Addressing child anemia– the case for convergence of nutritional and sanitation interventions

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Abstract

This paper calls for convergence of nutritional and sanitation interventions to address the complex etiology that characterizes anemia. Given that anemia can be caused by nutritional as well as non- nutritional factors, we focus on the role of two nationawide programs implemented recently in India in explaining anemia for children 0 – 24 months. The first of these is a standard anemia mitigation program that is nutrition- specific in its focus on iron supplementation and intake of iron- rich foods. The second is a sanitation program that we consider as nutrition-sensitive, given the role of fecal pathogens in contributing to anemia via infections and nutrient losses. We map indicators from the National Family Health Survey to each of these programs at the individual, household and community level. We find that iron folic acid supplementation for mothers and intake of iron- rich foods by the child are associated with significantly higher hemoglobin levels. At the same time we find evidence in support of the sanitation program. The reduction in the practice of open defecation, both at the community and household levels is associated with significantly higher hemoglobin levels in children. This impact is more pronounced in rural areas, where open defecation is more prevalent as compared to urban areas. Likewise, conducting a sub-group analysis by the wealth status of the household, we find that community-level open defecation is significantly associated with children's hemoglobin levels at lower income levels. Taking into account synergies across nutritional and sanitation programs can help prioritize investments to combat the prevalence of anemia in the most effective manner.

Keywords: Anemia, India, Convergence, Nutrition, Sanitation, Micronutrient deficiencies

1. Introduction

About one- third of the 270 million children 6 – 59 months who are anemic worldwide, live in South Asia (Stevens et al 2022). Diagnosed by an insufficient level of hemoglobin (and/ or red blood cells) in the blood, anemia has implications for health and development outcomes particularly in children below the age of five. It can lead to poor child cognitive and motor development, educational outcomes and eventual income earning potential, and can also potentially impact intergenerational health outcomes (Bobonis et al., 2006; Grantham-McGregor & Ani, 2001; Stevens et al., 2022).

Chhaparo and Sachdev (2019) conceptualize the etiology of anemia in low and middle- income countries in terms of four levels – 1) fundamental factors like political economy, ecology, climate and geography, 2) underlying characteristics like education wealth, cultural norms and health policies, 3) intermediate determinants that include food security, access to healthcare services and WASH, and 4) immediate risk factors. The latter includes nutritional deficiencies, infections/ inflammation, and genetic blood- related disorder. An inadequate intake of nutrients like iron, Vitamin B12 and folate in the diet – which aid the production of hemoglobin - can result in anemia. At the same time, inflammation from infections can lead to anemia as a result of low absorption of nutrients and/ or higher nutrient losses in the body. Examples include helminth infections like hookworm and parasitic infections like malaria and schistosomiasis to name a few. Such diseases are very often transmitted by unsanitary environmental conditions like open defecation, unclean drinking water, and poor handwashing habits. And finally, hemoglobinopathies or blood- related disorders like sickle- cell, and thalassemia can also cause anemia. The likely coexistence of these varied drivers of anemia calls for a multi- sectoral convergence in the design of policy interventions designed to track progress on addressing this micronutrient deficiency effectively. In this paper, we analyze the complementary role of nutritional and sanitation policies in explaining anemia in children under the age of five, in India.

India bears a disproportionate burden of global anemia. Despite remarkable economic progress and longstanding public policies, the pace of reduction in prevalence of anemia has been disappointing in the country. Over the decade 2005- 2015, the proportion of children under 5 with anemia declined from 69.5% to 58.6%. This was also the decade that saw a corresponding improvement in various immediate and underlying drivers of anemia like maternal BMI, access to antenatal care, child immunizations, and iron supplementation (Nguyen et al). With the availability of more recent data on health indicators from India's National Family Health Survey (NFHS) it is then worrying to see that there has been a reversal of gains made in alleviating anemia in the country. This is reflected in 67.1% - or more than two- thirds - of children under five being anemic as of 2019- 20.

In the five years between NFHS 4 and NFHS 5, the government of India launched two massive public health programs that directly or indirectly can influence anemia outcomes. The first of these – *Swachh Bharat Mission* (or Clean India Mission, referred to as SBM from here on) - was launched in 2014-15 with the objective of eliminating the practice of open defecation in the country by 2019. The second program – *Anemia Mukt Bharat* (or Anemia Free India, referred to as AMB henceforth) – was initiated with the aim of reducing the prevalence of anemia by 3 percentage points per year among six different target groups including children under five, through a set of nutrition- specific interventions over the period 2018- 2022. In this paper, we explicitly link the AMB and SBM to prevalence of anemia in children under 5 in India.

This study makes three main contributions to the evidence base on drivers of anemia in children, in India.

