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Household sanitation and personal hygiene practices are associated with child stunting in rural India

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ABSTRACT

Objectives: Increasing evidence suggests that water, sanitation and hygiene (WASH) practices affect linear growth in early childhood. We determined the association between household access to water, sanitation, and personal hygiene practices and stunting among children aged 0-23 months in rural India.

Setting: Rural India

Participants: A total of 8,949, 34,639, and 1,282 under-twos who participated in the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included in the analysis.

Primary outcomes measured: The association between WASH indicators and child stunting was assessed using logistic regression models. All analyses were performed separately for children aged 0-5 and 6-23 months.

Results: The prevalence of stunting ranged from 25% to 50%. Compared with open defecation, household access to toilet facility was associated with a 23-44% reduced odds of stunting among children aged 6-23 months, after adjusting for all potential confounders [NHFS-3 (OR=0.71, 95%CI:0.57-0.88); HUNGaMA (OR=0.77, 95%CI:0.70-0.85); CNSM (OR=0.56, 95%CI:0.35-0.88)]. Household access to improved water supply or piped water was not in itself associated with stunting. The caregiver's practices of washing hands with soap before food (OR=0.85, 95%CI:0.65-0.94) or after defecation (OR=0.85, 95%CI:0.78-0.93) were protective against child stunting. However, the inverse association between personal hygiene practices and stunting

existed only among households with access to toilet facility or piped water (all interaction terms, $P<0.05$).

Conclusion: Improved conditions of sanitation and hygiene practices are associated with reduced prevalence of stunting in rural India. Policies and programming aiming to address child stunting should encompass WASH interventions, thus shifting the emphasis from nutrition specific to nutrition sensitive programming. Future randomized trials are warranted to validate the causal association.

Trial Registration: Not applicable.

ARTICLE SUMMARY

Strengths and Limitations of this Study

- This study assessed the WASH predictors of child stunting using three large representative survey datasets coming from the local context.
- This analysis used cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established
- The mother/caregiver's personal hygiene practices were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems;
- While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data
- Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight.

INTRODUCTION

In 2012, the World Health Organization adopted a new global target of reducing the number of stunted children under-five by 40% by 2025.[1] Despite decades of significant economic growth, India has one of the world's highest child stunting rates. The 2006 National Family Health Survey shows that 48% of Indian children under five – 61 million children – are stunted due to chronic nutrition deprivation, accounting for more than one third of stunted children in the developing world.[2] Child stunting is linked to serious and largely irreversible consequences for survival, health, development, school performance, and productivity in adult life.[3, 4]

For many children, stunted growth starts before birth as a result of poor maternal nutritional status and worsens gradually during the first two years of life.[5] Thus, the first 1000 days, from conception until the age of two years, are a critical window of opportunity, during which timely interventions can have a measurable and lasting impact on the prevention of child stunting.[2] Importantly, however, in the current context of widespread infection and contamination in children's environments, dietary interventions alone may be insufficient to promote optimal growth in children in developing countries. In such environments, efficacy studies with nutrient-dense food supplements have shown to improve approximately 0.7 height-for-age z-score at best.[6] This is only a third of the average height deficit in South Asian and sub-Saharan African children.[7]

Growing evidence suggests a link between child linear growth and household water, sanitation, and hygiene (WASH) practices.[8] It has been estimated that as much as 50% of child undernutrition may be attributable to poor WASH practices.[9] Ingestion of high quantities of fecal bacteria from both human and animal sources by infants and young children through mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry feces are common in many rural low income environments. This leads to intestinal infections which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption, and increasing nutrient losses.[10]

In India, approximately 53% of households and 624 million people defecate in the open.[2] Open defecation is more pervasive in rural areas (74% vs. 17%). Recently, an ecological analysis of data from 112 rural districts of India demonstrated a strong association between the prevalence of open defecation and stunting, after adjusting for potential confounders.[11] This analysis added to a growing body of suggestive evidence on the effect of open defecation on child linear growth. However, further evidence is needed to corroborate the findings, as ecological studies are prone to ecological fallacy and other errors, and are often used to generate hypotheses for additional investigation employing more rigorous methods.[11]

Strengthening the evidence base on the linkages between child linear growth and WASH practices in Indian population will support informed development of policy and guidelines that inform optimal programmatic strategies, actions, and monitoring. This study therefore sought to determine whether improved WASH conditions are associated with reduced child stunting in rural India. Specifically, the analysis aimed to determine the association between stunting and household access to sanitation facilities, water supply, and personal hygiene practices using multiple logistic regression analyses.

METHODS

Data

We analyzed three large datasets obtained from the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). Details of the three surveys are described elsewhere.[2, 12, 13] Briefly, the NFHS-3 is a Demographic Health Survey carried out by the International Institute for Population Services (IIPS) in 2005-6, that provides information on mortality, fertility, family planning, environmental hygiene, nutrition, and health status of India's population.[2] A stratified multistage cluster sampling method was used to identify a nationally representative sample of India's population living in both urban and rural areas in 29 states. A total of 109,041 households were selected, from which a total of 124,385 women age 15-49 years and 74,369 men age 15-54 years were included in the survey.[2]

The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect district level data on the nutritional status of Indian children below five years of age.[12] The survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this, 100 districts were those with the poorest indicators of child wellbeing in the country, and the remaining 12 districts were selected among those with some of the best indicators of child wellbeing for the purpose of within-state comparison. The selected areas represent about one-sixth of India's population and one-fifth of India's children under-five. A stratified cluster sampling was employed to identify a representative sample of 73,670 households from which a total of 109,903 children under-five were included in the survey. Information on child nutritional status was collected together with relevant maternal, household and environmental determinants.[12]

The CNSM is the first ever state-specific survey in India that provides information on nutritional status and feeding practices of children below two years of age and relevant maternal and household determinants.[13] The survey is a joint initiative of the Government of Maharashtra and UNICEF, implemented by the IIPS. A multi-stage stratified sampling method was used to select a total of 2,650 children undertow from 2,630 households from the six administrative divisions of the state, namely Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune.[13] The sampling scheme was designed to represent Maharashtra State.

Data Collection

Data were collected using similar methods in all three surveys.[2, 12, 13] All interviews and anthropometric measurements were conducted at home by field teams who visited eligible respondents in each of the selected household. Written consent was sought from each respondent and parents or guardians provided consent for infants and children. Interviews and assessments were carried out only after consent was obtained.

Information on the child's age, sex, morbidity in the past week(s), immunization status, breastfeeding practices and dietary intake was collected from the mother of the child or caregiver. Mothers/caregivers were interviewed regarding their age, education, reproductive history, nutritional status, morbidity, and reported personal hygiene practices. Information on household composition, source of drinking water and sanitation facility, socioeconomic status, and utilization of social safety net programs was also collected. All interviews were carried out using a structured questionnaire.

Anthropometric measurements were taken from the children and mothers following standard procedures.[14] Height was measured using a height/length board to the nearest 0.1 cm.

Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children was determined using the immunization cards or home records of date of birth to the extent possible. When these documents were unavailable, the local events calendar was used to help with the recall of the child's age.

The field interviewers/anthropomerists were from local non-governmental organization partners and were thoroughly trained before data collection. The performance of field staff during data collection was continuously monitored by supervisors and quality control teams who rechecked some of the data the following day to ensure data reliability. Nonresponse and refusal to participate in the surveys were minimal.

Statistical Analysis

This analysis included 8,949, 34,639, and 1282 children 0-23 months of age in rural India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than one child under-two was assessed in a given household, only the youngest child from each household was included in the analysis. All analyses were weighted according to the population size and adjusted for the multistage cluster design of the surveys.

Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009 software.[15] Maternal body mass index (BMI) was defined as weight divided by the square of height (kg/m^2). In the analysis of data obtained from the NFHS and CNSM, sources of drinking water were classified into improved water sources including water piped into a dwelling, plot or yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater vs. unimproved water.[16, 17] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet.[16] A comparison was also made between piped water vs. other sources of drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of drinking water only as hand pump and piped water and others and sanitation as defecating in the open vs. any toilet.[12]

In the NFHS-3 and CNSM, a wealth index was computed as an indicator of household economic status. Details on the estimation of household wealth index are described elsewhere.[12, 13] Briefly, each asset was assigned a standardized score generated through a principal components analysis. The selected households were then ranked according to the sum of household asset scores and were grouped into five wealth quintiles from the lowest (poorest) to the highest (richest) score. For HUNGaMA a wealth index was not generated and household ownership of durable assets was used as the primary indicator of household economic status.

Data for each survey were analyzed separately. Descriptive statistics were used to examine the distribution of the full range of variables. Using appropriate cutoffs, dichotomous or categorical variables were created for a few variables such as birth order (1-2, 3-4 or ≥5); maternal education (no education, primary school, secondary school, or > secondary school); maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5 kg/m^2); and household composition (2-6, ≥7).

Analyses were performed separately for children 0-5 and 6-23 months of age because the two groups of children have predominantly different feeding practices. Multiple logistic regression analyses were used to examine the association between the risk of stunting and WASH practices adjusting for potential confounders. Stunting was included as the dependent variable and household sanitation facilities, source of drinking water, and personal hygiene practices as the independent variables, together with the potential confounding factors.

Confounding factors included major determinants of child stunting based on UNICEF's conceptual framework[17], which differed by child stunting status and were associated with each WASH indicator in the bivariate analyses using χ^2 test ($P < 0.05$). The interactions between household sanitation facilities, source of drinking water, and personal hygiene were created to examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical significance defined as $P<0.05$. All analyses were performed using STATA version 13.0 (Stat Corp., College Station, TX, USA).

RESULTS

NFHS-3

The mean (± standard error (SE)) age of children in the analysis was 11.8 ± 0.09 months and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15% were reported to have had diarrhea in the past two weeks. The mean (± SE) age of the mothers of under-twos was 25.0 ± 0.08 years. More than half the mothers had no education and 41% had short stature (<150 cm). About 83% of the households had access to improved drinking water sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation facilities, whereas 77% had no toilet facility.

Household sanitation facility was a key predictor of stunting among children aged 6-23 months. In a multivariate analysis, compared with open defecation, household access to toilet facility was associated with a 27% lower odds of being stunted, adjusting for all potential confounders (OR=0.73, 95% CI: 0.59-0.91) (Table 2). Household access to an improved drinking water source or piped water was not a predictor of child stunting. No interactions between household access to sanitation facilities and drinking water sources were observed (data not shown).

HUNGaMA

The mean (±SE) age of the children was 11.7 ± 0.04 months with both sexes equally represented (Table 1). About one-half (50%) were stunted, 16% were wasted and 41% had had diarrhea in the past week. The mean (± SE) age of the mothers was 26.8 ± 0.04 years and approximately 63% had no education. About a quarter of the households (24%) had access to piped water, whereas most of the households (83%) had no toilet facility.

Having a toilet facility at home was associated with a 22% reduced odds of being stunted among children aged 6-23 months, after adjusting for all potential confounders (OR=0.77, 95% CI: 0.70-0.86) (Table 3). Household access to a piped water source was not associated with stunting. There were no synergistic effects of household sanitation and water supply on child stunting.

The mother/caregiver's hygiene practices appeared to predict the risk of child stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands with soap after defecation was associated with a 15% reduced risk of stunting among children aged 6-23 months (OR=0.85, 95% CI: 0.78-0.93) (Table 3). Likewise, the caregiver's reported practice of washing their hands with soap before food was associated with a 15% lower odds of stunting among children aged 6-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).

There was a significant interaction between mother/caregiver's hygiene practices and household sanitation and drinking water conditions in their association with child stunting. The protective effect of mother/caregiver's practice of washing their hands with soap before food against child stunting existed only among households with access to piped water (OR=0.78, 95% CI: 0.65-0.94 vs. OR=0.90, 95% CI: 0.79-1.03, interaction term $P<0.05$) (Table 4). In addition, the inverse association between mother/caregiver's practices of washing their hands with soap after defecation and stunting was stronger among households with access to toilet facility (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).

CNSM

The mean (± SE) age of the children was 11.0 ± 0.24 months and about 56% were male (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had had diarrhea in the past two weeks. The mean (± SE) age of the mothers was 23.6 ± 0.12 years and 14% had no education. Approximately 87% of the households had improved sources of drinking water, and about 30% had access to piped water. Twenty seven percent of the households had access to improved sanitation facilities.

In multivariate analysis, household access to toilet facility was associated with a 45% reduced odds of being stunted among children aged 6-23 months, after adjusting for all potential confounders (OR=0.55, 95% CI: 0.35-0.86) (Table 5). Household access to an improved water source and piped water did not predict child stunting.

DISCUSSION

We report here the association between child stunting and household access to improved sanitation and drinking water source and personal hygiene in India based on large survey datasets representative at national, state and district levels. Notably, household access to toilet facility was associated with a 23-44% reduced odds of stunting among children aged 6-23 months. On the other hand, household access to an improved source of drinking water or piped water in particular was not a predictor of stunting. The mother/caregiver's practices of washing their hands with soap either before a meal or after defecation was associated with a 15% reduced risk of stunting.

Overall, our results of the inverse association between stunting and household access to toilet facility tend to confirm the findings of previous non-randomized research carried out in different parts of the world.[19-22] Using data from multiple countries in Africa, Asia and Latin America, Esrey showed that improved sanitation conditions were associated with a 0.06-0.62 and 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.[19] Similarly, in a cross-sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not included), access to improved sanitation was shown to be associated with a 27% lower risk of child stunting.[20] Recently, in an ecological analysis, Spears et al. found that differences in open defecation could statistically account for 35-55% of the average difference in stunting between districts in India.[11] The findings of our analysis based on three large survey datasets collected at the household level, reinforce the notion that poor sanitation may indeed greatly increase the likelihood of child stunting in rural India where open defecation is pervasive and the burden of child stunting is massive.

Notably, the inverse association between stunting and household sanitation condition was observed only among children aged 6-23 months. It is evident that children become more affected by environmental contamination as they start crawling, walking, exploring, and putting objects in their mouths, which increases the risk of ingesting fecal bacteria from both human and animal sources. This leads to repeated bouts of diarrhea and intestinal worms, which in turn deteriorates the nutritional status of children.[23] Importantly, growing evidence suggests that a key cause of child undernutrition is a subclinical disorder of the small intestine known as environmental enteropathy which is in turn caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene.[24] This hypothesis makes addressing the issues of sanitation even more critical.

Household access to an improved source of drinking water or piped water was not associated with child stunting. This corroborates earlier findings from non-randomized studies which indicated that the potential effects of improved water supply on child linear growth tend to be much smaller than those of improved sanitation.[19] The lack of association in our analysis may be explained by the current predominant use of an improved drinking water source in India. The NFHS and CNSM showed that ~83% and ~74% of the households in rural areas, respectively, have access to improved drinking water sources.[2,13] About a quarter of households reported having water piped into the dwelling, plot or yard.[2,13] Although household access to piped water was significantly associated with stunting in bivariate analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential confounders.

Our results indicated no significant interactions between household access to improved water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and sanitation on child linear growth.[19,21,25] In a cross-sectional, multi-country study, Esrey noted that the positive association between improved sanitation and child linear growth was enhanced by household access to an improved water supply.[19] Similarly, in a longitudinal study in Peru, Checkley et al found that the positive association between improved water sources and child linear growth existed only when it was accompanied by improved sanitation and water storage practices.[21] In contrast, no synergistic effects of water and sanitation were found in a large prospective cohort study in Sudan.[25] Therefore, further research is required to determine if improved household water supply and its handling and storage, and sanitation conditions have additive or synergistic effects on child linear growth.

Few studies have explored the association between the mother/caregiver's personal hygiene practices and child stunting in India. We found that mothers/caregivers who reported washing their hands with soap either before meal or after defecation were less likely to have stunted children. This corresponds with the findings from a community-based cross-sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were significantly associated with child undernutrition.[26] Our findings also suggest that the protective effects of mother/caregiver's personal hygiene practices existed only when it was accompanied by an improved household access to piped water and toilet facility. Clearly, efforts to improve personal hygiene practices of both mothers/caregivers and children themselves are essential to prevent diarrhea and other infections among children, which may in turn contribute to the reduction of stunting. In addition, relevant actions may need to be prioritized amongst those currently without access to water or sanitation facilities. These efforts should be accompanied by concrete actions to enhance household water and sanitation conditions. Further research is required to examine the impact of improved personal hygiene practices on child growth, especially as part of a multi-sectoral approach to effectively address child stunting.

The limitations to this study need to be considered. We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established. The mother/caregiver's personal hygiene practices were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems. While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data. Data on personal hygiene was not collected from the NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with soap was determined in the CNSM. Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight. Despite these limitations, assessing the WASH predictors of child stunting using large representative survey datasets coming from the local context is a critical step in strengthening the relevant evidence base and developing multi-sectoral interventions for optimal child growth.

In conclusion, this analysis revealed that household sanitation and the mother's/caregiver's personal hygiene practices are strong predictors of child stunting in India. This reinforces the growing evidence of the effects of WASH practices on child linear growth. Large-scale randomized effectiveness trials of toilet provision (and use) and handwashing at critical times, that include environmental enteropathy and child growth as outcomes, are warranted. However, this suggests the need for different programmatic responses by governments and development partners. Optimizing nutrition outcomes for young children now requires a framework that is broader than nutrition specific interventions alone. India's vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive interventions especially leading up to and during the first one thousand days. Children and mothers need basic WASH provision and behaviors to survive, grow and thrive.

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CONTRIBUTORSHIP STATEMENT

JHR conceptualize, designed and wrote the paper and conducted the data analysis; AC, VMA, SJC, SA wrote the manuscript; BB conducted the data analysis. All authors read the manuscript, made a substantial contribution, and approved the final manuscript.

