



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

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3 1 **Household sanitation and personal hygiene practices are associated with child stunting in**  
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## 1 ABSTRACT

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

6 **Setting:** Rural India

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

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

14 **Results:** The prevalence of stunting ranged from 25% to 50%. Compared with open defecation,  
15 household access to toilet facility was associated with a 23-44% reduced odds of stunting among  
16 children aged 6-23 months, after adjusting for all potential confounders [NFHS-3 (OR=0.71,  
17 95%CI:0.57-0.88); HUNGaMA (OR=0.77, 95%CI:0.70-0.85); CNSM (OR=0.56, 95%CI:0.35-  
18 0.88)]. Household access to improved water supply or piped water was not in itself associated  
19 with stunting. The caregiver's practices of washing hands with soap before food (OR=0.85,  
20 95%CI:0.65-0.94) or after defecation (OR=0.85, 95%CI:0.78-0.93) were protective against child  
21 stunting. However, the inverse association between personal hygiene practices and stunting

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3 1 existed only among households with access to toilet facility or piped water (all interaction terms,  
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5 2 P<0.05).  
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9 **Conclusion:** Improved conditions of sanitation and hygiene practices are associated with  
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11 4 reduced prevalence of stunting in rural India. Policies and programming aiming to address child  
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13 5 stunting should encompass WASH interventions, thus shifting the emphasis from nutrition  
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15 6 specific to nutrition sensitive programming. Future randomized trials are warranted to validate  
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17 7 the causal association.  
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22 8 **Trial Registration:** Not applicable.  
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## 1 ARTICLE SUMMARY

### 2 Strengths and Limitations of this Study

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

## 1 INTRODUCTION

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

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

20 Growing evidence suggests a link between child linear growth and household water,  
21 sanitation, and hygiene (WASH) practices.<sup>8</sup> It has been estimated that as much as 50% of child  
22 undernutrition may be attributable to poor WASH practices.<sup>9</sup> Ingestion of high quantities of fecal

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

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

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

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## 22 **METHODS**

## 1 Data

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

12 The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect  
13 district level data on the nutritional status of Indian children below five years of age.<sup>12</sup> The  
14 survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh,  
15 Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this,  
16 100 districts were those with the poorest indicators of child wellbeing in the country, and the  
17 remaining 12 districts were selected among those with some of the best indicators of child  
18 wellbeing for the purpose of within-state comparison. The selected areas represent about one-  
19 sixth of India's population and one-fifth of India's children under-five. A stratified cluster  
20 sampling was employed to identify a representative sample of 73,670 households from which a  
21 total of 109,903 children under-five were included in the survey. Information on child nutritional  
22 status was collected together with relevant maternal, household and environmental  
23 determinants.<sup>12</sup>



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

## 8 **Data Collection**

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

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

21 Anthropometric measurements were taken from the children and mothers following  
22 standard procedures.<sup>14</sup> Height was measured using a height/length board to the nearest 0.1 cm.

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

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

## 10 **Statistical Analysis**

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

16 Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-  
17 scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009  
18 software.<sup>15</sup> Maternal body mass index (BMI) was defined as weight divided by the square of  
19 height ( $\text{kg}/\text{m}^2$ ). In the analysis of data obtained from the NFHS and CNSM, sources of drinking  
20 water were classified into improved water sources including water piped into a dwelling, plot or  
21 yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and  
22 rainwater vs. unimproved water.<sup>16,17</sup> Improved sanitation facilities included flush toilet, piped

1 sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab,  
2 and composting toilet.<sup>16</sup> A comparison was also made between piped water vs. other sources of  
3 drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of  
4 drinking water only as hand pump and piped water and others and sanitation as defecating in the  
5 open vs. any toilet.<sup>12</sup>

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

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

19 Analyses were performed separately for children 0-5 and 6-23 months of age because the  
20 two groups of children have predominantly different feeding practices. Multiple logistic  
21 regression analyses were used to examine the association between the risk of stunting and  
22 WASH practices adjusting for potential confounders. Stunting was included as the dependent