First, we view the drivers of anemia from the point of view of convergence across two massive, national- level policies. Unlike the AMB which is clearly a nutrition- specific, anemia mitigation program, the SBM has been promoted as a sanitation drive in the country. However, it can also be considered a nutrition- sensitive intervention for anemia as a reduction in open defecation rates can lead to lower rates of anemia as the transmission of parasitic and intestinal infections falls. In doing so, we recognize that anemia can be caused by a host of nutritional as well as non-nutritional factors. Policy response to anemia has traditionally operated in silos with programs focusing on singular factors like health, behavior/ awareness, or sanitation. A multisectoral convergence across programs can result in synergies that allow us to identify and prioritize interventions, given the complex etiology that characterizes anemia. This becomes especially useful for designing policies that can effectively address this persistent micronutrient deficiency, and support India's progress towards Sustainable Development Goal#2 (reducing malnutrition in women and children).

Second, we identify convergence across programs by exploiting the breadth of health and nutrition data available in the nationally- representative NFHS 5 for this purpose. We map indicators at the individual, household, and community level from the NFHS to components of each of the two programs (described in detail in section 2). This is useful because, to our knowledge, such a mapping of indicators to these policies has not been done before. Related to that, there is no large- scale survey to track the impact of such policies over time *alongside other demographic and health data*. The Comprehensive National Nutrition Survey (CNNS) in 2016- 18 built on the limitations of the NFHS by analyzing blood samples for a host of biomarkers in addition to hemoglobin to understand the drivers of anemia in children in the country. While this provides much needed information on understanding the causes of anemia, it falls short of additional data on individual, household, and community level cofounders. We also note here that at the time of carrying out this analysis, public access to the Indian government's Health Management Information System (HMIS) data from the AMB platform itself was not available, for corroboration of results. Furthermore, reports from the AMB focus primarily on prevalence rates for anemia and coverage of IFA supplements aggregated at the state level. The timing of the NFHS 5 is also well- suited to associate progress made in the AMB and SBM with anemia outcomes. The SBM concluded in October 2019 with 100 million toilets having been constructed by the time data collection for NFHS 5 commenced. Given that it is expected to take atleast one year from ODF- status for it to be reflected in health outcomes, and that the country was declared ODF in 2019, we believe that information on ODF in 2019- 2021 NFHS would reflect the role of sanitation for health adequately. Similarly, the increase in coverage of iron and folic acid supplementation for women and children through the AMB between 2017 and 2019 is mirrored in data from NFHS 4 and 5 (Joe et al., 2022).

Third, our analysis draws on the most recent, nationally- representative data on health outcomes for young children in India. It is estimated that the widespread prevalence of IDA in children leads to a total loss of 1.3% of the gross domestic product for India (Plessow et al., 2015). Furthermore, focusing on child micronutrient deficiencies has come to the forefront since the COVID-19 pandemic which has adversely affected nutritional outcomes in different parts of the world including India. Although NFHS 3 (Bharati et al., 2015) and NFHS 4 (Hong Nguyen et al., 2018; Onyeneho et al., 2019; Puranik & N, 2022)have been used to analyze determinants of anemia in children 6 – 59 months in India, this is the first time that updated indicators from NFHS 5 are being used. Chakrabarti et al (2018) have done the same using DLHS data for the period 2002-2012. More recently an analysis of the Indian government's HMIS points to a decline in the rate of severe anemia in the country, from 6.4% in 2010- 11 to 3.29% in 2017- 18 (Bora, 2019). However, this analysis is not age- specific and therefore its comparability with anemia trends from the NFHS is limited. Furthermore, the earlier studies have not explicitly made a link between national- level policies and anemia.

Our results indicate that there is a strong association between children's hemoglobin levels and the AMB and SBM variables. Micronutrient supplementation program such as iron-folic acid supplements for mothers during pregnancy is associated with higher hemoglobin in children. For every 1 g/dL increase in the mother's hemoglobin, there is an increase of 0.16 g/dL in children's hemoglobin levels. As AMB also focuses on improving child feeding practices, our results suggest that a child's breastfeeding status, consumption of breastfeeding practices, vitamin-A, and protein-rich foods are also associated with higher hemoglobin levels in children below 2. Finally, SBM through the reduction in the practice of open defecation, both at the community and household levels is also associated with significantly higher hemoglobin levels in children. This impact is more pronounced in rural areas, where open defecation is more prevalent as compared to urban areas. Likewise, conducting a sub-group analysis by the wealth status of the household, we find that community-level open defecation is significantly associated with children's hemoglobin levels at lower income levels.

The rest of this paper is structured as follows. In the remainder of section 1 we provide a brief overview of both, the AMB and SBM. Section 2 describes the data and empirical strategy used for analysis. We present results related to the association between SBM, AMB and anemia in section 3, and conclude with policy implications in section 4.

1.1 *India's anemia mitigation program*

India's primary anemia response program is known as the *Anemia Mukt Bharat* (AMB) program and translates as *anemia free India*. It was initiated in 2018 and builds on the best practices and lessons generated from earlier anemia mitigation programs in the country. The AMB aims to reduce the prevalence of anemia in mothers and children by 3 percentage points per year over the period 2018- 2022, based on a 6x6x6 approach. The program focuses on six beneficiary groups (3 for children: 6 – 59 months, 5 – 9 years, adolescent boys and girls; and 3 groups of women – reproductive age, pregnant, lactating). It is implemented through six institutional mechanisms and consists of six key interventions. The latter include (1) prophylactic IFA supplementation (biweekly for children 6 – 59 months, (2) deworming (biannual for 6- 59 months), (3) intensified year-round behavior change communication campaigns including ensuring delayed cord clamping in newborns, appropriate IYCF, and 'solid body smart mind' campaign, (4) testing of anemia using digital methods and point of care treatment, (5) mandatory provision of IFA- fortified foods in public health programs and (6) redressal of non-nutritional causes of anemia in endemic pockets with special focus on malaria, hemoglobinopathies, and fluorosis.