COMPETING INTERESTS

None

DATA SHARING STATEMENT

N/A

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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS)[1]	Hunger and Malnutrition Survey (HUNGaMA) [2]	Comprehensive Nutrition Survey in Maharashtra (CNSM)[3]
N	8,949	34,639	1,282
Child Characteristics			
Age, months (mean ± SE)	11.8 ± 0.09	11.7 ± 0.04	11.0 ± 0.24
Male (%)	52	52	56
Birth order (%)			
1-3	71	76	93
≥4	29	24	7
Stunted height-for-age z-score, <-2 (%)*	41	50	25
Wasted weight-for-height z-score, <-2 (%)*	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30
Breastfeeding started within 1 hour of birth (%)	22	42	67

Maternal Characteristics			
Age, year (mean ± SE)	25.0 ± 0.08	26.8 ± 0.04	23.6 ± 0.12
Education (%)			
No schooling	55	63	14
Primary school	15	11	13
Secondary school	27	14	57
>Secondary school	3	12	15
Short stature, <150 cm (%)	41	-	37
BMI<18.5 kg/m^2 (%)	44	-	40
Household Characteristics			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility†	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source‡	74	-	57

[1] Missing values existed in the NFHS sample, including the following: child diarrhea (n=5), breastfeeding within 1 hour of birth (n=82), maternal height (n=27), maternal BMI (n=32)

[2] Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209), breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438), household size (n=257), source of drinking water (n=3395)

[3] Missing values existing in the CNSM sample, including the following: maternal age (n=10), maternal education (n=10), maternal height (n=12), maternal BMI (n=14)

* Estimated by using 2006 WHO growth reference

[†] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet

[‡] Improved water sources other than piped water included public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater

Table 2. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the National Family Health Survey by age group

	0-5 months			6-23 months		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source						
Other	1667	1.0 (Reference)	1.0 (Reference)	6146	1.0 (Reference)	1.0 (Reference)
Piped	230	0.53 (0.33-0.85)	0.62 (0.30-1.29)	906	0.63 (0.51-0.77)	1.00 (0.75-1.34)
Place of defecation						
No facility/bush/field	1239	1.0 (Reference)	1.0 (Reference)	4477	1.0 (Reference)	1.0 (Reference)
Any toilet facility	658	0.95 (0.70-1.30)	1.36 (0.85-2.17)	2575	0.46 (0.40-0.53)	0.73 (0.59-0.91)
Wealth index						
Poorest	524	1.0 (Reference)	1.0 (Reference)	1795	1.0 (Reference)	1.0 (Reference)
Poorer	496	0.90	0.79	1747	0.73	0.93

		(0.65-1.26)	(0.53-1.17)		(0.62-0.85)	(0.78-1.11)
Middle	417	0.85 (0.57-1.26)	0.90 (0.50-1.62)	1647	0.59 (0.50-0.70)	0.85 (0.69-1.04)
Richer	303	0.57 (0.36-0.91)	0.60 (0.29-1.22)	1245	0.42 (0.35-0.50)	0.77 (0.58-1.02)
Richest	157	0.52 (0.27-0.98)	1.04 (0.33-3.27)	618	0.21 (0.16-0.28)	0.71 (0.44-1.14)
Social class						
Other	541	1.0 (Reference)	1.0 (Reference)	2078	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	1356	0.85 (0.62-1.16)	0.74 (0.48-1.14)	4974	1.77 (1.55-2.02)	1.32 (1.10-1.60)
Maternal education						
No schooling	944	1.0 (Reference)	1.0 (Reference)	3324	1.0 (Reference)	1.0 (Reference)
Primary school	299	1.46 (1.02-2.08)	1.54 (0.98-2.42)	1105	0.68 (0.57-0.80)	0.85 (0.69-1.05)
Secondary school	586	0.74	0.86	2398	0.43	0.66

		(0.53-1.04)	(0.50-1.51)		(0.38-0.50)	(0.54-0.81)
>Secondary school	68	0.29 (0.10-0.85)	0.28 (0.04-2.11)	225	0.23 (0.15-0.34)	0.38 (0.19-0.78)
Maternal height						
≥150 cm	1098	1.0 (Reference)	1.0 (Reference)	4326	1.0 (Reference)	1.0 (Reference)
<150 cm	796	1.28 (0.98-1.67)	1.28 (0.94-1.75)	2702	1.94 (1.72-2.19)	1.71 (1.47-1.99)
Maternal age						
≥ 30	342	1.0 (Reference)	1.0 (Reference)	1577	1.0 (Reference)	1.0 (Reference)
<20	254	1.36 (0.85-2.16)	1.16 (0.56-2.41)	677	0.88 (0.71-1.10)	1.04 (0.76-1.41)
20-29	1301	0.83 (0.58-1.19)	0.78 (0.46-1.31)	4798	0.75 (0.64-0.87)	1.01 (0.80-1.27)
Frequency of antenatal care visit during pregnancy						
Less than 3 times	1057	1.0 (Reference)	1.0 (Reference)	3572	1.0 (Reference)	1.0 (Reference)
≥3 times	826	1.03	1.13	3380	0.58	0.89

		(0.79-1.35)	(0.80-1.60)		(0.51-0.65)	(0.76-1.04)
Maternal dietary intake†						
Consumed <4 food groups a week	941	1.0 (Reference)	1.0 (Reference)	3348	1.0 (Reference)	1.0 (Reference)
Consumed ≥4 food groups a week	355	1.07 (0.75-1.54)	0.98 (0.67-1.44)	1553	0.80 (0.69-0.94)	1.03 (0.88-2.22)
Birth order						
≥5	357	1.0 (Reference)	1.0 (Reference)	1182	1.0 (Reference)	1.0 (Reference)
1-2	990	1.03 (0.71-1.50)	0.95 (0.53-1.71)	3897	0.55 (0.47-0.65)	0.82 (0.63-1.06)
3-4	550	1.18 (0.79-1.76)	1.36 (0.79-2.34)	1973	0.69 (0.58-0.82)	0.87 (0.68-1.11)
Initiation of breastfeeding						
After 1 hour	1365	1.0 (Reference)	1.0 (Reference)	4758	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	520	1.09 (0.80-1.48)	1.25 (0.87-1.79)	2224	0.83 (0.73-0.94)	1.12 (0.95-1.31)
Complementary feeding practices						

Not fed minimum number of times and appropriate number of food group*				3712	1.0 (Reference)	1.0 (Reference)
Fed minimum number of times and appropriate number of food group				3305	1.03 (0.91-1.16)	1.06 (0.91-1.24)

† Food groups include milk and curd, pulse or beans, dark green leafy vegetables, fruits, eggs, fish, chicken or meat

‡ Required vaccinations include BCG, measles, and three doses each of DPT and polio vaccine

*Appropriate number of food groups including three or more food groups for breastfed children and four or more food groups for non-breastfed children; Minimum number of times are defined as at least twice a day for breastfed infants 6-8 months and at least three times a day for breastfed children 9-23 months

Table 3. Crude and adjusted odds ratios (OR) of household water and sanitation conditions and personal hygiene in relation to stunting for children who participated in the Hunger and Malnutrition Survey by age group

	0-5 months			6-23 months		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source						
Other	5,552	1.0 (Reference)	1.0 (Reference)	17,961	1.0 (Reference)	1.0 (Reference)
Piped	1,674	0.81 (0.70-0.94)	0.87 (0.74-1.01)	6,057	0.85 (0.79-0.91)	1.01 (0.93-1.10)
Place of defecation						
No facility/bush/field	6,673	1.0 (Reference)	1.0 (Reference)	21,784	1.0 (Reference)	1.0 (Reference)
Any toilet facility	1,242	0.76 (0.64-0.90)	0.93 (0.77-1.12)	4,780	0.57 (0.53-0.62)	0.78 (0.70-0.86)
Mother/Caregiver's practice of washing hands with soap after defecation						
No	6,451	1.0 (Reference)	1.0 (Reference)	21,550	1.0 (Reference)	1.0 (Reference)
Yes	1,500	0.77	1.00	5,138	0.65	0.85

		(0.66-0.88)	(0.85-1.18)		(0.61-0.70)	(0.78-0.93)
Household ownership of durable assets[†]						
Owning <2 items	3,336	1.0 (Reference)	1.0 (Reference)	11,419	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	4,543	0.77 (0.69-0.87)	0.89 (0.78-1.01)	15,017	0.71 (0.66-0.75)	0.90 (0.83-0.97)
Religion						
Other	1,088	1.0 (Reference)	1.0 (Reference)	3,958	1.0 (Reference)	1.0 (Reference)
Hindu	6,858	1.01 (0.85-1.19)	0.96 (0.79-1.15)	22,723	0.90 (0.83-0.98)	0.92 (0.83-1.02)
Social class						
Other	4,863	1.0 (Reference)	1.0 (Reference)	16,378	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	3,083	1.29 (1.15-1.44)	1.28 (1.12-1.45)	10,303	1.36 (1.28-1.44)	1.25 (1.16-1.35)
Maternal education						
No schooling	4,765	1.0 (Reference)	1.0 (Reference)	15,801	1.0 (Reference)	1.0 (Reference)
Primary school	950	0.86	0.87	2,997	0.76	0.82

		(0.63-1.16)	(0.63-1.22)		(0.64-0.90)	(0.67-0.99)
Secondary school	1,205	0.72 (0.63-0.83)	0.80 (0.68-0.93)	3,916	0.63 (0.59-0.68)	0.73 (0.67-0.80)
>Secondary school	950	0.53 (0.44-0.65)	0.66 (0.52-0.83)	3,617	0.36 (0.33-0.39)	0.48 (0.42-0.54)
Maternal age						
≥ 30	1,836	1.0 (Reference)	1.0 (Reference)	7,372	1.0 (Reference)	1.0 (Reference)
<20	330	0.97 (0.74-1.32)	1.15 (0.82-1.63)	624	0.97 (0.79-1.18)	1.19 (0.93-1.53)
20-29	5,737	0.89 (0.78-1.02)	0.98 (0.83-1.15)	18,554	0.82 (0.77-0.88)	1.02 (0.93-1.11)
Utilized ICDS's health check up service for their child						
No	5,815	1.0 (Reference)	1.0 (Reference)	18,512	1.0 (Reference)	1.0 (Reference)
Yes	2,084	0.91 (0.81-1.04)	0.98 (0.85-1.12)	8,009	0.87 (0.82-0.93)	0.92 (0.85-0.99)
Birth order						

≥5	846	1.0 (Reference)	1.0 (Reference)	3,077	1.0 (Reference)	1.0 (Reference)
1-2	4,599	0.78 (0.65-0.95)	0.98 (0.78-1.24)	15,567	0.73 (0.66-0.81)	0.96 (0.84-1.09)
3-4	2,456	0.87 (0.72-1.07)	0.98 (0.78-1.24)	7,881	0.85 (0.76-0.94)	0.95 (0.84-1.08)
Initiation of breastfeeding						
After 1 hour	4,326	1.0 (Reference)	1.0 (Reference)	14,513	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	3,541	0.79 (0.71-0.89)	0.83 (0.72-0.96)	11,870	0.77 (0.73-0.82)	0.89 (0.82-0.97)
Fed colostrum						
No	2,443	1.0 (Reference)	1.0 (Reference)	8,595	1.0 (Reference)	1.0 (Reference)
Yes	5,460	0.82 (0.73-0.93)	0.95 (0.82-1.11)	17,852	0.67 (0.61-0.74)	0.91 (0.83-0.99)
Complementary feeding practices						
Started before 6 months or after 8 Months				6,168	1.0 (Reference)	1.0 (Reference)

Started 6-8 months				18,672	0.92 (0.85-0.99)	0.99 (0.91-1.07)

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

Table 4. Crude and adjusted odds ratios (OR) of household sanitation conditions and personal hygiene practices in relation to stunting for children aged 6-23 months who participated in the Hunger and Malnutrition Survey by household access to piped water

	No access to piped water			Having access to piped water		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Place of defecation						
No facility/bush/field	15,360	1.0 (Reference)	1.0 (Reference)	4,217	1.0 (Reference)	1.0 (Reference)
Any toilet facility	2,527	0.59 (0.53-0.66)	0.77 (0.68-0.87)	1,801	0.54 (0.46-0.62)	0.81 (0.67-0.97)
Mother/Caregiver's practice of washing hands with soap before meal						
No	16,322	1.0 (Reference)	1.0 (Reference)	4,617	1.0 (Reference)	1.0 (Reference)
Yes	1,639	0.74 (0.65-0.83)	0.90 (0.79-1.03)	1,440	0.56 (0.48-0.66)	0.78 (0.65-0.94)
Household ownership of durable assets[†]						
Owning <2 items	8,064	1.0 (Reference)	1.0 (Reference)	2,144	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	9,755	0.74	0.90	3,830	0.63	0.87

		(0.68-0.79)	(0.83-0.98)		(0.55-0.72)	(0.75-1.02)
Social class						
Other	10,787	1.0 (Reference)	1.0 (Reference)	3,869	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	7,168	1.36 (1.26-1.46)	1.23 (1.13-1.34)	2,187	1.37 (1.20-1.57)	1.23 (1.06-1.43)
Maternal education						
No schooling	2,774	1.0 (Reference)	1.0 (Reference)	1,771	1.0 (Reference)	1.0 (Reference)
Primary school	658	0.78 (0.64-0.96)	0.83 (0.67-1.02)	273	0.89 (0.60-1.31)	0.98 (0.65-1.47)
Secondary school	1,043	0.67 (0.61-0.73)	0.72 (0.65-0.79)	334	0.60 (0.51-0.71)	0.72 (0.60-0.86)
>Secondary school	1,485	0.38 (0.34-0.43)	0.47 (0.41-0.54)	268	0.34 (0.28-0.40)	0.47 (0.38-0.58)
Maternal age						
≥ 30	5,165	1.0 (Reference)	1.0 (Reference)	1,436	1.0 (Reference)	1.0 (Reference)
<20	434	1.03	1.22	4,466	0.76	0.11

		(0.81-1.32)	(0.93-1.59)		(0.49-1.18)	(0.69-1.77)
20-29	12,274	0.85 (0.79-0.92)	1.00 (0.91-1.10)	1,436	0.77 (0.67-0.90)	1.04 (0.87-1.25)
Utilized ICDS's health check up service for their child						
No	12,891	1.0 (Reference)	1.0 (Reference)	3,719	1.0 (Reference)	1.0 (Reference)
Yes	4,996	0.92 (0.85-1.00)	0.94 (0.86-1.03)	2,265	0.82 (0.72-0.94)	0.90 (0.77-1.04)
Birth order						
≥5	2,241	1.0 (Reference)	1.0 (Reference)	502	1.0 (Reference)	1.0 (Reference)
1-2	9,998	0.79 (0.70-0.89)	0.98 (0.85-1.13)	4,097	0.57 (0.44-0.72)	0.82 (0.62-1.08)
3-4	5,617	0.86 (0.76-0.98)	0.94 (0.82-1.08)	1,420	0.83 (0.64-1.08)	0.99 (0.75-1.30)
Initiation of breastfeeding						
After 1 hour	10,222	1.0 (Reference)	1.0 (Reference)	2,813	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	7,552	0.85	0.92	3,161	0.67	0.86

		(0.79-0.91)	(0.85-1.01)		(0.59-0.76)	(0.73-1.01)
Fed colostrum						
No	6,206	1.0 (Reference)	1.0 (Reference)	1,593	1.0 (Reference)	1.0 (Reference)
Yes	11,611	0.83 (0.77-0.90)	0.93 (0.85-1.02)	4,387	0.64 (0.55-0.74)	0.86 (0.72-1.03)

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

Table 5. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the Comprehensive Nutrition Survey in Maharashtra by age group

	0-5 months			6-23 months		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source						
Other	238	1.0 (Reference)	1.0 (Reference)	675	1.0 (Reference)	1.0 (Reference)
Piped	98	0.36 (0.14-0.91)	0.43 (0.16-1.18)	271	0.94 (0.62-1.42)	1.08 (0.73-1.60)
Place of defecation						
No facility/bush/field	217	1.0 (Reference)	1.0 (Reference)	573	1.0 (Reference)	1.0 (Reference)
Any toilet facility	119	0.54 (0.28-1.03)	1.00 (0.49-2.04)	373	0.54 (0.36-0.81)	0.55 (0.35-0.86)
Wealth index						
Poorest	97	1.0 (Reference)	1.0 (Reference)	295	1.0 (Reference)	1.0 (Reference)
Poorer	107	0.71	0.47	308	1.06	1.28

		(0.28-1.79)	(0.16-1.33)		(0.69-1.63)	(0.83-1.96)
Middle	91	0.96 (0.33-2.81)	0.86 (0.28-2.67)	215	1.14 (0.68-1.88)	1.35 (0.81-2.25)
Richer	36	0.54 (0.10-2.87)	0.77 (0.12-4.97)	97	0.81 (0.43-1.52)	1.16 (0.59-2.25)
Richest[†]	5	-	-	31	0.71 (0.22-2.24)	1.26 (0.33-4.78)
Maternal education						
No schooling	50	1.0 (Reference)	1.0 (Reference)	121	1.0 (Reference)	1.0 (Reference)
Primary school	36	0.72 (0.19-2.80)	1.72 (0.18-2.84)	107	0.71 (0.37-1.37)	0.67 (0.34-1.31)
Secondary school	190	0.40 (0.13-1.25)	0.47 (0.14-1.57)	553	0.67 (0.42-1.07)	0.74 (0.47-1.16)
>Secondary school	56	0.39 (0.10-1.47)	0.55 (0.13-2.38)	159	0.55 (0.25-1.19)	0.70 (0.33-1.51)
Maternal height						

≥150 cm	218	1.0 (Reference)	1.0 (Reference)	572	1.0 (Reference)	1.0 (Reference)
<150 cm	114	2.59 (1.04-6.42)	3.06 (1.12-8.33)	366	2.18 (1.52-3.13)	2.09 (1.48-2.95)

† OR (95% CI) for children 0-5 months was dropped due to a small sample size

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Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross sectional analysis of surveys

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ABSTRACT

Objectives: Increasing evidence suggests that water, sanitation and hygiene (WASH) practices affect linear growth in early childhood. We determined the association between household access to water, sanitation, and personal hygiene practices with stunting among children aged 0-23 months in rural India.

Setting: India

Participants: A total of 10,364, 34,639, and 1,282 under-twos who participated in the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included in the analysis.

Primary outcome measures: The association between WASH indicators and child stunting was assessed using logistic regression models.

Results: The prevalence of stunting ranged from 25% to 50%. Compared with open defecation, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months, after adjusting for all potential confounders [NHFS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was not in itself associated with stunting. The caregiver's self-reported practices of washing hands with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse association between reported personal hygiene practices and stunting was stronger among households with access to toilet facility or piped water (all interaction terms, P<0.05).

Conclusions: Improved conditions of sanitation and hygiene practices are associated with reduced prevalence of stunting in rural India. Policies and programming aiming to address child stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-specific to nutrition-sensitive programming. Future randomized trials are warranted to validate the causal association.

Article Summary

- Household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India
- The protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility

Strengths and limitations of this study

- We analyzed three large survey datasets collected at the household level and representative of different administrative units; national, state and district
- We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established

INTRODUCTION

In 2012, the World Health Organization adopted a new global target of reducing the number of stunted children under-five by 40% by 2025.[1] Despite over two decades of significant economic growth, India has one of the world's highest child stunting rates. The 2006 National Family Health Survey shows that 48% of Indian children under five – 61 million children – are stunted due to chronic nutrition deprivation, accounting for more than one third of stunted children in the developing world.[2] Child stunting is linked to serious and largely irreversible consequences for survival, health, development, school performance, and productivity in adult life.[3, 4]

For many children, stunted growth starts before birth as a result of poor maternal nutritional status and worsens gradually during the first two years of life.[5] Thus, the first 1,000 days, from conception until the age of two years, are a critical window of opportunity, during which timely interventions can have a measurable and lasting impact on the prevention of child stunting.[2] Importantly, however, in the current context of widespread infection and contamination in children's environments, dietary interventions alone may be insufficient to promote optimal growth in children in developing countries. In such environments, efficacy studies with nutrient-dense food supplements have shown to improve approximately 0.7 height-for-age z-score at best.[6] This reflects on only one third of the average height deficit in South Asian and sub-Saharan African children.[7]

Growing evidence suggests a link between child linear growth and household water, sanitation, and hygiene (WASH) practices.[8] It has previously been estimated that as much as 50% of child undernutrition may be attributable to poor WASH practices.[9] Ingestion of high quantities

of fecal bacteria from both human and animal sources by infants and young children through mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry feces are common in many rural low income environments. This leads to intestinal infections which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption, and increasing nutrient losses.[10]

In India, approximately 53% of households and 624 million people defecate in the open.[2] Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). Recently, an ecological analysis of data from 112 rural districts of India demonstrated a strong association between the prevalence of open defecation and stunting, after adjusting for potential confounders.[11] This analysis added to a growing body of suggestive evidence on the effect of open defecation on child linear growth. However, further evidence is needed to corroborate the findings, as ecological studies are prone to ecological fallacy and other errors, and are often used to generate hypotheses for additional investigation employing more rigorous methods.[11]

Strengthening the evidence base on the linkages between child linear growth and WASH practices in Indian population will help support informed development of policy and guidelines that inform optimal programmatic strategies, actions, and monitoring. This study therefore sought to determine whether improved WASH conditions are associated with reduced child stunting in rural India. Specifically, the analysis aimed to determine the association between stunting and household access to sanitation facilities, water supply, and personal hygiene practices using multiple logistic regression analyses.