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3 1 variable and household sanitation facilities, source of drinking water, and personal hygiene  
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6 2 practices as the independent variables, together with the potential confounding factors.  
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9 3 Confounding factors included major determinants of child stunting based on UNICEF's  
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11 4 conceptual framework<sup>17</sup>, which differed by child stunting status and were associated with each  
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13 5 WASH indicator in the bivariate analyses using  $\chi^2$  test ( $P < 0.05$ ). The interactions between  
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15 6 household sanitation facilities, source of drinking water, and personal hygiene were created to  
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17 7 examine the synergistic effects of WASH indicators on the risk of child stunting. The odds ratios  
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19 8 (OR) and corresponding 95% confidence intervals (CI) were estimated with statistical  
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21 9 significance defined as  $P < 0.05$ . All analyses were performed using STATA version 13.0 (Stat  
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23 10 Corp., College Station, TX, USA).  
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## 32 **RESULTS**

### 33 34 35 **NFHS-3**

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38 14 The mean ( $\pm$  standard error (SE)) age of children in the analysis was  $11.8 \pm 0.09$  months  
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40 15 and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15%  
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42 16 were reported to have had diarrhea in the past two weeks. The mean ( $\pm$  SE) age of the mothers of  
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44 17 under-twos was  $25.0 \pm 0.08$  years. More than half the mothers had no education and 41% had  
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46 18 short stature ( $<150$  cm). About 83% of the households had access to improved drinking water  
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48 19 sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation  
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50 20 facilities, whereas 77% had no toilet facility.  
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1 Household sanitation facility was a key predictor of stunting among children aged 6-23  
2 months. In a multivariate analysis, compared with open defecation, household access to toilet  
3 facility was associated with a 27% lower odds of being stunted, adjusting for all potential  
4 confounders (OR=0.73, 95% CI: 0.59-0.91) (Table 2). Household access to an improved  
5 drinking water source or piped water was not a predictor of child stunting. No interactions  
6 between household access to sanitation facilities and drinking water sources were observed (data  
7 not shown).

## 8 HUNGaMA

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

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

19 The mother/caregiver's hygiene practices appeared to predict the risk of child stunting. In  
20 the multivariate analysis, the caregiver's reported practice of washing their hands with soap after  
21 defecation was associated with a 15% reduced risk of stunting among children aged 6-23 months  
22 (OR=0.85, 95% CI: 0.78-0.93) (Table 3). Likewise, the caregiver's reported practice of washing

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3 1 their hands with soap before food was associated with a 15% lower odds of stunting among  
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6 2 children aged 6-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).  
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9 3 There was a significant interaction between mother/caregiver's hygiene practices and  
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11 4 household sanitation and drinking water conditions in their association with child stunting. The  
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13 5 protective effect of mother/caregiver's practice of washing their hands with soap before food  
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15 6 against child stunting existed only among households with access to piped water (OR=0.78, 95%  
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17 7 CI: 0.65-0.94 vs. OR=0.90, 95% CI: 0.79-1.03, interaction term  $P < 0.05$ ) (Table 4). In addition,  
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19 8 the inverse association between mother/caregiver's practices of washing their hands with soap  
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21 9 after defecation and stunting was stronger among households with access to toilet facility  
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23 10 (OR=0.73, 95% CI: 0.61-0.88 vs. OR=0.88, 95% CI: 0.80-0.98) (data not shown).  
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## 28 11 **CNSM**

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32 12 The mean ( $\pm$  SE) age of the children was  $11.0 \pm 0.24$  months and about 56% were male  
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34 13 (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had  
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36 14 had diarrhea in the past two weeks. The mean ( $\pm$  SE) age of the mothers was  $23.6 \pm 0.12$  years  
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38 15 and 14% had no education. Approximately 87% of the households had improved sources of  
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40 16 drinking water, and about 30% had access to piped water. Twenty seven percent of the  
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42 17 households had access to improved sanitation facilities.  
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47 18 In multivariate analysis, household access to toilet facility was associated with a 45%  
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49 19 reduced odds of being stunted among children aged 6-23 months, after adjusting for all potential  
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51 20 confounders (OR=0.55, 95% CI: 0.35-0.86) (Table 5). Household access to an improved water  
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53 21 source and piped water did not predict child stunting.  
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## 1 DISCUSSION