The design of the AMB reflects the multifaceted drivers of anemia. It is primarily a nutrition-specific intervention with focus on iron supplementation and improved child- feeding practices that promote intake of iron- rich foods. Most commentaries about the AMB thus far have focused on constraints related to the implementation of the program in general and/ or IFA supplementation in particular – eg. manpower, supply chain and inter- department coordination (Ahmad et al., 2023; Kapil et al., 2019). Joe et al (2022) analyze data from AMB's data dashboard and find that the coverage of iron supplementation has increased significantly between 2017 – 2019 for all beneficiary groups. Specifically for the 6 – 59 months group, although coverage increased from 6.6% in 2017-18 to 14.9% in 2019- 20, that is the lowest coverage rate across all beneficiary groups. Furthermore, the authors note, that despite the expansion in coverage of IFA supplements, there has been an increase in anemia rates between NFHS 4 and 5. Although it can be argued that the relatively short time period between the initiation of the AMB (2018) and data collection for NFHS 5 (2019- 2020) is unlikely to reflect long- term changes, it cannot be denied that the stated objective of the program (a 3% decline) has not been achieved. Specifically for the 0 – 5 age group this would mean an anemia prevalence rate of 40% by 2022 which is certainly not reflected in NFHS 5 numbers (Verma, 2020). On the contrary anemia prevalence has increased. This suggests that there is a need to track (non- nutritional) factors other than those included in the AMB interventions that can be influencing anemia outcomes in the country.

1.2 India's sanitation campaign

Swachh Bharat Mission (SBM), or *Clean India Mission* was a nation-wide campaign launched by the government of India in 2014 to eliminate open defecation (OD) and make India an open defecation free (ODF) nation within the next five years. On 2 October 2019, India was declared an ODF country. Nearly 100 million individual household toilets were built under SBM.[1]The objective of the program was also to generate awareness and bring about a behavior change regarding sanitation practices at the community level.[2] The declaration of India as an ODF nation using the statistics from SBM program has often been contested in large part because of evidence that suggests that the use of toilets is lagging behind the access to toilets (Seth, 2021). We elaborate on this distinction in the methods section below.

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[1]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1797158#:~:text=About%2010.9%20crore%20individual%20household,country%20under%20SBM%20(G).
[2]https://pib.gov.in/newsite/printrelease.aspx?relid=113643

In addition to the intrinsic benefits of access to and use of improved sanitation facilities, the SBM influences public health outcomes by reducing the fecal – oral transmission of pathogens in human bodies (Raman & Muralidharan, 2019). Intestinal infections as a result of fecal pathogens can lead to poor nutritional outcomes by reducing appetite and nutrient absorption in the body (Rah et al., 2015). OD in particular can contribute to the occurrence of anemia through the transmission of intestinal worms that can inhibit the absorption of nutrients and/ or through parasitic infections like malaria, resulting from a poor sanitation environment.

Improved sanitation practices have been associated with a significantly lower occurrence of diarrhea in children in India, both pre- as well as post- SBM (Clasen et al., 2014; Dandabathula et al., 2019; Patil et al., 2014). Similarly, open defecation by neighbors (i.e. community- level) can generate negative externalities for child nutrition outcomes (Chakrabarti et al., 2018; Coffey et al., 2018; Hammer & Spears, 2013; Michael Geruso et al., 2018). On the other hand, Patil et al (2014) fail to find a significant relationship between improved sanitation and child anemia in their study of two districts in Madhya Pradesh. The authors link this to a modest decline in the practice of OD relative to improved access to toilets. This is in contrast to findings from Nepal (Coffey et al., 2018) and India (Chakrabarti et al., 2018) that point towards an improvement in Hb levels and fall in anemia rates as regional OD rates decline.

An early comparison of child nutritional outcomes from 4000 households across five states in India indicated that the prevalence of diarrhea, underweight, and wasting was significantly lower in children belonging to ODF districts as compared to OD districts (MoDWS, 2017). More recently Parvati et al (2021) use district- level secondary data from NFHS 4 to estimate that child stunting rates declined by 0.06% for every 1% increase in access to toilets stemming from the SBM. To our knowledge an explicit convergence of the role of the SBM, alongside the AMB, as a driver of anemia in young children in India has not been explored in detail in the existing literature.