METHODS

Data

We analyzed three large datasets obtained from the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). Details of the three surveys are described elsewhere.[2, 12, 13] Briefly, the NFHS-3 is a Demographic Health Survey carried out by the International Institute for Population Services (IIPS) in 2005-6, that provides information on mortality, fertility, family planning, environmental hygiene, nutrition, and health status of India's population.[2] A stratified multistage cluster sampling method was used to identify a nationally representative sample of India's population living in both urban and rural areas in 29 states. A total of 109,041 households were selected, from which a total of 124,385 women age 15-49 years and 74,369 men age 15-54 years were included in the survey.[2]

The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect district level data on the nutritional status of Indian children below five years of age.[12] The survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this, 100 districts were those with the poorest indicators of child wellbeing in the country, and the remaining 12 districts were selected among those with some of the best indicators of child wellbeing for the purpose of within-state comparison. The selected areas represent about one-sixth of India's population and one-fifth of India's children under-five. A stratified cluster sampling was employed to identify a representative sample of 73,670 households from which a total of 109,903 children under-five were included in the survey. Information on child nutritional status was collected together with relevant maternal, household and environmental determinants.[12]

The CNSM is the first ever state-specific survey in India that provides information on nutritional status and feeding practices of children below two years of age and relevant maternal and household determinants.[13] The CNSM survey is a joint initiative of the Government of Maharashtra and UNICEF, implemented by the IIPS. A multi-stage stratified sampling method was used to select a total of 2,650 children under two years of age from 2,630 households from the six administrative divisions of the state, namely Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune.[13] The sampling scheme was designed to represent Maharashtra State.

These surveys all have different sample sizes as they are representative of different administrative units; national for NFHS and state for CNSM. The HUNGaMA survey represents a spread of the poorest districts in India and has a large sample size with a larger open defecation rate, but one in line with Census data. Ethical approval was not sought for this secondary analysis of publicly available survey data.

Data Collection

Data were collected using similar methods in all three surveys.[2, 12, 13] All interviews and anthropometric measurements were conducted at home by field teams who visited eligible respondents in each of the selected household. Written consent was sought from each respondent and parents or guardians provided consent for infants and children. Interviews and assessments were carried out only after consent was obtained.

Information on the child's age, sex, morbidity in the past week(s), immunization status, breastfeeding practices and dietary intake was collected from the mother of the child or caregiver. Mothers/caregivers were interviewed regarding their age, education, reproductive history,

nutritional status, morbidity, and reported personal hygiene practices. Information on household composition, source of drinking water and sanitation facility, socioeconomic status, and utilization of social safety net programs was also collected. All interviews were carried out using a structured questionnaire.

Anthropometric measurements were taken from the children and mothers following standard procedures.[14] Height was measured using a height/length board to the nearest 0.1 cm. Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children was determined using the immunization cards or home records of date of birth to the extent possible. When these documents were unavailable, the local events calendar was used to help with the recall of the child's age.

The field interviewers/anthropomerists were from local non-governmental organization partners and were thoroughly trained before data collection. The performance of field staff during data collection was continuously monitored by supervisors and quality control teams who rechecked some of the data the following day to ensure data reliability. Non-response and refusal to participate in the surveys were minimal.

Statistical Analysis

This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than one child under-two was assessed in a given household, only the youngest child from each household was included in the analysis. All analyses were weighted according to the population size and adjusted for the multistage cluster design of the surveys.

Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009 software.[15] Maternal body mass index (BMI) was defined as weight divided by the square of height (kg/m^2). In the analysis of data obtained from the NFHS and CNSM, sources of drinking water were classified into improved water sources including water piped into a dwelling, plot or yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater vs. unimproved water.[16, 17] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet.[16] A comparison was also made between piped water vs. other sources of drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of drinking water only as hand pump and piped water and others and sanitation as defecating in the open vs. any toilet.[12]

In the NFHS-3 and CNSM, a wealth index was computed as an indicator of household economic status. Details on the estimation of household wealth index are described elsewhere.[12, 13] Briefly, each asset was assigned a standardized score generated through a principal components analysis. The selected households were then ranked according to the sum of household asset scores and were grouped into five wealth quintiles from the lowest (poorest) to the highest (richest) score. For HUNGaMA a wealth index was not generated and household ownership of durable assets was used as the primary indicator of household economic status.

Data for each survey were analyzed separately. Descriptive statistics were used to examine the distribution of the full range of variables. Using appropriate cutoffs, dichotomous or categorical variables were created for a few variables such as birth order (1-2, 3-4 or ≥5); maternal education (no education, primary school, secondary school, or > secondary school);

maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5 kg/m^2); and household composition (2-6, ≥7).

Although children 0-5 and 6-23 months of age have predominantly different feeding practices, analyses for the two age groups were merged, because age was not a significant effect modifier for indicators examined in predicting stunting. Multiple logistic regression analyses were used to examine the association between the risk of stunting and WASH practices adjusting for potential confounders. Stunting was included as the dependent variable and household sanitation facilities, source of drinking water, and reported personal hygiene practices as the independent variables, together with the potential confounding factors.

Confounding factors included the major determinants of child stunting based on UNICEF's conceptual framework[17]. These were associated with each WASH indicator in the bivariate analyses using χ^2 test ($P < 0.05$). The interactions between household sanitation facilities, source of drinking water, and personal hygiene were created to examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical significance defined as $P<0.05$. All analyses were performed using STATA version 13.0 (Stat Corp., College Station, TX, USA).

RESULTS

NFHS-3

The mean (± standard error (SE)) age of children in the analysis was 11.5 ± 0.05 months and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15% were reported to have had diarrhea in the past two weeks. The mean (± SE) age of the mothers of under-twos was 25.0 ± 0.08 years. More than half the mothers had no education and 41% had short stature (<150 cm). About 83% of the households had access to improved drinking water sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation facilities, whereas 77% had no toilet facility.

The presence of a household sanitation facility was associated with stunting among children aged 0-23 months. In a multivariate analysis, compared with open defecation, household access to toilet facility was associated with a 16% lower odds of being stunted, adjusting for all potential confounders (OR=0.84, 95% CI: 0.71-0.99) (Table 2). Household access to an improved drinking water source or piped water was not a predictor of child stunting. No interactions between household access to sanitation facilities and drinking water sources were observed (data not shown).

HUNGaMA

The mean (±SE) age of the children was 11.7 ± 0.04 months with both sexes equally represented (Table 1). About one-half (50%) were stunted, 16% were wasted and 41% had had diarrhea in the past week. The mean (± SE) age of the mothers was 26.8 ± 0.04 years and approximately 63% had no education. About a quarter of the households (24%) had access to piped water, whereas most of the households (83%) had no toilet facility.

Having a toilet facility at home was associated with a 16% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.84, 95%

CI: 0.78-0.91) (Table 3). Household access to a piped water source was not associated with stunting. There were no synergistic effects of household sanitation and water supply on child stunting.

The mother/caregiver's reported hygiene practices appeared to predict the risk of child stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands with soap after defecation was associated with a 14% reduced risk of stunting among children aged 0-23 months (OR=0.86, 95% CI: 0.80-0.93) (Table 3). Likewise, the caregiver's reported practice of washing their hands with soap before food was associated with a 15% lower odds of stunting among children aged 0-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).

There was a significant interaction between mother/caregiver's reported hygiene practices and household sanitation and drinking water conditions in their association with child stunting. The protective effect of mother/caregiver's reported practice of washing their hands with soap before food against child stunting was stronger among households with access to piped water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term P<0.05) (Table 4). In addition, the inverse association between mother/caregiver's reported practices of washing their hands with soap after defecation and stunting was stronger among households with access to toilet facility (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).

CNSM

The mean (± SE) age of the children was 11.0 ± 0.24 months and about 56% were male (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had had diarrhea in the past two weeks. The mean (± SE) age of the mothers was 23.6 ± 0.12 years

and 14% had no education. Approximately 87% of the households had improved sources of drinking water, and about 30% had access to piped water. Twenty seven percent of the households had access to improved sanitation facilities.

In multivariate analysis, household access to toilet facility was associated with a 39% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.61, 95% CI: 0.44-0.85) (Table 5). Household access to an improved water source and piped water did not predict child stunting.

DISCUSSION

We report here the association between child stunting and household access to improved sanitation and drinking water source and personal hygiene in India, based on large survey datasets representative at national, state and district levels. Notably, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months. On the other hand, household access to an improved source of drinking water or piped water in particular was not a predictor of stunting. The mother/caregiver's reported practices of washing their hands with soap either before a meal or after defecation was associated with a 15% reduced risk of stunting.

Overall, our results of the inverse association between stunting and household access to toilet facility tend to confirm the findings of previous non-randomized research carried out in different parts of the world.[19-22] Using data from multiple countries in Africa, Asia and Latin America, Esrey showed that improved sanitation was associated with a 0.06-0.62 and 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.[19] Similarly, in a cross-

sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not included), access to improved sanitation was shown to be associated with a 27% lower risk of child stunting.[20] Recently, in an ecological analysis, Spears et al. found that differences in open defecation could statistically account for 35-55% of the average difference in stunting between districts in India.[11] The findings of our analysis based on three large survey datasets collected at the household level, reinforce the notion that poor sanitation may indeed greatly increase the likelihood of child stunting in rural India where open defecation is pervasive and the burden of child stunting is massive.

It is evident that children become more affected by environmental contamination as they start crawling, walking, exploring, and putting objects in their mouths, which increases the risk of ingesting fecal bacteria from both human and animal sources. This leads to repeated bouts of diarrhea and intestinal worms, which in turn deteriorates the nutritional status of children.[23] Importantly, growing evidence suggests that a key cause of child undernutrition is a subclinical disorder of the small intestine known as environmental enteropathy which is in turn caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene.[24] This hypothesis makes addressing the issue of sanitation even more critical.

Household access to an improved source of drinking water or piped water was not associated with child stunting. This corroborates earlier findings from non-randomized studies which indicate that the potential effects of improved water supply on child linear growth tend to be much smaller than those of improved sanitation.[19] This lack of association in our analysis may be explained by the current predominant use of an improved drinking water source in India, reflecting source only, not on water safety. The NFHS and CNSM showed that ~83% and ~74%

of the households in rural areas, respectively, have access to improved drinking water sources.[2,13] About a quarter of households reported having water piped into the dwelling, plot or yard.[2,13] Although household access to piped water was significantly associated with stunting in bivariate analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential confounders.

Our results indicated no significant interactions between household access to improved water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and sanitation on child linear growth.[19,21,25] In a cross-sectional, multi-country study, Esrey noted that the positive association between improved sanitation and child linear growth was enhanced by household access to an improved water supply.[19] Similarly, in a longitudinal study in Peru, Checkley et al found that the positive association between improved water sources and child linear growth existed only when it was accompanied by improved sanitation and water storage practices.[21] In contrast, no synergistic effects of water and sanitation were found in a large prospective cohort study in Sudan.[25] Therefore, further research is required to determine if improved household water supply and its handling and storage, and sanitation have additive or synergistic effects on child linear growth.

Few studies have explored the association between the mother/caregiver's personal hygiene practices and child stunting in India. We found that mothers/caregivers who reported washing their hands with soap either before meal or after defecation had a lower association with stunted children. This corresponds with the findings from a community-based cross-sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were significantly associated with child undernutrition.[26] Our findings also suggest that the protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility. Clearly, efforts to improve hand washing practices of both mothers/caregivers and children themselves are essential to prevent diarrhea and other infections among children, which may in turn contribute to the reduction of stunting. These efforts should be accompanied by concrete actions to enhance household water and sanitation conditions. Further research is required to examine the impact of improved personal hygiene practices on child growth, especially as part of a multi-sectoral and convergent approach to effectively address child stunting.

The limitations to this study need to be considered. We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established. The mother/caregiver's reported personal hygiene practices were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems. Moreover, the HUNGaMA survey only inquired whether the mother/caregiver was using soap for washing hands before meals. It was not clear whether the mother/caregiver washed hands before eating her own meal or feeding her child. While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data. Data on personal hygiene was not collected from the NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with soap was determined in the CNSM. Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight. Despite these limitations, assessing the WASH association with child stunting using large representative survey datasets coming from the local context is a critical step in strengthening the relevant evidence base and developing multi-sectoral interventions for optimal child growth.

In conclusion, this analysis revealed that household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India. This reinforces the growing evidence of the effects of WASH practices on child linear growth. Large-scale randomized effectiveness trials of toilet provision (and use) and reported handwashing at critical times, that include environmental enteropathy and child growth as outcomes, are warranted to go beyond association in order to estimate causality. However, this suggests the need for different programmatic responses by governments and development partners. Optimizing nutrition outcomes for young children now requires a framework that is broader than nutrition specific interventions alone. India's vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive interventions especially leading up to and during the first one thousand days. Children and mothers need basic WASH provision and behaviors to survive, grow and thrive.

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TRIAL REGISTRATION

As this is a secondary analysis of publicly available survey data, no trial registration was required

CONTRIBUTORSHIP STATEMENT

JHR and AC conceptualized, designed and wrote the paper; JHR and BB analyzed the datasets; JHR, VMA, SC wrote the paper; All authors read the manuscript, made a substantial contribution to the revision, and approved the final manuscript.

COMPETING INTERESTS

The authors declare no conflict of interest

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DATA SHARING

No additional data available

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1

2

3 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS)[1]	Hunger and Malnutrition Survey (HUNGaMA)[2]	Comprehensive Nutrition Survey in Maharashtra (CNSM)[3]
N	10,364	34,639	1,282
Child Characteristics			
Age, months (mean ± SE)	11.5 ± 0.05	11.7 ± 0.04	11.0 ± 0.24
Male (%)	52	52	56
Birth order (%)			
1-3	71	76	93
≥4	29	24	7
Stunted height-for-age z-score, <-2 (%)*	41	50	25
Wasted weight-for-height z-score, <-2 (%)*	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30

Breastfeeding started within 1 hour of birth (%)	22	42	67
Maternal Characteristics			
Age, year (mean ± SE)	25.0 ± 0.08	26.8 ± 0.04	23.6 ± 0.12
Education (%)			
No schooling	55	63	14
Primary school	15	11	13
Secondary school	27	14	57
>Secondary school	3	12	15
Short stature, <150 cm (%)	41	-	37
BMI<18.5 kg/m^2 (%)	44	-	40
Household Characteristics			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility[†]	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			

Pipe water	9	24	30
Other improved source[‡]	74	-	57

[1] Missing values existed in the NFHS sample, including the following: child diarrhea (n=5), breastfeeding within 1 hour of birth (n=82), maternal height (n=27), maternal BMI (n=32)

[2] Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209), breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438), household size (n=257), source of drinking water (n=3395)

[3] Missing values existing in the CNSM sample, including the following: maternal age (n=10), maternal education (n=10), maternal height (n=12), maternal BMI (n=14)

* Estimated by using 2006 WHO growth reference

[†] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet

[‡] Improved water sources other than piped water included public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater

Table 2. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the National Family Health Survey for 0-23 month olds§

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household Drinking Water			
Other	9,049	1.0 (Reference)	Not retained in the final model
Piped	1,315	0.64 (0.53 - 0.76)	
Place of defecation			
No facility/bush/field	6,635	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,729	0.53 (0.46 - 0.61)	0.84 (0.71-0.99)
Wealth Index			
Poorest	2,727	1.0 (Reference)	1.0 (Reference)
Poorer	2,617	0.78 (0.67 - 0.89)	0.86 (0.74-0.99)
Middle	2,390	0.66 (0.56 - 0.76)	0.83 (0.71-0.97)

Richer	1,764	0.46 (0.39 - 0.55)	0.71 (0.59-0.87)
Richest	866	0.26 (0.20 - 0.33)	0.52 (0.39-0.69)
Social Class			
Other	2,962	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	7,402	1.54 (1.36-1.74)	1.23 (1.07-1.42)
Maternal Education			
No schooling	4,973	1.0 (Reference)	1.0 (Reference)
Primary school	1,631	0.79 (0.68-0.91)	0.88 (0.76-1.02)
Secondary school	3,425	0.49 (0.43 - 0.55)	0.65 (0.56-0.74)
>Secondary school	334	0.25 (0.17-0.37)	0.43 (0.29-0.65)
Maternal height			
≥150 cm	9,276	1.0 (Reference)	1.0 (Reference)
<150 cm	1,087	1.70 (1.53-1.89)	1.59 (1.43±1.78)
Maternal age			
≥ 30	2,256	1.0 (Reference)	1.0 (Reference)

<20	1,087	0.89 (0.73-1.07)	0.93 (0.76-1.14)
20-29	7,020	0.74 (0.65-0.85)	0.85 (0.74-0.98)
Frequency of ANC visit during pregnancy			
Less than 3 times	5,395	1.0 (Reference)	Not retained in the final model
≥3 times	4,869	0.67 (0.60-0.75)	
Maternal dietary intake			
Consumed <4 food groups a week	6,362	1.0 (Reference)	Not retained in the final model
Consumed ≥4 food groups a week	3,980	0.79 (0.70-0.88)	
Birth Order			
≥5	1,822	1.0 (Reference)	Not retained in the final model
1-2	5,615	0.66 (0.57-0.76)	
3-4	2,926	0.79 (0.68-0.92)	
Initiation of Breastfeeding			
After 1 hour	7,025	1.0 (Reference)	Not retained in the

Within 1 hour of birth	3,239	0.90 (0.80-1.01)	final model
Complementary feeding practices			
Not fed minimum number of times and appropriate number of food group*	7,313	1.0 (Reference)	1.0 (Reference)
Fed minimum number of times and appropriate number of food group	3.050	1.16 (1.00-1.35)	1.50 (1.28-1.76)

† Food groups include milk and curd, pulse or beans, dark green leafy vegetables, fruits, eggs, fish, chicken or meat

‡ Required vaccinations include BCG, measles, and three doses each of DPT and polio vaccine

*Appropriate number of food groups including three or more food groups for breastfed children and four or more food groups for non-breastfed children; Minimum number of times are defined as at least twice a day for breastfed infants 6-8 months and at least three times a day for breastfed children 9-23 months