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

10 Overall, our results of the inverse association between stunting and household access to  
11 toilet facility tend to confirm the findings of previous non-randomized research carried out in  
12 different parts of the world.<sup>19-22</sup> Using data from multiple countries in Africa, Asia and Latin  
13 America, Esrey showed that improved sanitation conditions were associated with a 0.06-0.62 and  
14 0.26-0.65 increment in HAZ in children living in rural and urban areas, respectively.<sup>19</sup> Similarly,  
15 in a cross-sectional analysis of 171 Demographic and Health Surveys conducted worldwide  
16 (India not included), access to improved sanitation was shown to be associated with a 27% lower  
17 risk of child stunting.<sup>20</sup> Recently, in an ecological analysis, Spears et al. found that differences in  
18 open defecation could statistically account for 35-55% of the average difference in stunting  
19 between districts in India.<sup>11</sup> The findings of our analysis based on three large survey datasets  
20 collected at the household level, reinforce the notion that poor sanitation may indeed greatly  
21 increase the likelihood of child stunting in rural India where open defecation is pervasive and the  
22 burden of child stunting is massive.

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

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

21 Our results indicated no significant interactions between household access to improved  
22 water and sanitation. Overall, there is mixed evidence on the synergistic effects of water and  
23 sanitation on child linear growth.<sup>19,21,25</sup> In a cross-sectional, multi-country study, Esrey noted that



1 the positive association between improved sanitation and child linear growth was enhanced by  
2 household access to an improved water supply.<sup>19</sup> Similarly, in a longitudinal study in Peru,  
3 Checkley et al found that the positive association between improved water sources and child  
4 linear growth existed only when it was accompanied by improved sanitation and water storage  
5 practices.<sup>21</sup> In contrast, no synergistic effects of water and sanitation were found in a large  
6 prospective cohort study in Sudan.<sup>25</sup> Therefore, further research is required to determine if  
7 improved household water supply and its handling and storage, and sanitation conditions have  
8 additive or synergistic effects on child linear growth.

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

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3 1 The limitations to this study need to be considered. We analyzed cross-sectional data, so  
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5 2 a causal association between improved WASH practices and reduced likelihood of stunting  
6  
7 3 cannot be established. The mother/caregiver's personal hygiene practices were determined based  
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9 4 on self-reported data which may reflect on improved knowledge as opposed to actual practice  
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11 5 and may lead to validity problems. While the NFHS and CNSM used similar classifications for  
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13 6 the source of drinking water and sanitation facilities, the HUNGaMA survey used a different  
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15 7 categorization. Thus, households having access to an improved source of drinking water and  
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17 8 sanitation facilities could not be determined using the HUNGaMA data. Data on personal  
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19 9 hygiene was not collected from the NFHS and only the proportion of mothers/caregivers  
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21 10 reporting that they washed their hands with soap was determined in the CNSM. Although an  
22  
23 11 important variable to consider, the birth weight of children was not included in the multivariate  
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25 12 analysis, as the information was collected from a small proportion of the sample. However, we  
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27 13 did control for maternal height, BMI, dietary intake and other relevant factors which are strong  
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29 14 predictors of child birth weight. Despite these limitations, assessing the WASH predictors of  
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31 15 child stunting using large representative survey datasets coming from the local context is a  
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33 16 critical step in strengthening the relevant evidence base and developing multi-sectoral  
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35 17 interventions for optimal child growth.

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39 18 In conclusion, this analysis revealed that household sanitation and the  
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41 19 mother's/caregiver's personal hygiene practices are strong predictors of child stunting in India.  
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43 20 This reinforces the growing evidence of the effects of WASH practices on child linear growth.  
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45 21 Large-scale randomized effectiveness trials of toilet provision (and use) and handwashing at  
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47 22 critical times, that include environmental enteropathy and child growth as outcomes, are  
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49 23 warranted. However, this suggests the need for different programmatic responses by  
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1 governments and development partners. Optimizing nutrition outcomes for young children now  
2 requires a framework that is broader than nutrition specific interventions alone. India's  
3 vulnerable children and mothers need to benefit from additional, well targeted nutrition sensitive  
4 interventions especially leading up to and during the first one thousand days. Children and  
5 mothers need basic WASH provision and behaviors to survive, grow and thrive.