2. Methods

This study uses data from the NFHS 5 that provides extensive information on individual and household level socioeconomic and nutrition outcomes and is representative at the national and sub-national (district) level in India. We use data on hemoglobin level of 62554 children to identify the prevalence and severity of anemia in children aged 6 to 24 months. Hemoglobin data in the NFHS surveys is collected by using HemoCure Hb 201 + machine[3]. NFHS observations that are available for us to analyze are already adjusted for smoking in women and altitudes above 1000 meters (Sullivan et al., 2008). Anemia in the 6 – 59 months age group is defined as hemoglobin (hb) level less than 11 gm/ dl, following the threshold specified by the WHO. The severity of anemia is graded as mild (hb 10- 10.9 gm/dl), moderate (hb 7 – 9.9 gm/dl) and severe (hb < 7gm/dl) (WHO, 2011).

Variables from NFHS 5 were mapped to the SBM and AMB, in line with program objectives, as described below.

2.1 Mapping NFHS variables to the AMB program

We account for nutritional factors that reflect three of the six health interventions included in the AMB program. The first two of these are related to the prophylactic iron and folic acid supplementation for the child and mother, and the intake of deworming pills by the child in the previous six months. The third intervention of the AMB reflects nutrition-sensitive behavior and feeding practices and is accounted for by child's breastfeeding status, and consumption of Vitamin A-rich fruits and vegetables, animal proteins, and dark green leafy vegetables in the last 24 hours. Although the NFHS has data on inake of antimalarial medication by the child, we do not include it in our analysis as the response was 'no' for all of the sample.

Indicators related to the three interventions of the AMB program listed above reflect the 'nutrition- specific' nature of AMB and are relevant, given that one of the most proximal causes

[3] The machine instantly generates the hemoconcentration through a finger prick for women and children above 12 months of age; and for children aged 6-11 months, it was a heel prick.

of anemia is the poor quality of diets amongst children. In the case of India, dietary iron deficiency is one of the top 10 causes of death and disability for young children (Abbafati et al., 2020). Our focus on intake of micronutrients like iron, Vitamin B-12 and folic acid is similar to other studies in the literature (Coffey et al., 2018; Onyeneho et al., 2019; Tolentino & Friedman, 2007; Yip & Ramakrishnan, 2002). The improvement in rates of coverage for iron supplementation in AMB have been found to be correlated with similar improvements reflected in NFHS data (Joe et al., 2022). Although NFHS data on anemia prevalence rates have been used for a rapid review of the AMB (Geographic Insights Lab, 2022), to our knowledge such a wide range of variables from NFHS have not been mapped to AMB thus far.

2.2 Mapping NFHS variables to the SBM program

We account for the role of sanitation as a non- nutritional driver of anemia, using the following two indicators – 1) whether or not the household practices open defecation and 2) open defecation rates at the community level. The NFHS data collects information about defecation at the household level by asking the respondents about where the household members "usually" defecate. Responses that fall in the category of '*bush, field, no facility, and using open spaces'* are classified as open defecation by the individual. We construct an indicator for village level open defecation i.e. the fraction of households who practice OD within a village. Village OD is a continuous variable ranging from zero (no household practices OD) to one (all households practice OD in the village). It is essentially the fraction of households who report using 'bush, field, or no toilet' in the NFHS surveys.

This isn't the first time that the NFHS data is being used to account for outcomes related to the SBM. In a district- level analysis, Parvati et al (2021) conclude that under- five declined by 0.06% for every percentage increase in households with a toilet facility. They account for SBM in terms of the share of households with individual, unshared toilet facilities. Seth (2021) however makes the case that the SBM the claim of 100% ODF free India is based on all households having *access* to improved sanitation facilities. This is distinct from toilet usage rates that are much lower in the NFHS data. Although the widespread access to toilets, following the SBM, is commendable, it has been argued that access has little meaning if it is not followed through with a behavior that reflects the use of those toilets (Seth, 2021). In that respect, our indicators from NFHS are well-suited as they extend to SBMs eventual goal which is to eliminate the *practice* of open defecation. This builds on the pre- SBM literature that has analyzed the relationship between sanitation and child nutrition outcomes like stunting by accounting for household access to toilets and not necessarily their usage (Clasen et al., 2014; Hammer & Spears, 2013; Patil et al., 2014; Rah et al., 2015).

2.3 Empirical specification

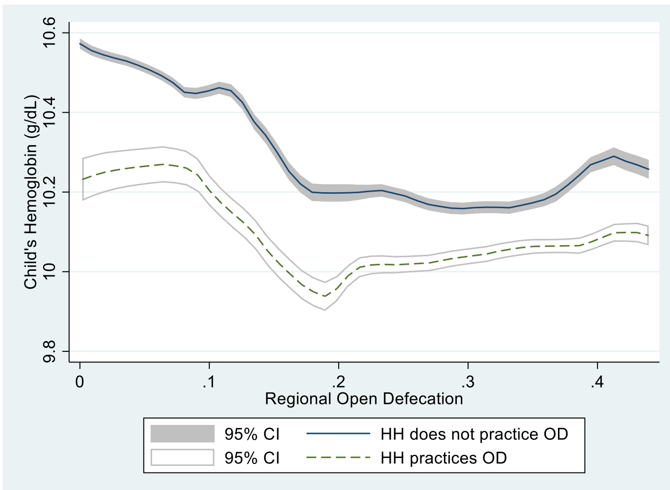
We use child hemoglobin level (g/dl) as our dependent variable for a sample of 62554 children aged 6 to 24 months. ($Hb_{\_i}$ in equation below). The choice to use Hb concentrations as our main variable of interest as opposed to a binary indicator for anemia was made purposively as epidemiologists argue against using dichotomous variables in the place of continuous variables as the former diminishes the power of econometric tests (Royston et al., 2006).