§ Missing values for all indicators was less than 3%

Table 3. Crude and adjusted odds ratios (OR) of household water and sanitation conditions and personal hygiene in relation to stunting for children who participated in the Hunger and Malnutrition Survey by age group[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	23,513	1.0 (Reference)	Not retained in the final model
Piped	7,731	0.84(0.79-0.9)	
Place of defecation			
No facility/bush/field	28,457	1.0 (Reference)	1.0 (Reference)
Any toilet facility	6,022	0.62 (0.58-0.67)	0.84 (0.78-0.91)
Mother/Caregiver's practice of washing hands with soap after defecation			
No	28,001	1.0 (Reference)	1.0 (Reference)
Yes	6,638	0.68 (0.64-0.73)	0.86 (0.80-0.93)
Household ownership of durable assets			
Owning <2 items	14,755	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	19,560	0.72 (0.68-0.76)	0.89 (0.84-0.95)

Religion			
Other	5,046	1.0 (Reference)	Not retained in the final model
Hindu	29,581	0.92 (0.85-0.99)	
Social Class			
Other	21,241	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	13,386	1.32 (1.25-1.4)	1.21 (1.14-1.28)
Maternal Education			
No schooling	20,566	1.0 (Reference)	1.0 (Reference)
Primary school	1,119	0.79 (0.68-0.91)	0.83 (0.71-0.96)
Secondary school	7,949	0.65 (0.61-0.7)	0.72 (0.67-0.77)
>Secondary school	4,567	0.40 (0.37-0.43)	0.49 (0.45-0.54)
Maternal age			
≥ 30	9,394	1.0 (Reference)	Not retained in the final model
<20	954	0.88 (0.75-1.03)	
20-29	24,291	0.82 (0.77-0.87)	

Utilized ICDS's health check up services for their child			
No	24,327	1.0 (Reference)	Not retained in the final model
Yes	10,093	0.90 (0.85±0.95)	
Birth Order			
≥5	4,134	1.0 (Reference)	Not retained in the final model
1-2	20,166	0.74 (0.68-0.81)	
3-4	10,337	0.85 (0.77-0.93)	
Initiation of breastfeeding			
After 1 hour	18,839	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	15,411	0.78 (0.74-0.82)	0.88 (0.82-0.93)
Fed Colostrum			
No	11,038	1.0 (Reference)	1.0 (Reference)
Yes	23,312	0.77 (0.72-0.81)	0.89 (0.83-0.95)
Complementary feeding practices*(6-23 months)			
Started before 6 months or after 8 Months	7,577	1.0 (Reference)	Not retained in the final model

Started 6-8 months	22,230	0.98 (0.92-1.05)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 4. Crude and adjusted odds ratios (OR) of household sanitation conditions and personal hygiene practices in relation to stunting for children aged 0-23 months who participated in the Hunger and Malnutrition Survey by household access to piped water[§]

	No access to piped water			Having access to piped water		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Place of defecation						
No facility/bush/field	20,125	1.0 (Reference)	1.0 (Reference)	5,506	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,289	0.66 (0.60-0.72)	0.85 (0.77-0.94)	2,176	0.56 (0.49-0.64)	0.77 (0.66-0.91)
Mother/Caregiver's reported practice of washing hands with soap before meal						
No	21,346	1.0 (Reference)	1.0 (Reference)	6,001	1.0 (Reference)	1.0 (Reference)
Yes	2,167	0.74 (0.66-0.82)	0.89 (0.80-0.99)	1,730	0.61 (0.53-0.70)	0.77 (0.66-0.90)
Household ownership of durable assets[†]						
Owning <2 items	10,497	1.0 (Reference)	1.0 (Reference)	2,721	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	12,820	0.75	0.90	4,912	0.64	0.84

		(0.71-0.80)	(0.84-0.96)		(0.57-0.73)	(0.74-0.96)
Social class						
Other	14,148	1.0 (Reference)	1.0 (Reference)	4,918	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	9,356	1.34 (1.25-1.43)	1.23 (1.15-1.32)	2,810	1.29 (1.15-1.46)	1.16 (1.02-1.32)
Maternal education						
No schooling	14,683	1.0 (Reference)	1.0 (Reference)	3,623	1.0 (Reference)	1.0 (Reference)
Primary school	2,708	0.79 (0.67-0.95)	0.83 (0.70-0.99)	880	0.96 (0.68-1.36)	1.02 (0.71-1.46)
Secondary school	3,374	0.68 (0.63-0.73)	0.73 (0.67-0.80)	1,332	0.65 (0.57-0.75)	0.72 (0.62-0.83)
>Secondary school	2,462	0.41 (0.37-0.46)	0.49 (0.44-0.55)	1,773	0.40 (0.34-0.47)	0.51 (0.43-0.61)
Maternal age						
≥ 30	6,487	1.0 (Reference)	Not retained in the final model	1,786	1.0 (Reference)	Not retained in the final model
<20	668	0.93		182	0.75	

		(0.76-1.13)			(0.52-1.08)	
20-29	16,241	0.84 (0.78-0.90)		5,715	0.81 (0.71-0.93)	
Utilized ICDS's health check up service for their child						
No	17,010	1.0 (Reference)	Not retained in the final model	4,850	1.0 (Reference)	Not retained in the final model
Yes	6,400	0.95 (0.89-1.02)		2,793	0.85 (0.75-0.95)	
Birth order						
≥5	2,859	1.0 (Reference)	Not retained in the final model	648	1.0 (Reference)	Not retained in the final model
1-2	13,111	0.80 (0.72-0.88)		5,190	0.59 (0.47-0.72)	
3-4	7,412	0.86 (0.77-0.96)		1,842	0.83 (0.66-1.05)	
Initiation of breastfeeding						
After 1 hour	13,351	1.0 (Reference)	1.0 (Reference)	3,616	1.0 (Reference)	Not retained in the final model
Within 1 hour of birth	9,920	0.82	0.90	4,010	0.71	

		(0.77-0.88)	(0.83-0.97)		(0.63-0.80)	
Fed colostrum						
No	7,993	1.0 (Reference)	1.0 (Reference)	2,054	1.0 (Reference)	Not retained in the final model
Yes	15,350	0.82 (0.77-0.87)	0.91 (0.84-0.99)	5,585	0.69 (0.61-0.79)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 5. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the Comprehensive Nutrition Survey in Maharashtra for under 2s§

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	913	1.0 (Reference)	Not retained in the final model
Piped	369	0.86 (0.60-1.23)	
Place of defecation			
No facility/bush/field	790	1.0 (Reference)	1.0 (Reference)
Any toilet facility	492	0.57 (0.41-0.78)	0.61 (0.44-0.85)
Wealth Index			
Poorest	392	1.0 (Reference)	Not retained in the final model
Poorer	415	1.00 (0.68-1.46)	
Middle	306	1.04 (0.70-1.57)	
Richer	133	0.75 (0.43-1.31)	
Richest†	36	0.70 (0.25-1.93)	

Maternal Education			
No schooling	181	1.0 (Reference)	Not retained in the final model
Primary school	143	0.82 (0.47-1.4)	
Secondary school	743	0.70 (0.46-1.06)	
>Secondary school	215	0.58 (0.31-1.11)	
Maternal Height			
≥150 cm	790	1.0 (Reference)	1.0 (Reference)
<150 cm	480	2.30 (1.69-3.13)	2.22 (1.63-3.01)

† OR (95% CI) for children 0-5 months was dropped due to a small sample size

§ Missing values for all indicators was less than 3%

Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross sectional analysis of surveys

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ABSTRACT

Background: Increasing evidence suggests that water, sanitation and hygiene (WASH) practices affect linear growth in early childhood. We determined the association between household access to water, sanitation, and personal hygiene practices with stunting among children aged 0-23 months in rural India.

Methods: A total of 10,364, 34,639, and 1,282 under-twos who participated in the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included in the analysis. The association between WASH indicators and child stunting was assessed using logistic regression models.

Findings: The prevalence of stunting ranged from 25% to 50%. Compared with open defecation, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months, after adjusting for all potential confounders [NHFS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was not in itself associated with stunting. The caregiver's self-reported practices of washing hands with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse association between **reported** personal hygiene practices and stunting was stronger among households with access to toilet facility or piped water (all interaction terms, P<0.05).

Interpretation: Improved conditions of sanitation and hygiene practices are associated with reduced prevalence of stunting in rural India. Policies and programming aiming to address child

stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-specific to nutrition-sensitive programming. Future randomized trials are warranted to validate the causal association.

INTRODUCTION

In 2012, the World Health Organization adopted a new global target of reducing the number of stunted children under-five by 40% by 2025.[1] Despite over two decades of significant economic growth, India has one of the world's highest child stunting rates. The 2006 National Family Health Survey shows that 48% of Indian children under five – 61 million children – are stunted due to chronic nutrition deprivation, accounting for more than one third of stunted children in the developing world.[2] Child stunting is linked to serious and largely irreversible consequences for survival, health, development, school performance, and productivity in adult life.[3, 4]

For many children, stunted growth starts before birth as a result of poor maternal nutritional status and worsens gradually during the first two years of life.[5] Thus, the first 1,000 days, from conception until the age of two years, are a critical window of opportunity, during which timely interventions can have a measurable and lasting impact on the prevention of child stunting.[2] Importantly, however, in the current context of widespread infection and contamination in children's environments, dietary interventions alone may be insufficient to promote optimal growth in children in developing countries. In such environments, efficacy studies with nutrient-dense food supplements have shown to improve approximately 0.7 height-for-age z-score at best.[6] This reflects on only one third of the average height deficit in South Asian and sub-Saharan African children.[7]

Growing evidence suggests a link between child linear growth and household water, sanitation, and hygiene (WASH) practices.[8] It has previously been estimated that as much as 50% of child undernutrition may be attributable to poor WASH practices.[9] Ingestion of high quantities

of fecal bacteria from both human and animal sources by infants and young children through mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry feces are common in many rural low income environments. This leads to intestinal infections which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption, and increasing nutrient losses.[10]

In India, approximately 53% of households and 624 million people defecate in the open.[2] Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). **Recently, an ecological analysis of data from 112 rural districts of India demonstrated a strong association between the prevalence of open defecation and stunting, after adjusting for potential confounders.[11] This analysis added to a growing body of suggestive evidence on the effect of open defecation on child linear growth. However, further evidence is needed to corroborate the findings, as ecological studies are prone to ecological fallacy and other errors, and are often used to generate hypotheses for additional investigation employing more rigorous methods**.[11]

Strengthening the evidence base on the linkages between child linear growth and WASH practices in Indian population will help support informed development of policy and guidelines that inform optimal programmatic strategies, actions, and monitoring. This study therefore sought to determine whether improved WASH conditions are associated with reduced child stunting in rural India. Specifically, the analysis aimed to determine the association between stunting and household access to sanitation facilities, water supply, and personal hygiene practices using multiple logistic regression analyses.

METHODS

Data

We analyzed three large datasets obtained from the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). Details of the three surveys are described elsewhere.[2, 12, 13] Briefly, the NFHS-3 is a Demographic Health Survey carried out by the International Institute for Population Services (IIPS) in 2005-6, that provides information on mortality, fertility, family planning, environmental hygiene, nutrition, and health status of India's population.[2] A stratified multistage cluster sampling method was used to identify a nationally representative sample of India's population living in both urban and rural areas in 29 states. A total of 109,041 households were selected, from which a total of 124,385 women age 15-49 years and 74,369 men age 15-54 years were included in the survey.[2]

The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect district level data on the nutritional status of Indian children below five years of age.[12] The survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this, 100 districts were those with the poorest indicators of child wellbeing in the country, and the remaining 12 districts were selected among those with some of the best indicators of child wellbeing for the purpose of within-state comparison. The selected areas represent about one-sixth of India's population and one-fifth of India's children under-five. A stratified cluster sampling was employed to identify a representative sample of 73,670 households from which a total of 109,903 children under-five were included in the survey. Information on child nutritional status was collected together with relevant maternal, household and environmental determinants.[12]

The CNSM is the first ever state-specific survey in India that provides information on nutritional status and feeding practices of children below two years of age and relevant maternal and household determinants.[13] The CNSM survey is a joint initiative of the Government of Maharashtra and UNICEF, implemented by the IIPS. A multi-stage stratified sampling method was used to select a total of 2,650 children under two years of age from 2,630 households from the six administrative divisions of the state, namely Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune.[13] The sampling scheme was designed to represent Maharashtra State.

These surveys all have different sample sizes as they are representative of different administrative units; national for NFHS and state for CNSM. The HUNGaMA survey represents a spread of the poorest districts in India and has a large sample size with a larger open defecation rate, but one in line with Census data. Ethical approval was not sought for this secondary analysis of publicly available survey data.

Data Collection

Data were collected using similar methods in all three surveys.[2, 12, 13] All interviews and anthropometric measurements were conducted at home by field teams who visited eligible respondents in each of the selected household. Written consent was sought from each respondent and parents or guardians provided consent for infants and children. Interviews and assessments were carried out only after consent was obtained.

Information on the child's age, sex, morbidity in the past week(s), immunization status, breastfeeding practices and dietary intake was collected from the mother of the child or caregiver. Mothers/caregivers were interviewed regarding their age, education, reproductive history, nutritional status, morbidity, and **reported personal hygiene practices**. Information on household composition, source of drinking water and sanitation facility, socioeconomic status, and utilization of social safety net programs was also collected. All interviews were carried out using a structured questionnaire.

Anthropometric measurements were taken from the children and mothers following standard procedures.[14] Height was measured using a height/length board to the nearest 0.1 cm. Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children was determined using the immunization cards or home records of date of birth to the extent possible. When these documents were unavailable, the local events calendar was used to help with the recall of the child's age.

The field interviewers/anthropomerists were from local non-governmental organization partners and were thoroughly trained before data collection. The performance of field staff during data collection was continuously monitored by supervisors and quality control teams who rechecked some of the data the following day to ensure data reliability. Non-response and refusal to participate in the surveys were minimal.

Statistical Analysis

This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than one child under-two was assessed in a given household, only the youngest child from each household was included in the analysis. All analyses were weighted according to the population size and adjusted for the multistage cluster design of the surveys.

Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009 software.[15] Maternal body mass index (BMI) was defined as weight divided by the square of height (kg/m^2). In the analysis of data obtained from the NFHS and CNSM, sources of drinking water were classified into improved water sources including water piped into a dwelling, plot or yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater vs. unimproved water.[16, 17] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet.[16] A comparison was also made between piped water vs. other sources of drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of drinking water only as hand pump and piped water and others and sanitation as defecating in the open vs. any toilet.[12]

In the NFHS-3 and CNSM, a wealth index was computed as an indicator of household economic status. Details on the estimation of household wealth index are described elsewhere.[12, 13] Briefly, each asset was assigned a standardized score generated through a principal components analysis. The selected households were then ranked according to the sum of household asset scores and were grouped into five wealth quintiles from the lowest (poorest) to the highest (richest) score. For HUNGaMA a wealth index was not generated and household ownership of durable assets was used as the primary indicator of household economic status.

Data for each survey were analyzed separately. Descriptive statistics were used to examine the distribution of the full range of variables. Using appropriate cutoffs, dichotomous or categorical variables were created for a few variables such as birth order (1-2, 3-4 or ≥5); maternal education (no education, primary school, secondary school, or > secondary school); maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5 kg/m^2); and household composition (2-6, ≥7).

Although children 0-5 and 6-23 months of age have predominantly different feeding practices, analyses for the two age groups were merged, because age was not a significant effect modifier for indicators examined in predicting stunting. Multiple logistic regression analyses were used to examine the association between the risk of stunting and WASH practices adjusting for potential confounders. Stunting was included as the dependent variable and household sanitation facilities, source of drinking water, and **reported personal hygiene practices** as the independent variables, together with the potential confounding factors.

Confounding factors included the major determinants of child stunting based on UNICEF's conceptual framework[17]. These were associated with each WASH indicator in the bivariate analyses using χ^2 test ($P < 0.05$). The interactions between household sanitation facilities, source of drinking water, and personal hygiene were created to examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical significance defined as P<0.05. All analyses were performed using STATA version 13.0 (Stat Corp., College Station, TX, USA).

RESULTS

NFHS-3

The mean (± standard error (SE)) age of children in the analysis was 11.5 ± 0.05 months and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15% were reported to have had diarrhea in the past two weeks. The mean (± SE) age of the mothers of under-twos was 25.0 ± 0.08 years. More than half the mothers had no education and 41% had short stature (<150 cm). About 83% of the households had access to improved drinking water sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation facilities, whereas 77% had no toilet facility.

The presence of a household sanitation facility was associated with stunting among children aged 0-23 months. In a multivariate analysis, compared with open defecation, household access to toilet facility was associated with a 16% lower odds of being stunted, adjusting for all potential confounders (OR=0.84, 95% CI: 0.71-0.99) (Table 2). Household access to an improved drinking water source or piped water was not a predictor of child stunting. No interactions between household access to sanitation facilities and drinking water sources were observed (data not shown).

HUNGaMA

The mean (±SE) age of the children was 11.7 ± 0.04 months with both sexes equally represented (Table 1). About one-half (50%) were stunted, 16% were wasted and 41% had had diarrhea in the past week. The mean (± SE) age of the mothers was 26.8 ± 0.04 years and approximately 63% had no education. About a quarter of the households (24%) had access to piped water, whereas most of the households (83%) had no toilet facility.

Having a toilet facility at home was associated with a 16% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.84, 95% CI: 0.78-0.91) (Table 3). Household access to a piped water source was not associated with stunting. There were no synergistic effects of household sanitation and water supply on child stunting.

The mother/**caregiver's reported hygiene practices** appeared to predict the risk of child stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands with soap after defecation was associated with a 14% reduced risk of stunting among children aged 0-23 months (OR=0.86, 95% CI: 0.80-0.93) (Table 3). Likewise, the caregiver's reported practice of washing their hands with soap before food was associated with a 15% lower odds of stunting among children aged 0-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).

There was a significant interaction between mother/caregiver's **reported hygiene practices** and household sanitation and drinking water conditions in their association with child stunting. The protective effect of mother/caregiver's reported practice of washing their hands with soap before food against child stunting was stronger among households with access to piped water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term $P<0.05$) (Table 4). In addition, the inverse association between mother/caregiver's reported practices of washing their hands with soap after defecation and stunting was stronger among households with access to toilet facility (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).

CNSM

The mean (± SE) age of the children was 11.0 ± 0.24 months and about 56% were male (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had had diarrhea in the past two weeks. The mean (± SE) age of the mothers was 23.6 ± 0.12 years and 14% had no education. Approximately 87% of the households had improved sources of drinking water, and about 30% had access to piped water. Twenty seven percent of the households had access to improved sanitation facilities.

In multivariate analysis, household access to toilet facility was associated with a 39% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.61, 95% CI: 0.44-0.85) (Table 5). Household access to an improved water source and piped water did not predict child stunting.

DISCUSSION

We report here the association between child stunting and household access to improved sanitation and drinking water source and personal hygiene in India, based on large survey datasets representative at national, state and district levels. **Notably, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months. On the other hand, household access to an improved source of drinking water or piped water in particular was not a predictor of stunting. The mother/caregiver's reported practices of washing their hands with soap either before a meal or after defecation was associated with a 15% reduced risk of stunting.**

Overall, our results of the inverse association between stunting and household access to toilet facility tend to confirm the findings of previous non-randomized research carried out in different parts of the world.[19-22] Using data from multiple countries in Africa, Asia and Latin America, Esrey showed that improved sanitation was associated with a 0.06-0.62 and 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.[19] Similarly, in a cross-sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not included), access to improved sanitation was shown to be associated with a 27% lower risk of child stunting.[20] Recently, in an ecological analysis, Spears et al. found that differences in open defecation could statistically account for 35-55% of the average difference in stunting between districts in India.[11] The findings of our analysis based on three large survey datasets collected at the household level, reinforce the notion that poor sanitation may indeed greatly increase the likelihood of child stunting in rural India where open defecation is pervasive and the burden of child stunting is massive.