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## 11 **CONTRIBUTORSHIP STATEMENT**

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

## 15 **COMPETING INTERESTS**

16 None

## 17 **DATA SHARING STATEMENT**

18 N/A

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## 1 REFERENCES

1. De Onis M, Dewey KG, Borghi E et al. The World Health Organization's global target for reducing child stunting by 2025: rationale and proposed actions. *Matern Child Nutr* 2013; 9 Suppl 2: 6-26.
2. International Institute for Population Sciences (IIPS) and Macro International. National Family Health Survey (NFHS-3) 2005-6. Mumbai: IIPS; 2007.
3. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; 382: 427-51.
4. Victora CG, Adair L, Fall C et al. Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008; 371: 340-57.
5. Ruel MT. The natural history of growth failure: importance of intrauterine and postnatal periods. In: Martorell R, Haschke F, eds. *Nutrition and Growth*. Philadelphia, USA: Lippincott Williams and Wilkins, 2001: 123-158.
6. Dewey KG, Adu-Afarwuah S. Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Matern Child Nutr* 2008; 4 (Suppl 1): 24-85.
7. Victora CG, de Onis M, Hallal PC, et al. Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics* 2010; 125: e473-80.
8. Ngure FM, Reid BM, Humphrey JH, et al. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Ann NY Acad Sci* 2014; 1308: 118-28.
9. World Bank. Environmental health and child survival: epidemiology, economics, experience. Washington, DC: World Bank; 2008.

- 1  
2  
3  
4 10. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact?  
5  
6 2 *Matern Child Nutr* 2011; 7 Suppl 3: 129-42.  
7  
8 3 11. Spears D, Ghosh A, Cumming O. Open defecation and childhood stunting in India: An  
9  
10 4 ecological analysis of new data from 112 districts. *Plos One* 2013; 8: e73784.  
11  
12 5 12. The Naandi Foundation. The hunger and malnutrition survey report – 2011.  
13  
14 6 <http://naandi.org/HungamaBKDec11LR.pdf> (Accessed February 16, 2014).  
15  
16 7 13. International Institute for Population Sciences (IIPS). Comprehensive nutrition survey in  
17  
18 8 Maharashtra 2012: IIPS; 2012.  
19  
20 9 14. Gibson RS. Principles of Nutritional Assessment. New York, NY: Oxford University  
21  
22 10 Press, 1990.  
23  
24 11 15. World Health Organization. WHO child growth standards: methods and development.  
25  
26 12 Geneva, Switzerland: WHO, 2006.  
27  
28 13 16. World Health Organization and United Nations Children’s Fund Joint Monitoring  
29  
30 14 Programme for Water Supply and Sanitation. Types of drinking water and sanitation.  
31  
32 15 <http://www.wssinfo.org/definitions-methods/watsan-categories/> (Accessed February 17,  
33  
34 16 2014).  
35  
36 17 17. World Health Organization. Drinking Water.  
37  
38 18 [http://www.who.int/water\\_sanitation\\_health/monitoring/water.pdf](http://www.who.int/water_sanitation_health/monitoring/water.pdf) (Accessed February 17,  
39  
40 19 2014).  
41  
42 20 18. De Pee S, Bloem MW. Assessing and communicating the impact of nutrition and health  
43  
44 21 programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries.  
45  
46 22 Totowa, NJ: Human Press, 2001: 483-506.  
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3 1 19. Esrey SA. Water, waste, and well-being: a multi-country study. *Am J Epidemiol*. 1996;  
4  
5 2 143: 608-23.  
6  
7  
8 3 20. Fink G, Gunther I, Hill K. The effect of water and sanitation on child health: evidence  
9  
10 4 from the demographic and health surveys 1986-2007. *Int J Epidemiol* 2011; 40: 1196-  
11  
12 5 1204.  
13  
14  
15 6 21. Checkley W, Gilman RH, Black RE, et al. Effect of water and sanitation on childhood  
16  
17 7 health in a poor Peruvian peri-urban community. *Lancet* 2004; 363: 112-8.  
18  
19  
20 8 22. Lin A, Arnold BF, Afreen S et al. Household environmental conditions are associated  
21  
22 9 with enteropathy and impaired growth in rural Bangladesh. *Am J Trop Med Hyg* 2013; 89:  
23  
24 10 130-7.  
25  
26  
27 11 23. Prüss-üstün A, Bos R, Gore F, et al. Safe water, better health: costs, benefits and  
28  
29 12 sustainability of interventions to protect and promote health. World Health Organization,  
30  
31 13 Geneva, 2008.  
32  
33  
34 14 24. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing.  
35  
36 15 *Lancet* 2009; 374:1032-5.  
37  
38  
39 16 25. Merchant AT, Jones C, Kiure A, et al. Water and sanitation associated with improved  
40  
41 17 child growth. *Eur J Clin Nutr* 2003; 57: 1562-8.  
42  
43  
44 18 26. Meshram II, Arlappa N, Balakrishna N et al. Influence of feeding practices and  
45  
46 19 associated factors on the nutritional status of infants in rural areas of Madhya Pradesh  
47  
48 20 State, India. *Asia Pac J Public Health* 2013 May 10.  
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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS) <sup>1</sup>	Hunger and Malnutrition Survey (HUNGaMA) <sup>2</sup>	Comprehensive Nutrition Survey in Maharashtra (CNSM) <sup>3</sup>
N	8,949	34,639	1,282
<b><i>Child Characteristics</i></b>			
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 (%) <sup>*</sup>	41	50	25
Wasted weight-for-height z-score, <-2 (%) <sup>*</sup>	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