$$Hb_i = \alpha_0 + \alpha_1 AMB + \alpha_2 SBA + \alpha_3 Child + \alpha_4 Individual + \alpha_5 Household + \alpha_6 Community$$

In the above equation, AMB is a vector that consists of the following variables – iron folic acid supplements consumed by the mother during pregnancy (binary), iron supplementation for child (binary). Medicines for intestinal parasites in the last six months (binary), child’s breastfeeding status (binary), and whether or not the child consumed Vitamin A- rich fruits and vegetables, animal proteins, and dark green leafy vegetables in the previous 24 hours.

Variables related to the SBM are included in the *SBM* vector in the equation above. These include whether or not the household practices OD (binary), and the share of households practicing OD in every village. As figure 1 shows, an increase in community level OD rates (i.e. an increase in the fraction of households defecating in the village) is associated with a decline in Hb levels of children residing in that village.

Figure 1: Relationship between community- level OD rates and child hemoglobin level



The age and gender of child are included in the *Child* vector. We also control for underlying maternal characteristics that have commonly been associated with anemia. These form the *Maternal* vector and include maternal BMI and hemoglobin level as in (Coffey et al., 2018; Hong Nguyen et al., 2018; Pasricha et al., 2010), mother's age at first birth, and education level.

Household level factors like wealth (wealth index), religion, and rural/ urban are included in the *Household* vector. And finally, to account for health and environmental characteristics at the community level that can vary with time, we control for community level indicators like the proportion of households with electricity, in- yard piped water and at- home piped water access (as in (Coffey et al., 2018). These make up the *Community* vector in the equation above.

The drivers of anemia are further analyzed for two separate levels: by spatial location (rural and urban) and different wealth quintiles.

3. Results

3.1 Descriptive statistics

Table 1 presents descriptive statistics for our sample of children who are under two years of age. A little over half the sample consists of boys and the average hemoglobin level in the country is 9.86 g/dL. About 39% of children were consuming iron pills, sprinkles, or syrup and 40% consumed parasitic medicine in the past six months. More that three- fifth of the children were breastfed. The consumption of fruits and vegetables in the sample was higher (48% children) as compared to the intake of protein- rich meats and eggs (21% children). Mothers' average hemoglobin levels were 11.46 g/dL and 86% of mothers reported having consumed iron supplementation during pregnancy. Nearly 79% of the households reported using a sanitation facility for defecation.

Table 1: Descriptive statistics for sample of children 0 – 24 months

	NFHS-5 (2019-21)		
	Mean (1)	SD (2)	Observations (3)
<u>*Child Attributes*</u>			
Age (months)	15.01	5.43	62554
Child is male (%)	0.52	0.50	62554
Hemoglobin (g/dL)	9.86	1.53	62554
Any Anaemia (Hb <11 g/dL)	0.60	0.49	62064
Mild Anaemia (Hb 10-10.9 g/dL)	0.27	0.44	62064
Moderate Anaemia (Hb 7-9.9 g/dL)	0.31	0.46	62064
Severe Anaemia (Hb < 7 g/dL)	0.02	0.14	62064
Currently taking iron pills, sprinkles, or syrup	0.39	0.49	62554
Parasitic medicine consumed in the past six months	0.40	0.49	62554
Child is currently breastfed	0.85	0.36	62554
Fruits and vegetables consumed in the past 24 hours	0.48	0.50	59631
Meat and eggs consumed in the past 24 hours	0.21	0.41	59630