It is evident that children become more affected by environmental contamination as they start crawling, walking, exploring, and putting objects in their mouths, which increases the risk of ingesting fecal bacteria from both human and animal sources. This leads to repeated bouts of diarrhea and intestinal worms, which in turn deteriorates the nutritional status of children.[23] Importantly, growing evidence suggests that a key cause of child undernutrition is a subclinical disorder of the small intestine known as environmental enteropathy which is in turn caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene.[24] This hypothesis makes addressing the issue of sanitation even more critical.

Household access to an improved source of drinking water or piped water was not associated with child stunting. This corroborates earlier findings from non-randomized studies which indicate that the potential effects of improved water supply on child linear growth tend to be much smaller than those of improved sanitation.[19] This lack of association in our analysis may be explained by the current predominant use of an improved drinking water source in India, reflecting source only, not on water safety. The NFHS and CNSM showed that ~83% and ~74% of the households in rural areas, respectively, have access to improved drinking water sources.[2,13] About a quarter of households reported having water piped into the dwelling, plot or yard.[2,13] Although household access to piped water was significantly associated with stunting in bivariate analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential confounders.

Our results indicated no significant interactions between household access to improved water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and sanitation on child linear growth.[19,21,25] In a cross-sectional, multi-country study, Esrey noted that the positive association between improved sanitation and child linear growth was enhanced by household access to an improved water supply.[19] Similarly, in a longitudinal study in Peru, Checkley et al found that the positive association between improved water sources and child linear growth existed only when it was accompanied by improved sanitation and water storage practices.[21] In contrast, no synergistic effects of water and sanitation were found in a large prospective cohort study in Sudan.[25] Therefore, further research is required to determine if improved household water supply and its handling and storage, and sanitation have additive or synergistic effects on child linear growth.

Few studies have explored the association between the mother/caregiver's personal hygiene practices and child stunting in India. We found that mothers/caregivers who reported washing their hands with soap either before meal or after defecation **had a lower association with** stunted children. This corresponds with the findings from a community-based cross-sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were significantly associated with child undernutrition.[26] Our findings also suggest that the protective effects of **mother/caregiver's reported personal hygiene practices** were stronger when it was accompanied by an improved household access to piped water and toilet facility. Clearly, efforts to improve **hand washing practices** of both mothers/caregivers and children themselves are essential to prevent diarrhea and other infections among children, which may in turn contribute to the reduction of stunting. These efforts should be accompanied by concrete actions to enhance household water and sanitation conditions. Further research is required to examine the impact of improved personal hygiene practices on child growth, especially as part of a multi-sectoral and convergent approach to effectively address child stunting.

The limitations to this study need to be considered. **We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established.** The **mother/caregiver's reported personal hygiene practices** were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems. **Moreover, the HUNGaMA survey only inquired whether the mother/caregiver was using soap for washing hands before meals. It was not clear whether the mother/caregiver washed hands before eating her own meal or feeding her child.** While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data. Data on personal hygiene was not collected from the NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with soap was determined in the CNSM. Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight. Despite these limitations, assessing the WASH association with child stunting using large representative survey datasets coming from the local context is a critical step in strengthening the relevant evidence base and developing multi-sectoral interventions for optimal child growth.

In conclusion, this analysis revealed that household sanitation and the **mother's/caregiver's reported personal hygiene practices** are strong predictors of child stunting in India. This reinforces the growing evidence of the effects of WASH practices on child linear growth. **Large-scale randomized effectiveness trials of toilet provision (and use) and reported handwashing at critical times, that include environmental enteropathy and child growth as outcomes, are warranted to go beyond association in order to estimate causality.** However, this suggests the need for different programmatic responses by governments and development partners. Optimizing nutrition outcomes for young children now requires a framework that is broader than nutrition specific interventions alone. India's vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive interventions especially leading up to and during the first one thousand days. Children and mothers need basic WASH provision and behaviors to survive, grow and thrive.

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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS)[1]	Hunger and Malnutrition Survey (HUNGaMA)[2]	Comprehensive Nutrition Survey in Maharashtra (CNSM)[3]
N	10,364	34,639	1,282
Child Characteristics			
Age, months (mean ± SE)	11.5 ± 0.05	11.7 ± 0.04	11.0 ± 0.24
Male (%)	52	52	56
Birth order (%)			
1-3	71	76	93
≥4	29	24	7
Stunted height-for-age z-score, <-2 (%)*	41	50	25
Wasted weight-for-height z-score, <-2 (%)*	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30
Breastfeeding started within 1 hour of birth (%)	22	42	67

Maternal Characteristics			
Age, year (mean ± SE)	25.0 ± 0.08	26.8 ± 0.04	23.6 ± 0.12
Education (%)			
No schooling	55	63	14
Primary school	15	11	13
Secondary school	27	14	57
>Secondary school	3	12	15
Short stature, <150 cm (%)	41	-	37
BMI<18.5 kg/m^2 (%)	44	-	40
Household Characteristics			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility[†]	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source[‡]	74	-	57

1 [1] Missing values existed in the NFHS sample, including the following: child diarrhea (n=5),

2 breastfeeding within 1 hour of birth (n=82), maternal height (n=27), maternal BMI (n=32)

[2] Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209), breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438), household size (n=257), source of drinking water (n=3395)

[3] Missing values existing in the CNSM sample, including the following: maternal age (n=10), maternal education (n=10), maternal height (n=12), maternal BMI (n=14)

* Estimated by using 2006 WHO growth reference

[†] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet

[‡] Improved water sources other than piped water included public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater

Table 2. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the National Family Health Survey for 0-23 month olds[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household Drinking Water			
Other	9,049	1.0 (Reference)	Not retained in the final model
Piped	1,315	0.64 (0.53 - 0.76)	
Place of defecation			
No facility/bush/field	6,635	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,729	0.53 (0.46 - 0.61)	0.84 (0.71-0.99)
Wealth Index			
Poorest	2,727	1.0 (Reference)	1.0 (Reference)
Poorer	2,617	0.78 (0.67 - 0.89)	0.86 (0.74-0.99)
Middle	2,390	0.66 (0.56 - 0.76)	0.83 (0.71-0.97)

Richer	1,764	0.46 (0.39 - 0.55)	0.71 (0.59-0.87)
Richest	866	0.26 (0.20 - 0.33)	0.52 (0.39-0.69)
Social Class			
Other	2,962	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	7,402	1.54 (1.36-1.74)	1.23 (1.07-1.42)
Maternal Education			
No schooling	4,973	1.0 (Reference)	1.0 (Reference)
Primary school	1,631	0.79 (0.68-0.91)	0.88 (0.76-1.02)
Secondary school	3,425	0.49 (0.43 - 0.55)	0.65 (0.56-0.74)
>Secondary school	334	0.25 (0.17-0.37)	0.43 (0.29-0.65)
Maternal height			
≥150 cm	9,276	1.0 (Reference)	1.0 (Reference)
<150 cm	1,087	1.70 (1.53-1.89)	1.59 (1.43±1.78)
Maternal age			
≥ 30	2,256	1.0 (Reference)	1.0 (Reference)

<20	1,087	0.89 (0.73-1.07)	0.93 (0.76-1.14)
20-29	7,020	0.74 (0.65-0.85)	0.85 (0.74-0.98)
Frequency of ANC visit during pregnancy			
Less than 3 times	5,395	1.0 (Reference)	Not retained in the final model
≥3 times	4,869	0.67 (0.60-0.75)	
Maternal dietary intake			
Consumed <4 food groups a week	6,362	1.0 (Reference)	Not retained in the final model
Consumed ≥4 food groups a week	3,980	0.79 (0.70-0.88)	
Birth Order			
≥5	1,822	1.0 (Reference)	Not retained in the final model
1-2	5,615	0.66 (0.57-0.76)	
3-4	2,926	0.79 (0.68-0.92)	
Initiation of Breastfeeding			
After 1 hour	7,025	1.0 (Reference)	Not retained in the

Within 1 hour of birth	3,239	0.90 (0.80-1.01)	final model
Complementary feeding practices			
Not fed minimum number of times and appropriate number of food group*	7,313	1.0 (Reference)	1.0 (Reference)
Fed minimum number of times and appropriate number of food group	3.050	1.16 (1.00-1.35)	1.50 (1.28-1.76)

† Food groups include milk and curd, pulse or beans, dark green leafy vegetables, fruits, eggs, fish, chicken or meat

‡ Required vaccinations include BCG, measles, and three doses each of DPT and polio vaccine

*Appropriate number of food groups including three or more food groups for breastfed children and four or more food groups for non-breastfed children; Minimum number of times are defined as at least twice a day for breastfed infants 6-8 months and at least three times a day for breastfed children 9-23 months

§ Missing values for all indicators was less than 3%

Table 3. Crude and adjusted odds ratios (OR) of household water and sanitation conditions and personal hygiene in relation to stunting for children who participated in the Hunger and Malnutrition Survey by age group§

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	23,513	1.0 (Reference)	Not retained in the final model
Piped	7,731	0.84(0.79-0.9)	
Place of defecation			
No facility/bush/field	28,457	1.0 (Reference)	1.0 (Reference)
Any toilet facility	6,022	0.62 (0.58-0.67)	0.84 (0.78-0.91)
Mother/Caregiver's practice of washing hands with soap after defecation			
No	28,001	1.0 (Reference)	1.0 (Reference)
Yes	6,638	0.68 (0.64-0.73)	0.86 (0.80-0.93)
Household ownership of durable assets			
Owning <2 items	14,755	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	19,560	0.72 (0.68-0.76)	0.89 (0.84-0.95)

Religion			
Other	5,046	1.0 (Reference)	Not retained in the final model
Hindu	29,581	0.92 (0.85-0.99)	
Social Class			
Other	21,241	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	13,386	1.32 (1.25-1.4)	1.21 (1.14-1.28)
Maternal Education			
No schooling	20,566	1.0 (Reference)	1.0 (Reference)
Primary school	1,119	0.79 (0.68-0.91)	0.83 (0.71-0.96)
Secondary school	7,949	0.65 (0.61-0.7)	0.72 (0.67-0.77)
>Secondary school	4,567	0.40 (0.37-0.43)	0.49 (0.45-0.54)
Maternal age			
≥ 30	9,394	1.0 (Reference)	Not retained in the final model
<20	954	0.88 (0.75-1.03)	
20-29	24,291	0.82 (0.77-0.87)	

Utilized ICDS's health check up services for their child			
No	24,327	1.0 (Reference)	Not retained in the final model
Yes	10,093	0.90 (0.85±0.95)	
Birth Order			
≥5	4,134	1.0 (Reference)	Not retained in the final model
1-2	20,166	0.74 (0.68-0.81)	
3-4	10,337	0.85 (0.77-0.93)	
Initiation of breastfeeding			
After 1 hour	18,839	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	15,411	0.78 (0.74-0.82)	0.88 (0.82-0.93)
Fed Colostrum			
No	11,038	1.0 (Reference)	1.0 (Reference)
Yes	23,312	0.77 (0.72-0.81)	0.89 (0.83-0.95)
Complementary feeding practices*(6-23 months)			
Started before 6 months or after 8 Months	7,577	1.0 (Reference)	Not retained in the final model

Started 6-8 months	22,230	0.98 (0.92-1.05)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 4. Crude and adjusted odds ratios (OR) of household sanitation conditions and personal hygiene practices in relation to stunting for children aged 0-23 months who participated in the Hunger and Malnutrition Survey by household access to piped water[§]

	No access to piped water			Having access to piped water		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Place of defecation						
No facility/bush/field	20,125	1.0 (Reference)	1.0 (Reference)	5,506	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,289	0.66 (0.60-0.72)	0.85 (0.77-0.94)	2,176	0.56 (0.49-0.64)	0.77 (0.66-0.91)
Mother/Caregiver's reported practice of washing hands with soap before meal						
No	21,346	1.0 (Reference)	1.0 (Reference)	6,001	1.0 (Reference)	1.0 (Reference)
Yes	2,167	0.74 (0.66-0.82)	0.89 (0.80-0.99)	1,730	0.61 (0.53-0.70)	0.77 (0.66-0.90)
Household ownership of durable assets[†]						
Owning <2 items	10,497	1.0 (Reference)	1.0 (Reference)	2,721	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	12,820	0.75	0.90	4,912	0.64	0.84

		(0.71-0.80)	(0.84-0.96)		(0.57-0.73)	(0.74-0.96)
Social class						
Other	14,148	1.0 (Reference)	1.0 (Reference)	4,918	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	9,356	1.34 (1.25-1.43)	1.23 (1.15-1.32)	2,810	1.29 (1.15-1.46)	1.16 (1.02-1.32)
Maternal education						
No schooling	14,683	1.0 (Reference)	1.0 (Reference)	3,623	1.0 (Reference)	1.0 (Reference)
Primary school	2,708	0.79 (0.67-0.95)	0.83 (0.70-0.99)	880	0.96 (0.68-1.36)	1.02 (0.71-1.46)
Secondary school	3,374	0.68 (0.63-0.73)	0.73 (0.67-0.80)	1,332	0.65 (0.57-0.75)	0.72 (0.62-0.83)
>Secondary school	2,462	0.41 (0.37-0.46)	0.49 (0.44-0.55)	1,773	0.40 (0.34-0.47)	0.51 (0.43-0.61)
Maternal age						
≥ 30	6,487	1.0 (Reference)	Not retained in the final model	1,786	1.0 (Reference)	Not retained in the final model
<20	668	0.93		182	0.75	

		(0.76-1.13)			(0.52-1.08)	
20-29	16,241	0.84 (0.78-0.90)		5,715	0.81 (0.71-0.93)	
Utilized ICDS's health check up service for their child						
No	17,010	1.0 (Reference)	Not retained in the final model	4,850	1.0 (Reference)	Not retained in the final model
Yes	6,400	0.95 (0.89-1.02)		2,793	0.85 (0.75-0.95)	
Birth order						
≥5	2,859	1.0 (Reference)	Not retained in the final model	648	1.0 (Reference)	Not retained in the final model
1-2	13,111	0.80 (0.72-0.88)		5,190	0.59 (0.47-0.72)	
3-4	7,412	0.86 (0.77-0.96)		1,842	0.83 (0.66-1.05)	
Initiation of breastfeeding						
After 1 hour	13,351	1.0 (Reference)	1.0 (Reference)	3,616	1.0 (Reference)	Not retained in the final model
Within 1 hour of birth	9,920	0.82	0.90	4,010	0.71	

		(0.77-0.88)	(0.83-0.97)		(0.63-0.80)	
Fed colostrum						
No	7,993	1.0 (Reference)	1.0 (Reference)	2,054	1.0 (Reference)	Not retained in the final model
Yes	15,350	0.82 (0.77-0.87)	0.91 (0.84-0.99)	5,585	0.69 (0.61-0.79)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 5. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the Comprehensive Nutrition Survey in Maharashtra for under 2s[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	913	1.0 (Reference)	Not retained in the final model
Piped	369	0.86 (0.60-1.23)	
Place of defecation			
No facility/bush/field	790	1.0 (Reference)	1.0 (Reference)
Any toilet facility	492	0.57 (0.41-0.78)	0.61 (0.44-0.85)
Wealth Index			
Poorest	392	1.0 (Reference)	Not retained in the final model
Poorer	415	1.00 (0.68-1.46)	
Middle	306	1.04 (0.70-1.57)	
Richer	133	0.75 (0.43-1.31)	
Richest[†]	36	0.70 (0.25-1.93)	

Maternal Education			
No schooling	181	1.0 (Reference)	Not retained in the final model
Primary school	143	0.82 (0.47-1.4)	
Secondary school	743	0.70 (0.46-1.06)	
>Secondary school	215	0.58 (0.31-1.11)	
Maternal Height			
≥150 cm	790	1.0 (Reference)	1.0 (Reference)
<150 cm	480	2.30 (1.69-3.13)	2.22 (1.63-3.01)

† OR (95% CI) for children 0-5 months was dropped due to a small sample size

§ Missing values for all indicators was less than 3%

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Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross sectional analysis of surveys

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ABSTRACT

Objectives: Increasing evidence suggests that water, sanitation and hygiene (WASH) practices affect linear growth in early childhood. We determined the association between household access to water, sanitation, and personal hygiene practices with stunting among children aged 0-23 months in rural India.

Setting: India

Participants: A total of 10,364, 34,639, and 1,282 under-twos who participated in the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included in the analysis.

Primary outcome measures: The association between WASH indicators and child stunting was assessed using logistic regression models.

Results: The prevalence of stunting ranged from 25% to 50% across the three studies. Compared with open defecation, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months, after adjusting for all potential confounders [NHFS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was not in itself associated with stunting. The caregiver's self-reported practices of washing hands with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse association between reported personal hygiene practices and stunting was stronger among households with access to toilet facility or piped water (all interaction terms, P<0.05).

Conclusions: Improved conditions of sanitation and hygiene practices are associated with reduced prevalence of stunting in rural India. Policies and programming aiming to address child stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-specific to nutrition-sensitive programming. Future randomized trials are warranted to validate the causal association.

Article Summary

- Household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India
- The protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility

Strengths and limitations of this study

- We analyzed three large survey datasets collected at the household level and representative of different administrative units; national, state and district
- We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established

INTRODUCTION

In 2012, the World Health Organization adopted a new global target of reducing the number of stunted children under-five by 40% by 2025.[1] Despite over two decades of significant economic growth, India has one of the world's highest child stunting rates. The 2006 National Family Health Survey shows that 48% of Indian children under five – 61 million children – are stunted due to chronic nutrition deprivation, accounting for more than one third of stunted children in the developing world.[2] Child stunting is linked to serious and largely irreversible consequences for survival, health, development, school performance, and productivity in adult life.[3, 4]

For many children, stunted growth starts before birth as a result of poor maternal nutritional status and worsens gradually during the first two years of life.[5] Thus, the first 1,000 days, from conception until the age of two years, are a critical window of opportunity, during which timely interventions can have a measurable and lasting impact on the prevention of child stunting.[2] Importantly, however, in the current context of widespread infection and contamination in children's environments, dietary interventions alone may be insufficient to promote optimal growth in children in developing countries. In such environments, efficacy studies with nutrient-dense food supplements have shown to improve approximately 0.7 height-for-age z-score at best.[6] This reflects on only one third of the average height deficit in South Asian and sub-Saharan African children.[7]

Growing evidence suggests a link between child linear growth and household water, sanitation, and hygiene (WASH) practices.[8] It has previously been estimated that as much as 50% of child undernutrition may be attributable to poor WASH practices.[9] Ingestion of high quantities

of fecal bacteria from both human and animal sources by infants and young children through mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry feces are common in many rural low income environments. This leads to intestinal infections which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption, and increasing nutrient losses.[10]

In India, approximately 53% of households and 624 million people defecate in the open.[2] Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). Recently, an ecological analysis of data from 112 rural districts of India demonstrated a strong association between the prevalence of open defecation and stunting, after adjusting for potential confounders.[11] This analysis added to a growing body of suggestive evidence on the effect of open defecation on child linear growth. However, further evidence is needed to corroborate the findings, as ecological studies are prone to ecological fallacy and other errors, and are often used to generate hypotheses for additional investigation employing more rigorous methods.[11]

Strengthening the evidence base on the linkages between child linear growth and WASH practices in Indian population will help support informed development of policy and guidelines that inform optimal programmatic strategies, actions, and monitoring. This study therefore sought to determine whether improved WASH conditions are associated with reduced child stunting in rural India. Specifically, the analysis aimed to determine the association between stunting and household access to sanitation facilities, water supply, and personal hygiene practices using multiple logistic regression analyses.