<b><i>Maternal Characteristics</i></b>			
Age, year (mean $\pm$ SE)	25.0 $\pm$ 0.08	26.8 $\pm$ 0.04	23.6 $\pm$ 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 <sup>2</sup> (%)	44	-	40
<b><i>Household Characteristics</i></b>			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
$\geq 7$	47	50	41
Place of defecation			
Improved sanitation facility <sup>†</sup>	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source <sup>‡</sup>	74	-	57

1 <sup>†</sup> 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)



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4 1 <sup>2</sup> Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209),  
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6 2 breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438),  
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8 3 household size (n=257), source of drinking water (n=3395)  
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11 4 <sup>3</sup> Missing values existing in the CNSM sample, including the following: maternal age (n=10),  
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13 5 maternal education (n=10), maternal height (n=12), maternal BMI (n=14)  
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17 6 \* Estimated by using 2006 WHO growth reference  
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20 7 † Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit  
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22 8 latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet  
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25 9 ‡ Improved water sources other than piped water included public tap or standpipe, tube well or  
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27 10 borehole, protected dug well, protected spring, and rainwater  
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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 <sup>†</sup>						
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	0.99
					(0.85-0.99)	(0.91-1.07)

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

For peer review only

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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 <sup>†</sup>						
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 <sup>†</sup>	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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# BMJ Open

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

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6 2 **rural India: A cross sectional analysis of surveys**  
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12 4 Jee Hyun Rah<sup>1</sup>, Aidan A. Cronin<sup>2</sup>, Bhupendra Badgaiyan<sup>1</sup>, Victor M. Aguayo<sup>3</sup>, Suzanne Joan  
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## 1 ABSTRACT

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

6 **Setting:** India

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

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

13 **Results:** The prevalence of stunting ranged from 25% to 50%. Compared with open defecation,  
14 household access to toilet facility was associated with a 16-39% reduced odds of stunting among  
15 children aged 0-23 months, after adjusting for all potential confounders [NFHS-3 (OR=0.84,  
16 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-  
17 0.85)]. Household access to improved water supply or piped water was not in itself associated  
18 with stunting. The caregiver's self-reported practices of washing hands with soap before meals  
19 (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely  
20 associated with child stunting. However, the inverse association between reported personal  
21 hygiene practices and stunting was stronger among households with access to toilet facility or  
22 piped water (all interaction terms,  $P<0.05$ ).

