalence found in our study, as children in urban, economically stable environments are less likely to experience chronic nutritional deficiencies compared to their rural counterparts. Over the past 15 years, childhood anemia in India has slightly declined, but young children (6–23 months), especially in rural and marginalized SC/ST communities, remain highly vulnerable. Urban–rural disparities persist, with rural children more affected.[3] In Uttar Pradesh and Bihar, anemia was significantly more prevalent among rural adolescents compared to urban ones, especially among boys (1.49 times higher odds). The key rural risk factors included low education, lack of media exposure, stunting, and late adolescence, highlighting the need for targeted anemia interventions in rural youth populations.[24] From 2006 to 2016, hemoglobin levels in Indian children aged 6–59 months improved by 4.5 g/L and anemia declined by 11 percentage points, with better outcomes linked to maternal education, improved socioeconomic status, and nutrition and health interventions. However, progress varied widely across states and between urban and rural settings, highlighting that sustained improvements in sanitation, education, and access to services are key to reducing rural–urban disparities in childhood anemia.[25] Between NFHS-4 (2015–16) and NFHS-5 (2019–21), childhood anemia in India (ages 6–59 months) rose from 59% to 67%, reversing earlier declines. This increase was seen in both urban and rural areas, with key contributors including maternal education, maternal anemia, and socio-economic disparities, factors more pronounced in rural settings.[4] The factors such as age, education, income, and sanitation significantly influenced anemia levels, highlighting both urban and rural vulnerabilities.[26] Most existing anemia studies in India are concentrated in rural areas or urban slum populations, where poverty, undernutrition, and limited healthcare access drive higher anemia rates. Urban children, particularly those in non-slum settings, often benefit from better nutrition, fortified foods, healthcare infrastructure, and parental awareness, contributing to lower anemia levels. Our study highlights this urban–rural disparity, showing that anemia burden in well-connected city populations may be significantly less than what broader, rural- focused data suggests.

Urban populations may also benefit more directly from the improved implementation of government schemes such as POSHAN Abhiyan, Anemia Mukt Bharat, and Integrated Child Development Services (ICDS). In schools and Anganwadi centers, interventions like iron and folic acid supplementation, mid-day meals, and deworming are more consistently delivered, especially in well-managed urban areas. The improved outreach and compliance with these programs in cities could partly explain the lower prevalence of anemia observed in our study sample. Our findings underline the need for future studies to assess city-specific prevalence, public health policies and interventions rather than relying solely on state-wide averages. Urban areas are highly heterogeneous, and pockets of both affluence and deprivation exist side by side. Therefore, tailored strategies based on localized data are essential to accurately identify at-risk groups and allocate resources efficiently. This study provides a foundation for such targeted policymaking, advocating for more granular, city-level health surveillance and intervention planning.

Conclusion

This study highlights that the prevalence of anemia among urban children aged 1–6 years in major Indian cities is closer to state estimates, with notable intercity variation. Implementing such non-invasive screening methods at the point of care along with capturing dietary habits can enhance early detection of anemia in preschoolers, allowing for timely interventions that can mitigate the adverse effects of the condition and improve health outcomes in this vulnerable population. The findings underscore the importance of early screening and including dietary evaluation to design targeted public health interventions that address nutritional disparities effectively.

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