METHODS

Data

We analyzed three large datasets obtained from the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). Details of the three surveys are described elsewhere.[2, 12, 13] Briefly, the NFHS-3 is a Demographic Health Survey carried out by the International Institute for Population Services (IIPS) in 2005-6, that provides information on mortality, fertility, family planning, environmental hygiene, nutrition, and health status of India's population.[2] A stratified multistage cluster sampling method was used to identify a nationally representative sample of India's population living in both urban and rural areas in 29 states. A total of 109,041 households were selected, from which a total of 124,385 women age 15-49 years and 74,369 men age 15-54 years were included in the survey.[2]

The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect district level data on the nutritional status of Indian children below five years of age.[12] The survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this, 100 districts were those with the poorest indicators of child wellbeing in the country, and the remaining 12 districts were selected among those with some of the best indicators of child wellbeing for the purpose of within-state comparison. The selected areas represent about one-sixth of India's population and one-fifth of India's children under-five. A stratified cluster sampling was employed to identify a representative sample of 73,670 households from which a total of 109,903 children under-five were included in the survey. Information on child nutritional status was collected together with relevant maternal, household and environmental determinants.[12]

The CNSM is the first ever state-specific survey in India that provides information on nutritional status and feeding practices of children below two years of age and relevant maternal and household determinants.[13] The CNSM survey is a joint initiative of the Government of Maharashtra and UNICEF, implemented by the IIPS. A multi-stage stratified sampling method was used to select a total of 2,650 children under two years of age from 2,630 households from the six administrative divisions of the state, namely Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune.[13] The sampling scheme was designed to represent Maharashtra State.

These surveys all have different sample sizes as they are representative of different administrative units; national for NFHS and state for CNSM. The HUNGaMA survey represents a spread of the poorest districts in India and has a large sample size with a larger open defecation rate, but one in line with Census data. Ethical approval was not sought for this secondary analysis of publicly available survey data.

Data Collection

Data were collected using similar methods in all three surveys.[2, 12, 13] All interviews and anthropometric measurements were conducted at home by field teams who visited eligible respondents in each of the selected household. Written consent was sought from each respondent and parents or guardians provided consent for infants and children. Interviews and assessments were carried out only after consent was obtained.

Information on the child's age, sex, morbidity in the past week(s), immunization status, breastfeeding practices and dietary intake was collected from the mother of the child or caregiver. Mothers/caregivers were interviewed regarding their age, education, reproductive history,

nutritional status, morbidity, and reported personal hygiene practices. Information on household composition, source of drinking water and sanitation facility, socioeconomic status, and utilization of social safety net programs was also collected. All interviews were carried out using a structured questionnaire.

Anthropometric measurements were taken from the children and mothers following standard procedures.[14] Height was measured using a height/length board to the nearest 0.1 cm. Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children was determined using the immunization cards or home records of date of birth to the extent possible. When these documents were unavailable, the local events calendar was used to help with the recall of the child's age.

The field interviewers/anthropomerists were from local non-governmental organization partners and were thoroughly trained before data collection. The performance of field staff during data collection was continuously monitored by supervisors and quality control teams who rechecked some of the data the following day to ensure data reliability. Non-response and refusal to participate in the surveys were minimal.

Statistical Analysis

This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than one child under-two was assessed in a given household, only the youngest child from each household was included in the analysis. All analyses were weighted according to the population size and adjusted for the multistage cluster design of the surveys.

Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009 software.[15] Maternal body mass index (BMI) was defined as weight divided by the square of height (kg/m^2). In the analysis of data obtained from the NFHS and CNSM, sources of drinking water were classified into improved water sources including water piped into a dwelling, plot or yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater vs. unimproved water.[16, 17] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet.[16] A comparison was also made between piped water vs. other sources of drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of drinking water only as hand pump and piped water and others and sanitation as defecating in the open vs. any toilet.[12]

In the NFHS-3 and CNSM, a wealth index was computed as an indicator of household economic status. Details on the estimation of household wealth index are described elsewhere.[12, 13] Briefly, each asset was assigned a standardized score generated through a principal components analysis. The selected households were then ranked according to the sum of household asset scores and were grouped into five wealth quintiles from the lowest (poorest) to the highest (richest) score. For HUNGaMA a wealth index was not generated and household ownership of durable assets was used as the primary indicator of household economic status.

Data for each survey were analyzed separately. Descriptive statistics were used to examine the distribution of the full range of variables. Using appropriate cutoffs, dichotomous or categorical variables were created for a few variables such as birth order (1-2, 3-4 or ≥5); maternal education (no education, primary school, secondary school, or > secondary school);

maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5 kg/m^2); and household composition (2-6, ≥7).

Although children 0-5 and 6-23 months of age have predominantly different feeding practices, analyses for the two age groups were merged, because age was not a significant effect modifier for indicators examined in predicting stunting. Multiple logistic regression analyses were used to examine the association between the risk of stunting and WASH practices adjusting for potential confounders. Stunting was included as the dependent variable and household sanitation facilities, source of drinking water, and reported personal hygiene practices as the independent variables, together with the potential confounding factors.

Confounding factors included the major determinants of child stunting based on UNICEF's conceptual framework[17, 18]. These were associated with each WASH indicator in the bivariate analyses using χ^2 test ($P < 0.05$). The interactions between household sanitation facilities, source of drinking water, and personal hygiene were created to examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical significance defined as $P<0.05$. All analyses were performed using STATA version 13.0 (Stat Corp., College Station, TX, USA).

RESULTS

NFHS-3

The mean (± standard error (SE)) age of children in the analysis was 11.5 ± 0.05 months and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15% were reported to have had diarrhea in the past two weeks. The mean (± SE) age of the mothers of under-twos was 25.0 ± 0.08 years. More than half the mothers had no education and 41% had short stature (<150 cm). About 83% of the households had access to improved drinking water sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation facilities, whereas 77% had no toilet facility.

The presence of a household sanitation facility was associated with stunting among children aged 0-23 months. In a multivariate analysis, compared with open defecation, household access to toilet facility was associated with a 16% lower odds of being stunted, adjusting for all potential confounders (OR=0.84, 95% CI: 0.71-0.99) (Table 2). Household access to an improved drinking water source or piped water was not a predictor of child stunting. No interactions between household access to sanitation facilities and drinking water sources were observed (data not shown).

HUNGaMA

The mean (±SE) age of the children was 11.7 ± 0.04 months with both sexes equally represented (Table 1). About one-half (50%) were stunted, 16% were wasted and 41% had had diarrhea in the past week. The mean (± SE) age of the mothers was 26.8 ± 0.04 years and approximately 63% had no education. About a quarter of the households (24%) had access to piped water, whereas most of the households (83%) had no toilet facility.

Having a toilet facility at home was associated with a 16% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.84, 95%

CI: 0.78-0.91) (Table 3). Household access to a piped water source was not associated with stunting. There were no synergistic effects of household sanitation and water supply on child stunting.

The mother/caregiver's reported hygiene practices appeared to predict the risk of child stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands with soap after defecation was associated with a 14% reduced risk of stunting among children aged 0-23 months (OR=0.86, 95% CI: 0.80-0.93) (Table 3). Likewise, the caregiver's reported practice of washing their hands with soap before food was associated with a 15% lower odds of stunting among children aged 0-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).

There was a significant interaction between mother/caregiver's reported hygiene practices and household sanitation and drinking water conditions in their association with child stunting. The protective effect of mother/caregiver's reported practice of washing their hands with soap before food against child stunting was stronger among households with access to piped water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term $P<0.05$) (Table 4). In addition, the inverse association between mother/caregiver's reported practices of washing their hands with soap after defecation and stunting was stronger among households with access to toilet facility (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).

CNSM

The mean (± SE) age of the children was 11.0 ± 0.24 months and about 56% were male (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had had diarrhea in the past two weeks. The mean (± SE) age of the mothers was 23.6 ± 0.12 years

and 14% had no education. Approximately 87% of the households had improved sources of drinking water, and about 30% had access to piped water. Twenty seven percent of the households had access to improved sanitation facilities.

In multivariate analysis, household access to toilet facility was associated with a 39% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.61, 95% CI: 0.44-0.85) (Table 5). Household access to an improved water source and piped water did not predict child stunting.

DISCUSSION

We report here the association between child stunting and household access to improved sanitation and drinking water source and personal hygiene in India, based on large survey datasets representative at national, state and district levels. Notably, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months. On the other hand, household access to an improved source of drinking water or piped water in particular was not a predictor of stunting. The mother/caregiver's reported practices of washing their hands with soap either before a meal or after defecation was associated with a 15% reduced risk of stunting.

Overall, our results of the inverse association between stunting and household access to toilet facility tend to confirm the findings of previous non-randomized research carried out in different parts of the world.[19-22] Using data from multiple countries in Africa, Asia and Latin America, Esrey showed that improved sanitation was associated with a 0.06-0.62 and 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.[19] Similarly, in a cross-

sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not included), access to improved sanitation was shown to be associated with a 27% lower risk of child stunting.[20] Recently, in an ecological analysis, Spears et al. found that differences in open defecation could statistically account for 35-55% of the average difference in stunting between districts in India.[11] The findings of our analysis based on three large survey datasets collected at the household level, reinforce the notion that poor sanitation may indeed greatly increase the likelihood of child stunting in rural India where open defecation is pervasive and the burden of child stunting is massive.

It is evident that children become more affected by environmental contamination as they start crawling, walking, exploring, and putting objects in their mouths, which increases the risk of ingesting fecal bacteria from both human and animal sources. This leads to repeated bouts of diarrhea and intestinal worms, which in turn deteriorates the nutritional status of children.[23] Importantly, growing evidence suggests that a key cause of child undernutrition is a subclinical disorder of the small intestine known as environmental enteropathy which is in turn caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene.[24] This hypothesis makes addressing the issue of sanitation even more critical.

Household access to an improved source of drinking water or piped water was not associated with child stunting. This corroborates earlier findings from non-randomized studies which indicate that the potential effects of improved water supply on child linear growth tend to be much smaller than those of improved sanitation.[19] This lack of association in our analysis may be explained by the current predominant use of an improved drinking water source in India, reflecting source only, not on water safety. The NFHS and CNSM showed that ~83% and ~74%

of the households in rural areas, respectively, have access to improved drinking water sources.[2,13] About a quarter of households reported having water piped into the dwelling, plot or yard.[2,13] Although household access to piped water was significantly associated with stunting in bivariate analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential confounders.

Our results indicated no significant interactions between household access to improved water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and sanitation on child linear growth.[19,21,25] In a cross-sectional, multi-country study, Esrey noted that the positive association between improved sanitation and child linear growth was enhanced by household access to an improved water supply.[19] Similarly, in a longitudinal study in Peru, Checkley et al found that the positive association between improved water sources and child linear growth existed only when it was accompanied by improved sanitation and water storage practices.[21] In contrast, no synergistic effects of water and sanitation were found in a large prospective cohort study in Sudan.[25] Therefore, further research is required to determine if improved household water supply and its handling and storage, and sanitation have additive or synergistic effects on child linear growth. It should also be noted that the major pathways of fecal-oral transmission of bacteria may be different for infants compared to older people. Infants that are breastfed receive the majority of their fluid and nutrient requirements from breastmilk and consume little amount of drinking water. Thus, the amount of bacteria they ingest from contaminated water may be small compared to other things babies put in their mouths during developmental exploration.

Few studies have explored the association between the mother/caregiver's personal hygiene practices and child stunting in India. We found that mothers/caregivers who reported washing their hands with soap either before meal or after defecation had a lower association with stunted children. This corresponds with the findings from a community-based cross-sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were significantly associated with child undernutrition.[26] Our findings also suggest that the protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility. Clearly, efforts to improve hand washing practices of both mothers/caregivers and children themselves are essential to prevent diarrhea and other infections among children, which may in turn contribute to the reduction of stunting. These efforts should be accompanied by concrete actions to enhance household water and sanitation conditions. Further research is required to examine the impact of improved personal hygiene practices on child growth, especially as part of a multi-sectoral and convergent approach to effectively address child stunting.

The limitations to this study need to be considered. We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established. The mother/caregiver's reported personal hygiene practices were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems. Moreover, the HUNGaMA survey only inquired whether the mother/caregiver was using soap for washing hands before meals. It was not clear whether the mother/caregiver washed hands before eating her own meal or feeding her child. While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data. Data on personal hygiene was not collected from the

NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with soap was determined in the CNSM. Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight. Despite these limitations, assessing the WASH association with child stunting using large representative survey datasets coming from the local context is a critical step in strengthening the relevant evidence base and developing multi-sectoral interventions for optimal child growth.

In conclusion, this analysis revealed that household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India. This reinforces the growing evidence of the effects of WASH practices on child linear growth. Large-scale randomized effectiveness trials of toilet provision (and use) and reported handwashing at critical times, that include environmental enteropathy and child growth as outcomes, are warranted to go beyond association in order to estimate causality. However, this suggests the need for different programmatic responses by governments and development partners. Optimizing nutrition outcomes for young children now requires a framework that is broader than nutrition specific interventions alone. India's vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive interventions especially leading up to and during the first one thousand days. Children and mothers need basic WASH provision and behaviors to survive, grow and thrive.

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TRIAL REGISTRATION

As this is a secondary analysis of publicly available survey data, no trial registration was required

CONTRIBUTORSHIP STATEMENT

JHR and AC conceptualized, designed and wrote the paper; JHR and BB analyzed the datasets; JHR, VMA, SC wrote the paper; All authors read the manuscript, made a substantial contribution to the revision, and approved the final manuscript.

COMPETING INTERESTS

The authors declare no conflict of interest

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DATA SHARING

No additional data available

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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS)[1]	Hunger and Malnutrition Survey (HUNGaMA) [2]	Comprehensive Nutrition Survey in Maharashtra (CNSM)[3]
N	10,364	34,639	1,282
Child Characteristics			
Age, months (mean ± SE)	11.5 ± 0.05	11.7 ± 0.04	11.0 ± 0.24
Male (%)	52	52	56
Birth order (%)			
1-3	71	76	93
≥4	29	24	7
Stunted height-for-age z-score, <-2 (%)*	41	50	25
Wasted weight-for-height z-score, <-2 (%)*	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30
Breastfeeding started within 1 hour of birth (%)	22	42	67

Maternal Characteristics			
Age, year (mean ± SE)	25.0 ± 0.08	26.8 ± 0.04	23.6 ± 0.12
Education (%)			
No schooling	55	63	14
Primary school	15	11	13
Secondary school	27	14	57
>Secondary school	3	12	15
Short stature, <150 cm (%)	41	-	37
BMI<18.5 kg/m^2 (%)	44	-	40
Household Characteristics			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility[†]	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source[‡]	74	-	57

1 [1] Missing values existed in the NFHS sample, including the following: child diarrhea (n=5),

2 breastfeeding within 1 hour of birth (n=82), maternal height (n=27), maternal BMI (n=32)

[2] Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209), breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438), household size (n=257), source of drinking water (n=3395)

[3] Missing values existing in the CNSM sample, including the following: maternal age (n=10), maternal education (n=10), maternal height (n=12), maternal BMI (n=14)

* Estimated by using 2006 WHO growth reference

† Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet

‡ Improved water sources other than piped water included public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater

Table 2. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the National Family Health Survey for 0-23 month olds§

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household Drinking Water			
Other	9,049	1.0 (Reference)	Not retained in the final model
Piped	1,315	0.64 (0.53 - 0.76)	
Place of defecation			
No facility/bush/field	6,635	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,729	0.53 (0.46 - 0.61)	0.84 (0.71-0.99)
Wealth Index			
Poorest	2,727	1.0 (Reference)	1.0 (Reference)
Poorer	2,617	0.78 (0.67 - 0.89)	0.86 (0.74-0.99)
Middle	2,390	0.66 (0.56 - 0.76)	0.83 (0.71-0.97)

Richer	1,764	0.46 (0.39 - 0.55)	0.71 (0.59-0.87)
Richest	866	0.26 (0.20 - 0.33)	0.52 (0.39-0.69)
Social Class			
Other	2,962	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	7,402	1.54 (1.36-1.74)	1.23 (1.07-1.42)
Maternal Education			
No schooling	4,973	1.0 (Reference)	1.0 (Reference)
Primary school	1,631	0.79 (0.68-0.91)	0.88 (0.76-1.02)
Secondary school	3,425	0.49 (0.43 - 0.55)	0.65 (0.56-0.74)
>Secondary school	334	0.25 (0.17-0.37)	0.43 (0.29-0.65)
Maternal height			
≥150 cm	9,276	1.0 (Reference)	1.0 (Reference)
<150 cm	1,087	1.70 (1.53-1.89)	1.59 (1.43±1.78)
Maternal age			
≥ 30	2,256	1.0 (Reference)	1.0 (Reference)

<20	1,087	0.89 (0.73-1.07)	0.93 (0.76-1.14)
20-29	7,020	0.74 (0.65-0.85)	0.85 (0.74-0.98)
Frequency of ANC visit during pregnancy			
Less than 3 times	5,395	1.0 (Reference)	Not retained in the final model
≥3 times	4,869	0.67 (0.60-0.75)	
Maternal dietary intake			
Consumed <4 food groups a week	6,362	1.0 (Reference)	Not retained in the final model
Consumed ≥4 food groups a week	3,980	0.79 (0.70-0.88)	
Birth Order			
≥5	1,822	1.0 (Reference)	Not retained in the final model
1-2	5,615	0.66 (0.57-0.76)	
3-4	2,926	0.79 (0.68-0.92)	
Initiation of Breastfeeding			
After 1 hour	7,025	1.0 (Reference)	Not retained in the

Within 1 hour of birth	3,239	0.90 (0.80-1.01)	final model
Complementary feeding practices			
Not fed minimum number of times and appropriate number of food group*	7,313	1.0 (Reference)	1.0 (Reference)
Fed minimum number of times and appropriate number of food group	3.050	1.16 (1.00-1.35)	1.50 (1.28-1.76)

† Food groups include milk and curd, pulse or beans, dark green leafy vegetables, fruits, eggs, fish, chicken or meat

‡ Required vaccinations include BCG, measles, and three doses each of DPT and polio vaccine

*Appropriate number of food groups including three or more food groups for breastfed children and four or more food groups for non-breastfed children; Minimum number of times are defined as at least twice a day for breastfed infants 6-8 months and at least three times a day for breastfed children 9-23 months