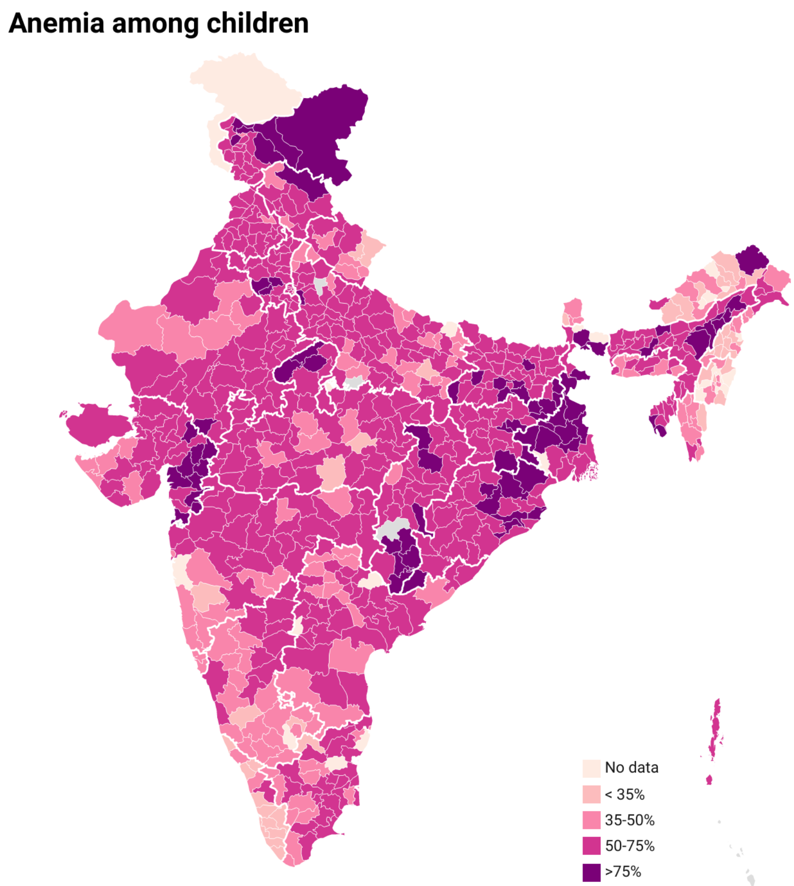
Dietary count of food groups consumed in the past 24 hours	1.93	1.27	62554
Resides in an urban area	0.19	0.40	62554
Mother's Characteristics			
Age (years)	26.22	4.38	62554
Age at first birth (years)	21.58	3.73	62554
Literate	0.74	0.44	62554
Has attended primary	0.12	0.32	62554
Has attended secondary	0.54	0.50	62554
Has completed secondary	0.15	0.36	62554
Height (cms)	151.73	6.31	62328
Weight (kg)	49.53	10.08	62332
BMI	21.46	3.88	62267
Hemoglobin (g/dL)	11.46	1.53	62056
Consumed iron supplements during last pregnancy	0.86	0.34	59383
Household's Socio-Economic Characteristics			
Sanitation facility	0.79	0.41	62554
Sanitation facility for urban households	0.18	0.39	62554
Sanitation facility for rural households	0.61	0.49	62554
Electricity	0.91	0.28	62554
Improved water source	0.91	0.29	62554
Radio	0.05	0.22	62554
TV	0.59	0.49	62554
Fridge	0.31	0.46	62554
Bike	0.44	0.50	62554
Motorcycle	0.49	0.50	62554
Electricity	0.91	0.28	62554

Notes: This table depicts the summary statistics for our sample of observations in NFHS-5. Observations are children between 6 to 59 months, whose hemoglobin levels were measured.

3.1 Prevalence of anemia in children, 6 – 24 months

Anemia in children is said to occur when the hemoglobin levels fall below 11 g/dl. The average hemoglobin levels were 9.86 g/dl in children belonging to the 0- 24 months (Table 1). According to the NFHS 5 data, 60% of children from 6 to 24 months were anemic in the country in 2019- 21. We also note that there has been a relatively greater increase in the share of children with moderate and severe anemia as compared to mild anemia. This is in contrast with global (and South Asia) trends that have seen the converse i.e., a shift away from moderate and severe anemia, towards mild (Stevens et al 2022). Across wealth quintiles, we observe that the prevalence of anemia is higher in the poorest households (64%) as compared to the richest (52%). District- level prevalence of anemia in women and children can be seen in figure 2.

Figure 2: District- level anemia prevalence in children aged 6 to 24 months, 2019- 20



3.2 Determinants of child hemoglobin levels

Table 2 below highlights the role of various determinants of child hemoglobin levels for children under 2. We find strong evidence in support of the AMB through its micronutrient supplementation programs such as iron-folic acid supplements for mothers during pregnancy. Mothers' hemoglobin (hb) levels are a significant driver of hemoglobin levels in children. For every 1 g/dL increase in maternal hb levels, there is an associated increase of 0.16 g/dL increase in child hb levels. Also significant is the component of AMB that focuses on improved child feeding practices. We find that child's breastfeeding status and consumption of Vitamin-A rich fruits and vegetables as well as protein- rich foods is associated with significantly higher hb levels in children under 2. The negative association between child's consumption of iron supplements and hemoglobin levels is unexpected, given the historical emphasis on iron supplementation in India. However, in the absence of data on the extent to which anemia in our data is the result of iron- deficiency, it is plausible to expect that iron supplementation might not be as efficacious as expected if iron- deficiency anemia is not the predominant cause of anemia in this age group (Kurpad & Sachdev, 2022).

Reinforcing the increase in hemoglobin levels from the AMB, we see evidence of SBM through the role of sanitation with the practice of open defecation at both, the household level and community level being associated with significantly higher hemoglobin levels. As the community moves from complete OD to zero rates of OD, the Hb concentration in children improves by 0.12 g/dL.

The results for the rural sample are similar to that of the total sample. In the case of the urban sample, we find that the role of open defecation loses its significance, as do maternal indicators like BMI and iron supplementation during pregnancy.

Table 2: Determinants of hemoglobin level for children under 2

	All Sample	Rural	Urban

	(1)	(2)	(3)
Mother's Hemoglobin	0.16***	0.16***	0.15***
	0	0.01	0.01
Mother's BMI	0.01***	0.02***	0
	0	0	0
Mother took Iron Pills during Pregnancy	0.04**	0.05**	-0.03
	0.02	0.02	0.05
Child is currently Breastfed	0.10***	0.10***	0.08*
	0.02	0.02	0.04
Child consumed Vitamin A Fruits and Vegetables in the past 24 hours	0.03*	0.02	0.06*
	0.02	0.02	0.04
Child consumed Animal Protein in the past 24 hours	0.08***	0.06***	0.14***
	0.02	0.02	0.04
Child consumed DGLF in the past 24 hours	0.02	0.01	0.03
	0.02	0.02	0.04
Drugs for intestinal parasites in the last six months	0	0	0.01
	0.02	0.02	0.04
Taking iron pills, sprinkles or syrup	-0.04***	-0.05***	0
	0.02	0.02	0.04
Household Open Defecation	-0.05***	-0.05***	-0.08
	0.02	0.02	0.07
Mean Open Defecation Levels at the Community Level	-0.23***	-0.25***	0

	0.04	0.04	0.13
Mother's Characteristics	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes
Child Age and Gender Dummies	Yes	Yes	Yes
Regional Characteristics	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
Observations (Number of children aged 6 to 24 months)	55979	45071	10908

Notes: Each column displays the result of a separate OLS regression with child's hemoglobin as the dependent variable. The standard errors are reported in brackets below the coefficient and are clustered at the level of the primary sampling unit. Maternal characteristics include the mother's age at first birth and the mother's education (an indicator for literacy). Household characteristics include place of residence, religion of the household head, and wealth. Regional characteristics consist of village-level fraction of households with electricity, in-yard piped water and at-home piped water access.

*+ p<0.15, * p<0.10, ** p<0.05, *** p<.01*

3.3 Subgroup analysis by household wealth: wealth quintiles

Table 3 shows the results by wealth quintile. Across household wealth quintiles we find that maternal hb is a significant determinant of child hb levels. Child intake of animal proteins is associated with significantly higher hemoglobin levels in all quintiles except the middle. Community-level open defecation is significant for child hemoglobin at lower income levels and loses significance in the two richest quintiles.

Table 3: Determinants of hemoglobin by wealth quintile, children under-2

	Poorest	Poor	Middle	Richer	Richest
	(1)	(2)	(3)	(4)	(5)
Mother's Hemoglobin	0.15***	0.15***	0.16***	0.16***	0.17***
	0.01	0.01	0.01	0.01	0.01
Mother's BMI	0.02***	0.01***	0.01***	0.02***	0
	0	0	0	0	0
Mother took Iron Pills during Pregnancy	0.03	0.12***	0.03	-0.01	0.02
	0.03	0.04	0.05	0.05	0.06
Child is currently Breastfed	0.04	0.04	0.04	0.22***	0.16***
	0.04	0.04	0.04	0.04	0.05
Child consumed Vitamin A Fruits and Vegetables in the past 24 hours	0	0.06*	0.04	0.05	-0.02
	0.03	0.03	0.04	0.04	0.05
Child consumed Animal Protein in the past 24 hours	0.05+	0.06+	0.04	0.12***	0.17***
	0.03	0.04	0.04	0.04	0.05
Child consumed DGLF in the past 24 hours	0.01	0.01	0.08**	-0.02	-0.02
	0.03	0.03	0.04	0.04	0.05

Drugs for intestinal parasites in the last six months	0	-0.01	-0.02	0.01	0.05
	0.03	0.03	0.03	0.04	0.04
Taking iron pills, sprinkles or syrup	-0.08***	-0.04	-0.01	-0.08**	0.03
	0.03	0.03	0.03	0.04	0.04
Household Open Defecation	-0.03	-0.03	-0.09*	-0.05	-0.35
	0.03	0.04	0.05	0.1	0.55
Mean Open Defecation Levels at the Community Level	-0.30***	-0.27***	-0.18**	0.02	-0.17
	0.06	0.07	0.08	0.11	0.16
Mother's Characteristics	Yes	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes	Yes
Child Age and Gender Dummies	Yes	Yes	Yes	Yes	Yes
Regional Characteristics	Yes	Yes	Yes	Yes	Yes
Observations (Number of children aged 6 to 24 months)	14952	13059	11135	9455	7369

Notes: Each column displays the result of a separate OLS regression with child's hemoglobin under 5 years of age as the dependent variable. The standard errors are reported in brackets below the coefficient and are clustered at the level of the primary sampling unit. Maternal characteristics include the mother's age at first birth and the mother's education (an indicator for literacy). Household characteristics include the place of residence and religion of the household head. Regional characteristics consist of village-level fraction of households with electricity, in-yard piped water and at-home piped water access.