§ Missing values for all indicators was less than 3%

Table 3. Crude and adjusted odds ratios (OR) of household water and sanitation conditions and personal hygiene in relation to stunting for children who participated in the Hunger and Malnutrition Survey by age group[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	23,513	1.0 (Reference)	Not retained in the final model
Piped	7,731	0.84(0.79-0.9)	
Place of defecation			
No facility/bush/field	28,457	1.0 (Reference)	1.0 (Reference)
Any toilet facility	6,022	0.62 (0.58-0.67)	0.84 (0.78-0.91)
Mother/Caregiver's practice of washing hands with soap after defecation			
No	28,001	1.0 (Reference)	1.0 (Reference)
Yes	6,638	0.68 (0.64-0.73)	0.86 (0.80-0.93)
Household ownership of durable assets			
Owning <2 items	14,755	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	19,560	0.72 (0.68-0.76)	0.89 (0.84-0.95)

Religion			
Other	5,046	1.0 (Reference)	Not retained in the final model
Hindu	29,581	0.92 (0.85-0.99)	
Social Class			
Other	21,241	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	13,386	1.32 (1.25-1.4)	1.21 (1.14-1.28)
Maternal Education			
No schooling	20,566	1.0 (Reference)	1.0 (Reference)
Primary school	1,119	0.79 (0.68-0.91)	0.83 (0.71-0.96)
Secondary school	7,949	0.65 (0.61-0.7)	0.72 (0.67-0.77)
>Secondary school	4,567	0.40 (0.37-0.43)	0.49 (0.45-0.54)
Maternal age			
≥ 30	9,394	1.0 (Reference)	Not retained in the final model
<20	954	0.88 (0.75-1.03)	
20-29	24,291	0.82 (0.77-0.87)	

Utilized ICDS's health check up services for their child			
No	24,327	1.0 (Reference)	Not retained in the final model
Yes	10,093	0.90 (0.85±0.95)	
Birth Order			
≥5	4,134	1.0 (Reference)	Not retained in the final model
1-2	20,166	0.74 (0.68-0.81)	
3-4	10,337	0.85 (0.77-0.93)	
Initiation of breastfeeding			
After 1 hour	18,839	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	15,411	0.78 (0.74-0.82)	0.88 (0.82-0.93)
Fed Colostrum			
No	11,038	1.0 (Reference)	1.0 (Reference)
Yes	23,312	0.77 (0.72-0.81)	0.89 (0.83-0.95)
Complementary feeding practices*(6-23 months)			
Started before 6 months or after 8 Months	7,577	1.0 (Reference)	Not retained in the final model

Started 6-8 months	22,230	0.98 (0.92-1.05)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 4. Crude and adjusted odds ratios (OR) of household sanitation conditions and personal hygiene practices in relation to stunting for children aged 0-23 months who participated in the Hunger and Malnutrition Survey by household access to piped water[§]

	No access to piped water			Having access to piped water		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Place of defecation						
No facility/bush/field	20,125	1.0 (Reference)	1.0 (Reference)	5,506	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,289	0.66 (0.60-0.72)	0.85 (0.77-0.94)	2,176	0.56 (0.49-0.64)	0.77 (0.66-0.91)
Mother/Caregiver's reported practice of washing hands with soap before meal						
No	21,346	1.0 (Reference)	1.0 (Reference)	6,001	1.0 (Reference)	1.0 (Reference)
Yes	2,167	0.74 (0.66-0.82)	0.89 (0.80-0.99)	1,730	0.61 (0.53-0.70)	0.77 (0.66-0.90)
Household ownership of durable assets[†]						
Owning <2 items	10,497	1.0 (Reference)	1.0 (Reference)	2,721	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	12,820	0.75	0.90	4,912	0.64	0.84

		(0.71-0.80)	(0.84-0.96)		(0.57-0.73)	(0.74-0.96)
Social class						
Other	14,148	1.0 (Reference)	1.0 (Reference)	4,918	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	9,356	1.34 (1.25-1.43)	1.23 (1.15-1.32)	2,810	1.29 (1.15-1.46)	1.16 (1.02-1.32)
Maternal education						
No schooling	14,683	1.0 (Reference)	1.0 (Reference)	3,623	1.0 (Reference)	1.0 (Reference)
Primary school	2,708	0.79 (0.67-0.95)	0.83 (0.70-0.99)	880	0.96 (0.68-1.36)	1.02 (0.71-1.46)
Secondary school	3,374	0.68 (0.63-0.73)	0.73 (0.67-0.80)	1,332	0.65 (0.57-0.75)	0.72 (0.62-0.83)
>Secondary school	2,462	0.41 (0.37-0.46)	0.49 (0.44-0.55)	1,773	0.40 (0.34-0.47)	0.51 (0.43-0.61)
Maternal age						
≥ 30	6,487	1.0 (Reference)	Not retained in the final model	1,786	1.0 (Reference)	Not retained in the final model
<20	668	0.93		182	0.75	

		(0.76-1.13)			(0.52-1.08)	
20-29	16,241	0.84 (0.78-0.90)		5,715	0.81 (0.71-0.93)	
Utilized ICDS's health check up service for their child						
No	17,010	1.0 (Reference)	Not retained in the final model	4,850	1.0 (Reference)	Not retained in the final model
Yes	6,400	0.95 (0.89-1.02)		2,793	0.85 (0.75-0.95)	
Birth order						
≥5	2,859	1.0 (Reference)	Not retained in the final model	648	1.0 (Reference)	Not retained in the final model
1-2	13,111	0.80 (0.72-0.88)		5,190	0.59 (0.47-0.72)	
3-4	7,412	0.86 (0.77-0.96)		1,842	0.83 (0.66-1.05)	
Initiation of breastfeeding						
After 1 hour	13,351	1.0 (Reference)	1.0 (Reference)	3,616	1.0 (Reference)	Not retained in the final model
Within 1 hour of birth	9,920	0.82	0.90	4,010	0.71	

		(0.77-0.88)	(0.83-0.97)		(0.63-0.80)	
Fed colostrum						
No	7,993	1.0 (Reference)	1.0 (Reference)	2,054	1.0 (Reference)	Not retained in the final model
Yes	15,350	0.82 (0.77-0.87)	0.91 (0.84-0.99)	5,585	0.69 (0.61-0.79)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 5. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the Comprehensive Nutrition Survey in Maharashtra for under 2s[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	913	1.0 (Reference)	Not retained in the final model
Piped	369	0.86 (0.60-1.23)	
Place of defecation			
No facility/bush/field	790	1.0 (Reference)	1.0 (Reference)
Any toilet facility	492	0.57 (0.41-0.78)	0.61 (0.44-0.85)
Wealth Index			
Poorest	392	1.0 (Reference)	Not retained in the final model
Poorer	415	1.00 (0.68-1.46)	
Middle	306	1.04 (0.70-1.57)	
Richer	133	0.75 (0.43-1.31)	
Richest[†]	36	0.70 (0.25-1.93)	

Maternal Education			
No schooling	181	1.0 (Reference)	Not retained in the final model
Primary school	143	0.82 (0.47-1.4)	
Secondary school	743	0.70 (0.46-1.06)	
>Secondary school	215	0.58 (0.31-1.11)	
Maternal Height			
≥150 cm	790	1.0 (Reference)	1.0 (Reference)
<150 cm	480	2.30 (1.69-3.13)	2.22 (1.63-3.01)

† OR (95% CI) for children 0-5 months was dropped due to a small sample size

§ Missing values for all indicators was less than 3%

Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross sectional analysis of surveys

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ABSTRACT

Objectives: Increasing evidence suggests that water, sanitation and hygiene (WASH) practices affect linear growth in early childhood. We determined the association between household access to water, sanitation, and personal hygiene practices with stunting among children aged 0-23 months in rural India.

Setting: India

Participants: A total of 10,364, 34,639, and 1,282 under-twos who participated in the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included in the analysis.

Primary outcome measures: The association between WASH indicators and child stunting was assessed using logistic regression models.

Results: The prevalence of stunting ranged from 25% to 50% across the three studies. Compared with open defecation, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months, after adjusting for all potential confounders [NHFS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was not in itself associated with stunting. The caregiver's self-reported practices of washing hands with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse association between reported personal hygiene practices and stunting was stronger among households with access to toilet facility or piped water (all interaction terms, $P<0.05$).

Conclusions: Improved conditions of sanitation and hygiene practices are associated with reduced prevalence of stunting in rural India. Policies and programming aiming to address child stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-specific to nutrition-sensitive programming. Future randomized trials are warranted to validate the causal association.

Article Summary

- Household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India
- The protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility

Strengths and limitations of this study

- We analyzed three large survey datasets collected at the household level and representative of different administrative units; national, state and district
- We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established

INTRODUCTION

In 2012, the World Health Organization adopted a new global target of reducing the number of stunted children under-five by 40% by 2025.[1] Despite over two decades of significant economic growth, India has one of the world's highest child stunting rates. The 2006 National Family Health Survey shows that 48% of Indian children under five – 61 million children – are stunted due to chronic nutrition deprivation, accounting for more than one third of stunted children in the developing world.[2] Child stunting is linked to serious and largely irreversible consequences for survival, health, development, school performance, and productivity in adult life.[3, 4]

For many children, stunted growth starts before birth as a result of poor maternal nutritional status and worsens gradually during the first two years of life.[5] Thus, the first 1,000 days, from conception until the age of two years, are a critical window of opportunity, during which timely interventions can have a measurable and lasting impact on the prevention of child stunting.[2] Importantly, however, in the current context of widespread infection and contamination in children's environments, dietary interventions alone may be insufficient to promote optimal growth in children in developing countries. In such environments, efficacy studies with nutrient-dense food supplements have shown to improve approximately 0.7 height-for-age z-score at best.[6] This reflects on only one third of the average height deficit in South Asian and sub-Saharan African children.[7]

Growing evidence suggests a link between child linear growth and household water, sanitation, and hygiene (WASH) practices.[8] It has previously been estimated that as much as 50% of child undernutrition may be attributable to poor WASH practices.[9] Ingestion of high quantities

of fecal bacteria from both human and animal sources by infants and young children through mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry feces are common in many rural low income environments. This leads to intestinal infections which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption, and increasing nutrient losses.[10]

In India, approximately 53% of households and 624 million people defecate in the open.[2] Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). Recently, an ecological analysis of data from 112 rural districts of India demonstrated a strong association between the prevalence of open defecation and stunting, after adjusting for potential confounders.[11] This analysis added to a growing body of suggestive evidence on the effect of open defecation on child linear growth. However, further evidence is needed to corroborate the findings, as ecological studies are prone to ecological fallacy and other errors, and are often used to generate hypotheses for additional investigation employing more rigorous methods.[11]

Strengthening the evidence base on the linkages between child linear growth and WASH practices in Indian population will help support informed development of policy and guidelines that inform optimal programmatic strategies, actions, and monitoring. This study therefore sought to determine whether improved WASH conditions are associated with reduced child stunting in rural India. Specifically, the analysis aimed to determine the association between stunting and household access to sanitation facilities, water supply, and personal hygiene practices using multiple logistic regression analyses.

METHODS

Data

We analyzed three large datasets obtained from the 2005-6 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition survey (HUNGaMA), and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). Details of the three surveys are described elsewhere.[2, 12, 13] Briefly, the NFHS-3 is a Demographic Health Survey carried out by the International Institute for Population Services (IIPS) in 2005-6, that provides information on mortality, fertility, family planning, environmental hygiene, nutrition, and health status of India's population.[2] A stratified multistage cluster sampling method was used to identify a nationally representative sample of India's population living in both urban and rural areas in 29 states. A total of 109,041 households were selected, from which a total of 124,385 women age 15-49 years and 74,369 men age 15-54 years were included in the survey.[2]

The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect district level data on the nutritional status of Indian children below five years of age.[12] The survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this, 100 districts were those with the poorest indicators of child wellbeing in the country, and the remaining 12 districts were selected among those with some of the best indicators of child wellbeing for the purpose of within-state comparison. The selected areas represent about one-sixth of India's population and one-fifth of India's children under-five. A stratified cluster sampling was employed to identify a representative sample of 73,670 households from which a total of 109,903 children under-five were included in the survey. Information on child nutritional status was collected together with relevant maternal, household and environmental determinants.[12]

The CNSM is the first ever state-specific survey in India that provides information on nutritional status and feeding practices of children below two years of age and relevant maternal and household determinants.[13] The CNSM survey is a joint initiative of the Government of Maharashtra and UNICEF, implemented by the IIPS. A multi-stage stratified sampling method was used to select a total of 2,650 children under two years of age from 2,630 households from the six administrative divisions of the state, namely Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune.[13] The sampling scheme was designed to represent Maharashtra State.

These surveys all have different sample sizes as they are representative of different administrative units; national for NFHS and state for CNSM. The HUNGaMA survey represents a spread of the poorest districts in India and has a large sample size with a larger open defecation rate, but one in line with Census data. Ethical approval was not sought for this secondary analysis of publicly available survey data.

Data Collection

Data were collected using similar methods in all three surveys.[2, 12, 13] All interviews and anthropometric measurements were conducted at home by field teams who visited eligible respondents in each of the selected household. Written consent was sought from each respondent and parents or guardians provided consent for infants and children. Interviews and assessments were carried out only after consent was obtained.

Information on the child's age, sex, morbidity in the past week(s), immunization status, breastfeeding practices and dietary intake was collected from the mother of the child or caregiver. Mothers/caregivers were interviewed regarding their age, education, reproductive history,

nutritional status, morbidity, and reported personal hygiene practices. Information on household composition, source of drinking water and sanitation facility, socioeconomic status, and utilization of social safety net programs was also collected. All interviews were carried out using a structured questionnaire.

Anthropometric measurements were taken from the children and mothers following standard procedures.[14] Height was measured using a height/length board to the nearest 0.1 cm. Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children was determined using the immunization cards or home records of date of birth to the extent possible. When these documents were unavailable, the local events calendar was used to help with the recall of the child's age.

The field interviewers/anthropomerists were from local non-governmental organization partners and were thoroughly trained before data collection. The performance of field staff during data collection was continuously monitored by supervisors and quality control teams who rechecked some of the data the following day to ensure data reliability. Non-response and refusal to participate in the surveys were minimal.

Statistical Analysis

This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than one child under-two was assessed in a given household, only the youngest child from each household was included in the analysis. All analyses were weighted according to the population size and adjusted for the multistage cluster design of the surveys.

Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009 software.[15] Maternal body mass index (BMI) was defined as weight divided by the square of height (kg/m^2). In the analysis of data obtained from the NFHS and CNSM, sources of drinking water were classified into improved water sources including water piped into a dwelling, plot or yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater vs. unimproved water.[16, 17] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet.[16] A comparison was also made between piped water vs. other sources of drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of drinking water only as hand pump and piped water and others and sanitation as defecating in the open vs. any toilet.[12]

In the NFHS-3 and CNSM, a wealth index was computed as an indicator of household economic status. Details on the estimation of household wealth index are described elsewhere.[12, 13] Briefly, each asset was assigned a standardized score generated through a principal components analysis. The selected households were then ranked according to the sum of household asset scores and were grouped into five wealth quintiles from the lowest (poorest) to the highest (richest) score. For HUNGaMA a wealth index was not generated and household ownership of durable assets was used as the primary indicator of household economic status.

Data for each survey were analyzed separately. Descriptive statistics were used to examine the distribution of the full range of variables. Using appropriate cutoffs, dichotomous or categorical variables were created for a few variables such as birth order (1-2, 3-4 or ≥5); maternal education (no education, primary school, secondary school, or > secondary school);

maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5 kg/m^2); and household composition (2-6, ≥7).

Although children 0-5 and 6-23 months of age have predominantly different feeding practices, analyses for the two age groups were merged, because age was not a significant effect modifier for indicators examined in predicting stunting. Multiple logistic regression analyses were used to examine the association between the risk of stunting and WASH practices adjusting for potential confounders. Stunting was included as the dependent variable and household sanitation facilities, source of drinking water, and reported personal hygiene practices as the independent variables, together with the potential confounding factors.

Confounding factors included the major determinants of child stunting based on UNICEF's conceptual framework[17, 18]. These were associated with each WASH indicator in the bivariate analyses using χ^2 test ($P < 0.05$). The interactions between household sanitation facilities, source of drinking water, and personal hygiene were created to examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical significance defined as $P<0.05$. All analyses were performed using STATA version 13.0 (Stat Corp., College Station, TX, USA).

RESULTS

NFHS-3

The mean (± standard error (SE)) age of children in the analysis was 11.5 ± 0.05 months and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15% were reported to have had diarrhea in the past two weeks. The mean (± SE) age of the mothers of under-twos was 25.0 ± 0.08 years. More than half the mothers had no education and 41% had short stature (<150 cm). About 83% of the households had access to improved drinking water sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation facilities, whereas 77% had no toilet facility.

The presence of a household sanitation facility was associated with stunting among children aged 0-23 months. In a multivariate analysis, compared with open defecation, household access to toilet facility was associated with a 16% lower odds of being stunted, adjusting for all potential confounders (OR=0.84, 95% CI: 0.71-0.99) (Table 2). Household access to an improved drinking water source or piped water was not a predictor of child stunting. No interactions between household access to sanitation facilities and drinking water sources were observed (data not shown).

HUNGaMA

The mean (±SE) age of the children was 11.7 ± 0.04 months with both sexes equally represented (Table 1). About one-half (50%) were stunted, 16% were wasted and 41% had had diarrhea in the past week. The mean (± SE) age of the mothers was 26.8 ± 0.04 years and approximately 63% had no education. About a quarter of the households (24%) had access to piped water, whereas most of the households (83%) had no toilet facility.

Having a toilet facility at home was associated with a 16% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.84, 95%

CI: 0.78-0.91) (Table 3). Household access to a piped water source was not associated with stunting. There were no synergistic effects of household sanitation and water supply on child stunting.

The mother/caregiver's reported hygiene practices appeared to predict the risk of child stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands with soap after defecation was associated with a 14% reduced risk of stunting among children aged 0-23 months (OR=0.86, 95% CI: 0.80-0.93) (Table 3). Likewise, the caregiver's reported practice of washing their hands with soap before food was associated with a 15% lower odds of stunting among children aged 0-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).

There was a significant interaction between mother/caregiver's reported hygiene practices and household sanitation and drinking water conditions in their association with child stunting. The protective effect of mother/caregiver's reported practice of washing their hands with soap before food against child stunting was stronger among households with access to piped water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term $P<0.05$) (Table 4). In addition, the inverse association between mother/caregiver's reported practices of washing their hands with soap after defecation and stunting was stronger among households with access to toilet facility (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).

CNSM

The mean (± SE) age of the children was 11.0 ± 0.24 months and about 56% were male (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had had diarrhea in the past two weeks. The mean (± SE) age of the mothers was 23.6 ± 0.12 years

and 14% had no education. Approximately 87% of the households had improved sources of drinking water, and about 30% had access to piped water. Twenty seven percent of the households had access to improved sanitation facilities.

In multivariate analysis, household access to toilet facility was associated with a 39% reduced odds of being stunted among children aged 0-23 months, after adjusting for all potential confounders (OR=0.61, 95% CI: 0.44-0.85) (Table 5). Household access to an improved water source and piped water did not predict child stunting.

DISCUSSION

We report here the association between child stunting and household access to improved sanitation and drinking water source and personal hygiene in India, based on large survey datasets representative at national, state and district levels. Notably, household access to toilet facility was associated with a 16-39% reduced odds of stunting among children aged 0-23 months. On the other hand, household access to an improved source of drinking water or piped water in particular was not a predictor of stunting. The mother/caregiver's reported practices of washing their hands with soap either before a meal or after defecation was associated with a 15% reduced risk of stunting.

Overall, our results of the inverse association between stunting and household access to toilet facility tend to confirm the findings of previous non-randomized research carried out in different parts of the world.[19-22] Using data from multiple countries in Africa, Asia and Latin America, Esrey showed that improved sanitation was associated with a 0.06-0.62 and 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.[19] Similarly, in a cross-

sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not included), access to improved sanitation was shown to be associated with a 27% lower risk of child stunting.[20] Recently, in an ecological analysis, Spears et al. found that differences in open defecation could statistically account for 35-55% of the average difference in stunting between districts in India.[11] The findings of our analysis based on three large survey datasets collected at the household level, reinforce the notion that poor sanitation may indeed greatly increase the likelihood of child stunting in rural India where open defecation is pervasive and the burden of child stunting is massive.

It is evident that children become more affected by environmental contamination as they start crawling, walking, exploring, and putting objects in their mouths, which increases the risk of ingesting fecal bacteria from both human and animal sources. This leads to repeated bouts of diarrhea and intestinal worms, which in turn deteriorates the nutritional status of children.[23] Importantly, growing evidence suggests that a key cause of child undernutrition is a subclinical disorder of the small intestine known as environmental enteropathy which is in turn caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene.[24] This hypothesis makes addressing the issue of sanitation even more critical.

Household access to an improved source of drinking water or piped water was not associated with child stunting. This corroborates earlier findings from non-randomized studies which indicate that the potential effects of improved water supply on child linear growth tend to be much smaller than those of improved sanitation.[19] This lack of association in our analysis may be explained by the current predominant use of an improved drinking water source in India, reflecting source only, not on water safety. The NFHS and CNSM showed that ~83% and ~74%

of the households in rural areas, respectively, have access to improved drinking water sources.[2,13] About a quarter of households reported having water piped into the dwelling, plot or yard.[2,13] Although household access to piped water was significantly associated with stunting in bivariate analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential confounders.

Our results indicated no significant interactions between household access to improved water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and sanitation on child linear growth.[19,21,25] In a cross-sectional, multi-country study, Esrey noted that the positive association between improved sanitation and child linear growth was enhanced by household access to an improved water supply.[19] Similarly, in a longitudinal study in Peru, Checkley et al found that the positive association between improved water sources and child linear growth existed only when it was accompanied by improved sanitation and water storage practices.[21] In contrast, no synergistic effects of water and sanitation were found in a large prospective cohort study in Sudan.[25] Therefore, further research is required to determine if improved household water supply and its handling and storage, and sanitation have additive or synergistic effects on child linear growth. It should also be noted that the major pathways of fecal-oral transmission of bacteria may be different for infants compared to older people. Infants that are breastfed receive the majority of their fluid and nutrient requirements from breastmilk and consume little amount of drinking water. Thus, the amount of bacteria they ingest from contaminated water may be small compared to other things babies put in their mouths during developmental exploration.

Few studies have explored the association between the mother/caregiver's personal hygiene practices and child stunting in India. We found that mothers/caregivers who reported washing their hands with soap either before meal or after defecation had a lower association with stunted children. This corresponds with the findings from a community-based cross-sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were significantly associated with child undernutrition.[26] Our findings also suggest that the protective effects of mother/caregiver's reported personal hygiene practices were stronger when it was accompanied by an improved household access to piped water and toilet facility. Clearly, efforts to improve hand washing practices of both mothers/caregivers and children themselves are essential to prevent diarrhea and other infections among children, which may in turn contribute to the reduction of stunting. These efforts should be accompanied by concrete actions to enhance household water and sanitation conditions. Further research is required to examine the impact of improved personal hygiene practices on child growth, especially as part of a multi-sectoral and convergent approach to effectively address child stunting.

The limitations to this study need to be considered. We analyzed cross-sectional data, so a causal association between improved WASH practices and reduced likelihood of stunting cannot be established. The mother/caregiver's reported personal hygiene practices were determined based on self-reported data which may reflect on improved knowledge as opposed to actual practice and may lead to validity problems. Moreover, the HUNGaMA survey only inquired whether the mother/caregiver was using soap for washing hands before meals. It was not clear whether the mother/caregiver washed hands before eating her own meal or feeding her child. While the NFHS and CNSM used similar classifications for the source of drinking water and sanitation facilities, the HUNGaMA survey used a different categorization. Thus, households having access to an improved source of drinking water and sanitation facilities could not be determined using the HUNGaMA data. Data on personal hygiene was not collected from the NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with soap was determined in the CNSM. Although an important variable to consider, the birth weight of children was not included in the multivariate analysis, as the information was collected from a small proportion of the sample. However, we did control for maternal height, BMI, dietary intake and other relevant factors which are strong predictors of child birth weight. Despite these limitations, assessing the WASH association with child stunting using large representative survey datasets coming from the local context is a critical step in strengthening the relevant evidence base and developing multi-sectoral interventions for optimal child growth.

In conclusion, this analysis revealed that household sanitation and the mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting in India. This reinforces the growing evidence of the effects of WASH practices on child linear growth. Large-scale randomized effectiveness trials of toilet provision (and use) and reported handwashing at critical times, that include environmental enteropathy and child growth as outcomes, are warranted to go beyond association in order to estimate causality. However, this suggests the need for different programmatic responses by governments and development partners. Optimizing nutrition outcomes for young children now requires a framework that is broader than nutrition specific interventions alone. India's vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive interventions especially leading up to and during the first one thousand days. Children and mothers need basic WASH provision and behaviors to survive, grow and thrive.

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TRIAL REGISTRATION

As this is a secondary analysis of publicly available survey data, no trial registration was required

CONTRIBUTORSHIP STATEMENT

JHR and AC conceptualized, designed and wrote the paper; JHR and BB analyzed the datasets; JHR, VMA, SC wrote the paper; All authors read the manuscript, made a substantial contribution to the revision, and approved the final manuscript.

COMPETING INTERESTS

The authors declare no conflict of interest

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DATA SHARING

No additional data available

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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS)[1]	Hunger and Malnutrition Survey (HUNGaMA)[2]	Comprehensive Nutrition Survey in Maharashtra (CNSM)[3]
N	10,364	34,639	1,282
Child Characteristics			
Age, months (mean ± SE)	11.5 ± 0.05	11.7 ± 0.04	11.0 ± 0.24
Male (%)	52	52	56
Birth order (%)			
1-3	71	76	93
≥4	29	24	7
Stunted height-for-age z-score, <-2 (%)*	41	50	25
Wasted weight-for-height z-score, <-2 (%)*	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30
Breastfeeding started within 1 hour of birth (%)	22	42	67

Maternal Characteristics			
Age, year (mean ± SE)	25.0 ± 0.08	26.8 ± 0.04	23.6 ± 0.12
Education (%)			
No schooling	55	63	14
Primary school	15	11	13
Secondary school	27	14	57
>Secondary school	3	12	15
Short stature, <150 cm (%)	41	-	37
BMI<18.5 kg/m^2 (%)	44	-	40
Household Characteristics			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility[†]	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source[‡]	74	-	57

[1] Missing values existed in the NFHS sample, including the following: child diarrhea (n=5), breastfeeding within 1 hour of birth (n=82), maternal height (n=27), maternal BMI (n=32)

[2] Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209), breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438), household size (n=257), source of drinking water (n=3395)

[3] Missing values existing in the CNSM sample, including the following: maternal age (n=10), maternal education (n=10), maternal height (n=12), maternal BMI (n=14)

* Estimated by using 2006 WHO growth reference

[†] Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet

[‡] Improved water sources other than piped water included public tap or standpipe, tube well or borehole, protected dug well, protected spring, and rainwater

Table 2. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the National Family Health Survey for 0-23 month olds[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household Drinking Water			
Other	9,049	1.0 (Reference)	Not retained in the final model
Piped	1,315	0.64 (0.53 - 0.76)	
Place of defecation			
No facility/bush/field	6,635	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,729	0.53 (0.46 - 0.61)	0.84 (0.71-0.99)
Wealth Index			
Poorest	2,727	1.0 (Reference)	1.0 (Reference)
Poorer	2,617	0.78 (0.67 - 0.89)	0.86 (0.74-0.99)
Middle	2,390	0.66 (0.56 - 0.76)	0.83 (0.71-0.97)

Richer	1,764	0.46 (0.39 - 0.55)	0.71 (0.59-0.87)
Richest	866	0.26 (0.20 - 0.33)	0.52 (0.39-0.69)
Social Class			
Other	2,962	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	7,402	1.54 (1.36-1.74)	1.23 (1.07-1.42)
Maternal Education			
No schooling	4,973	1.0 (Reference)	1.0 (Reference)
Primary school	1,631	0.79 (0.68-0.91)	0.88 (0.76-1.02)
Secondary school	3,425	0.49 (0.43 - 0.55)	0.65 (0.56-0.74)
>Secondary school	334	0.25 (0.17-0.37)	0.43 (0.29-0.65)
Maternal height			
≥150 cm	9,276	1.0 (Reference)	1.0 (Reference)
<150 cm	1,087	1.70 (1.53-1.89)	1.59 (1.43±1.78)
Maternal age			
≥ 30	2,256	1.0 (Reference)	1.0 (Reference)

<20	1,087	0.89 (0.73-1.07)	0.93 (0.76-1.14)
20-29	7,020	0.74 (0.65-0.85)	0.85 (0.74-0.98)
Frequency of ANC visit during pregnancy			
Less than 3 times	5,395	1.0 (Reference)	Not retained in the final model
≥3 times	4,869	0.67 (0.60-0.75)	
Maternal dietary intake			
Consumed <4 food groups a week	6,362	1.0 (Reference)	Not retained in the final model
Consumed ≥4 food groups a week	3,980	0.79 (0.70-0.88)	
Birth Order			
≥5	1,822	1.0 (Reference)	Not retained in the final model
1-2	5,615	0.66 (0.57-0.76)	
3-4	2,926	0.79 (0.68-0.92)	
Initiation of Breastfeeding			
After 1 hour	7,025	1.0 (Reference)	Not retained in the

Within 1 hour of birth	3,239	0.90 (0.80-1.01)	final model
Complementary feeding practices			
Not fed minimum number of times and appropriate number of food group*	7,313	1.0 (Reference)	1.0 (Reference)
Fed minimum number of times and appropriate number of food group	3.050	1.16 (1.00-1.35)	1.50 (1.28-1.76)

† Food groups include milk and curd, pulse or beans, dark green leafy vegetables, fruits, eggs, fish, chicken or meat

‡ Required vaccinations include BCG, measles, and three doses each of DPT and polio vaccine

*Appropriate number of food groups including three or more food groups for breastfed children and four or more food groups for non-breastfed children; Minimum number of times are defined as at least twice a day for breastfed infants 6-8 months and at least three times a day for breastfed children 9-23 months

§ Missing values for all indicators was less than 3%

Table 3. Crude and adjusted odds ratios (OR) of household water and sanitation conditions and personal hygiene in relation to stunting for children who participated in the Hunger and Malnutrition Survey by age group[§]

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	23,513	1.0 (Reference)	Not retained in the final model
Piped	7,731	0.84(0.79-0.9)	
Place of defecation			
No facility/bush/field	28,457	1.0 (Reference)	1.0 (Reference)
Any toilet facility	6,022	0.62 (0.58-0.67)	0.84 (0.78-0.91)
Mother/Caregiver's practice of washing hands with soap after defecation			
No	28,001	1.0 (Reference)	1.0 (Reference)
Yes	6,638	0.68 (0.64-0.73)	0.86 (0.80-0.93)
Household ownership of durable assets			
Owning <2 items	14,755	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	19,560	0.72 (0.68-0.76)	0.89 (0.84-0.95)

Religion			
Other	5,046	1.0 (Reference)	Not retained in the final model
Hindu	29,581	0.92 (0.85-0.99)	
Social Class			
Other	21,241	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	13,386	1.32 (1.25-1.4)	1.21 (1.14-1.28)
Maternal Education			
No schooling	20,566	1.0 (Reference)	1.0 (Reference)
Primary school	1,119	0.79 (0.68-0.91)	0.83 (0.71-0.96)
Secondary school	7,949	0.65 (0.61-0.7)	0.72 (0.67-0.77)
>Secondary school	4,567	0.40 (0.37-0.43)	0.49 (0.45-0.54)
Maternal age			
≥ 30	9,394	1.0 (Reference)	Not retained in the final model
<20	954	0.88 (0.75-1.03)	
20-29	24,291	0.82 (0.77-0.87)	

Utilized ICDS's health check up services for their child			
No	24,327	1.0 (Reference)	Not retained in the final model
Yes	10,093	0.90 (0.85±0.95)	
Birth Order			
≥5	4,134	1.0 (Reference)	Not retained in the final model
1-2	20,166	0.74 (0.68-0.81)	
3-4	10,337	0.85 (0.77-0.93)	
Initiation of breastfeeding			
After 1 hour	18,839	1.0 (Reference)	1.0 (Reference)
Within 1 hour of birth	15,411	0.78 (0.74-0.82)	0.88 (0.82-0.93)
Fed Colostrum			
No	11,038	1.0 (Reference)	1.0 (Reference)
Yes	23,312	0.77 (0.72-0.81)	0.89 (0.83-0.95)
Complementary feeding practices*(6-23 months)			
Started before 6 months or after 8 Months	7,577	1.0 (Reference)	Not retained in the final model

Started 6-8 months	22,230	0.98 (0.92-1.05)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 4. Crude and adjusted odds ratios (OR) of household sanitation conditions and personal hygiene practices in relation to stunting for children aged 0-23 months who participated in the Hunger and Malnutrition Survey by household access to piped water[§]

	No access to piped water			Having access to piped water		
	N	Crude OR (95% CI)	Adjusted OR (95% CI)	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Place of defecation						
No facility/bush/field	20,125	1.0 (Reference)	1.0 (Reference)	5,506	1.0 (Reference)	1.0 (Reference)
Any toilet facility	3,289	0.66 (0.60-0.72)	0.85 (0.77-0.94)	2,176	0.56 (0.49-0.64)	0.77 (0.66-0.91)
Mother/Caregiver's reported practice of washing hands with soap before meal						
No	21,346	1.0 (Reference)	1.0 (Reference)	6,001	1.0 (Reference)	1.0 (Reference)
Yes	2,167	0.74 (0.66-0.82)	0.89 (0.80-0.99)	1,730	0.61 (0.53-0.70)	0.77 (0.66-0.90)
Household ownership of durable assets[†]						
Owning <2 items	10,497	1.0 (Reference)	1.0 (Reference)	2,721	1.0 (Reference)	1.0 (Reference)
Owning ≥2 items	12,820	0.75	0.90	4,912	0.64	0.84

		(0.71-0.80)	(0.84-0.96)		(0.57-0.73)	(0.74-0.96)
Social class						
Other	14,148	1.0 (Reference)	1.0 (Reference)	4,918	1.0 (Reference)	1.0 (Reference)
Scheduled caste/tribe or other backward class	9,356	1.34 (1.25-1.43)	1.23 (1.15-1.32)	2,810	1.29 (1.15-1.46)	1.16 (1.02-1.32)
Maternal education						
No schooling	14,683	1.0 (Reference)	1.0 (Reference)	3,623	1.0 (Reference)	1.0 (Reference)
Primary school	2,708	0.79 (0.67-0.95)	0.83 (0.70-0.99)	880	0.96 (0.68-1.36)	1.02 (0.71-1.46)
Secondary school	3,374	0.68 (0.63-0.73)	0.73 (0.67-0.80)	1,332	0.65 (0.57-0.75)	0.72 (0.62-0.83)
>Secondary school	2,462	0.41 (0.37-0.46)	0.49 (0.44-0.55)	1,773	0.40 (0.34-0.47)	0.51 (0.43-0.61)
Maternal age						
≥ 30	6,487	1.0 (Reference)	Not retained in the final model	1,786	1.0 (Reference)	Not retained in the final model
<20	668	0.93		182	0.75	

		(0.76-1.13)			(0.52-1.08)	
20-29	16,241	0.84 (0.78-0.90)		5,715	0.81 (0.71-0.93)	
Utilized ICDS's health check up service for their child						
No	17,010	1.0 (Reference)	Not retained in the final model	4,850	1.0 (Reference)	Not retained in the final model
Yes	6,400	0.95 (0.89-1.02)		2,793	0.85 (0.75-0.95)	
Birth order						
≥5	2,859	1.0 (Reference)	Not retained in the final model	648	1.0 (Reference)	Not retained in the final model
1-2	13,111	0.80 (0.72-0.88)		5,190	0.59 (0.47-0.72)	
3-4	7,412	0.86 (0.77-0.96)		1,842	0.83 (0.66-1.05)	
Initiation of breastfeeding						
After 1 hour	13,351	1.0 (Reference)	1.0 (Reference)	3,616	1.0 (Reference)	Not retained in the final model
Within 1 hour of birth	9,920	0.82	0.90	4,010	0.71	

		(0.77-0.88)	(0.83-0.97)		(0.63-0.80)	
Fed colostrum						
No	7,993	1.0 (Reference)	1.0 (Reference)	2,054	1.0 (Reference)	Not retained in the final model
Yes	15,350	0.82 (0.77-0.87)	0.91 (0.84-0.99)	5,585	0.69 (0.61-0.79)	

† Household durable assets include television, radio, mobile phone, two-wheeler, tractor, and cycle

§ Missing values for all indicators were less than 3% except for household drinking water source (n=3,395)

Table 5. Crude and adjusted odds ratios (OR) of household water and sanitation conditions in relation to stunting for children who participated in the Comprehensive Nutrition Survey in Maharashtra for under 2s§

	N	Crude OR (95% CI)	Adjusted OR (95% CI)
Household drinking water source			
Other	913	1.0 (Reference)	Not retained in the final model
Piped	369	0.86 (0.60-1.23)	
Place of defecation			
No facility/bush/field	790	1.0 (Reference)	1.0 (Reference)
Any toilet facility	492	0.57 (0.41-0.78)	0.61 (0.44-0.85)
Wealth Index			
Poorest	392	1.0 (Reference)	Not retained in the final model
Poorer	415	1.00 (0.68-1.46)	
Middle	306	1.04 (0.70-1.57)	
Richer	133	0.75 (0.43-1.31)	
Richest†	36	0.70 (0.25-1.93)	

Maternal Education			
No schooling	181	1.0 (Reference)	Not retained in the final model
Primary school	143	0.82 (0.47-1.4)	
Secondary school	743	0.70 (0.46-1.06)	
>Secondary school	215	0.58 (0.31-1.11)	
Maternal Height			
≥150 cm	790	1.0 (Reference)	1.0 (Reference)
<150 cm	480	2.30 (1.69-3.13)	2.22 (1.63-3.01)

† OR (95% CI) for children 0-5 months was dropped due to a small sample size

§ Missing values for all indicators was less than 3%