+ $p<0.15$, * $p<0.10$, ** $p<0.05$, *** $p<.01$

4. Contributions and policy implications

This body of work presents evidence on the association between nutritional and non- nutritional public policy programs, and child anemia in India. Our analysis finds strong evidence in support of complementarities between nutritional policy interventions such as the AMB and non-nutritional policies like the SBM. We track the interventions within these policies using nationally representative data at multiple levels – individual, household, and community. By looking at both, the AMB and SBM, we are able to contribute to the knowledge base of how nutritional and non- nutritional factors drive anemia in young children. Such information can be useful for the implementation of appropriate interventions that simultaneously account for the varied causes of anemia (Chaparro & Suchdev, 2019).

Any discussion of anemia and its determinants cannot be complete without referring to data issues regarding three key aspects – 1) the method used to assess hemoglobin levels, 2) the integration of additional biomarkers that can offer clarity on the specific cause of anemia and 3) the hemoglobin cutoffs used to identify anemia in a given population. We discuss each of these in detail below.

Our classification of anemia is based on hemoglobin values provided in the NFHS dataset. The NFHS uses capillary blood samples from finger pricks for measuring blood hemoglobin level. While it offers granular estimates at the district level, the methodology itself has been criticized in recent times. Kurpad and Sachdev (2022) argue that this measure of hemoglobin assessment results in an overestimation of prevalence of anemia. Unlike the NFHS (anemia rate of 67% in children), anemia prevalence in children is estimated at 30% when venous blood samples were used in the Comprehensive National Nutrition Survey (CNNS) of children in India. Similar results are reported from Maharashtra where venous blood samples indicate an anemia prevalence rate of 40% in women (Gupta et al., 2019).

In addition to the methodological differences in the measurement of hemoglobin, one of the biggest data gaps in the assessment of anemia prevalence worldwide is the paucity of data on other, related blood markers. It has commonly been believed that iron deficiency is the leading cause of anemia in India (WHO[4]). In order to be able to attribute anemia to nutritional or non-nutritional causes, data is needed on additional biomarkers. Some examples of this include serum ferritin and transferrin receptor (for iron levels), C- reactive protein (for inflammation/ infection), and concentration of non- iron micronutrients like Vitamin A and B-12 (Gupta et al., 2019; Kurpad & Sachdev, 2022). In a study focusing on women's iron status in the state of Maharashtra, Gupta et al (2019) conclude that nearly 80% of anemia in women is attributable to iron deficiency. More recently, by using multiple biomarkers the CNNS is able to attribute child anemia to different nutritional deficiencies (Sarna et al., 2020). For instance, while 36% of anemia was due to iron deficiency, 20% is due to deficiency of folate or Vitamin B12 and another 25% is due to other causes (that include WASH). Having this kind of granular information on the causes of anemia can aid the choice of interventions included in anemia mitigation programs.

More recently, there have been calls for a reexamination of the hemoglobin cutoffs specified by the WHO to aid an accurate estimate of the prevalence of anemia. The existing cutoffs were put in place in 1968, and are based on the 5th percentile of hemoglobin distribution for a healthy Western population with adjustments over the years for different age groups (Chaparro & Suchdev, 2019; Kurpad & Sachdev, 2022). However, as Sachdev et al (2021) have recently shown using nationally representative data from CNNS, the 5th percentile cutoff for healthy children in India would result in a hemoglobin level that is 1-2g/dl lower than the threshold specified by the WHO. These, lower, India- specific cutoffs can potentially translate into a reduction in child anemia rates by two- thirds, relative to those resulting from the use of WHO cutoffs. Specifically, for children 1 – 4 years old (the focus age group for our paper), anemia rates fall from 40.5% based on WHO cutoff to 15.4% based on the age- and sex- specific cutoffs for India.

In addition to the emphasis on nutritional factors that can explain anemia, we also find that improved sanitation practices (less open defecation) are associated with significantly higher hemoglobin levels. This corroborates existing evidence on the sanitation- nutrition channel

[4] https://www.who.int/health-topics/anaemia#tab=tab_1

(insert refs). Specifically for India, this finding is also relevant in light of the CNNS survey data from India that finds a strong role of non- nutritional factors including inflammation in explaining child anemia (Kurpad & Sachdev, 2022). The AMB is led by India's Ministry for Health and Family Welfare (MoHFW). Although an element of inter- ministerial convergence is part of the AMB design, it is not clear how this is operationalized with the primary role being played by different programs within the MoHFW itself. While the Ministry of Drinking Water and Sanitation is envisaged as a partner, it is not clear how its role has been integrated within the AMB activities.

In this paper, we analyze the complementary role of nutrition-specific (AMB, or Anemia Free India) and nutrition-sensitive (SBM, or Clean India Mission) national-level programs on the prevalence of anemia in India. Using nationally representative data, our results provided strong evidence in support of AMB (through micronutrient supplementation programs such as iron-folic acid supplements for mothers during pregnancy) and SBM (through reduction in community OD rates) in reducing the prevalence of anemia in India. Given the complex etiology of the causes of anemia, ranging from nutrition deficiencies to unsanitary environment inhibiting absorption, our paper provides empirical evidence to promote collaboration among multiple sectors. Such programs can encourage synergistic interventions that can prioritize investments to combat the prevalence of anemia in the most effective manner.

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