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

### 7 **Article Summary**

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

### 13 *Strengths and limitations of this study*

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

## 1 INTRODUCTION

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

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

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

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3 1 of fecal bacteria from both human and animal sources by infants and young children through  
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5 2 mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry  
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8 3 feces are common in many rural low income environments. This leads to intestinal infections  
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11 4 which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption,  
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13 5 and increasing nutrient losses.<sup>10</sup>

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16 6 In India, approximately 53% of households and 624 million people defecate in the open.<sup>2</sup>  
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18 7 Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). Recently, an  
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21 8 ecological analysis of data from 112 rural districts of India demonstrated a strong association  
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23 9 between the prevalence of open defecation and stunting, after adjusting for potential  
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26 10 confounders.<sup>11</sup> This analysis added to a growing body of suggestive evidence on the effect of  
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28 11 open defecation on child linear growth. However, further evidence is needed to corroborate the  
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31 12 findings, as ecological studies are prone to ecological fallacy and other errors, and are often used  
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33 13 to generate hypotheses for additional investigation employing more rigorous methods.<sup>11</sup>

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36 14 Strengthening the evidence base on the linkages between child linear growth and WASH  
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38 15 practices in Indian population will help support informed development of policy and guidelines  
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41 16 that inform optimal programmatic strategies, actions, and monitoring. This study therefore  
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43 17 sought to determine whether improved WASH conditions are associated with reduced child  
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46 18 stunting in rural India. Specifically, the analysis aimed to determine the association between  
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48 19 stunting and household access to sanitation facilities, water supply, and personal hygiene  
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51 20 practices using multiple logistic regression analyses.

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## 54 55 56 22 **METHODS**

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## 1 Data

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

12 The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect  
13 district level data on the nutritional status of Indian children below five years of age.<sup>12</sup> The  
14 survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh,  
15 Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this,  
16 100 districts were those with the poorest indicators of child wellbeing in the country, and the  
17 remaining 12 districts were selected among those with some of the best indicators of child  
18 wellbeing for the purpose of within-state comparison. The selected areas represent about one-  
19 sixth of India's population and one-fifth of India's children under-five. A stratified cluster  
20 sampling was employed to identify a representative sample of 73,670 households from which a  
21 total of 109,903 children under-five were included in the survey. Information on child nutritional  
22 status was collected together with relevant maternal, household and environmental  
23 determinants.<sup>12</sup>

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

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

#### 13 14 Data Collection

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

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

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

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

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

#### 16 Statistical Analysis

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

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

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

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

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3 1 maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5  
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5 2 kg/m<sup>2</sup>); and household composition (2-6, ≥7).  
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9 3 Although children 0-5 and 6-23 months of age have predominantly different feeding  
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11 4 practices, analyses for the two age groups were merged, because age was not a significant effect  
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13 5 modifier for indicators examined in predicting stunting. Multiple logistic regression analyses  
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15 6 were used to examine the association between the risk of stunting and WASH practices adjusting  
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17 7 for potential confounders. Stunting was included as the dependent variable and household  
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19 8 sanitation facilities, source of drinking water, and reported personal hygiene practices as the  
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21 9 independent variables, together with the potential confounding factors.  
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26 10 Confounding factors included the major determinants of child stunting based on  
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28 11 UNICEF's conceptual framework<sup>17</sup>. These were associated with each WASH indicator in the  
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30 12 bivariate analyses using  $\chi^2$  test ( $P < 0.05$ ). The interactions between household sanitation  
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32 13 facilities, source of drinking water, and personal hygiene were created to examine the synergistic  
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34 14 effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and  
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36 15 corresponding 95% confidence intervals (CI) were estimated with statistical significance defined  
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38 16 as  $P < 0.05$ . All analyses were performed using STATA version 13.0 (Stat Corp., College Station,  
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## 49 **RESULTS**

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

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

#### 15 HUNGaMA

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

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

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

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

10 There was a significant interaction between mother/caregiver's reported hygiene  
11 practices and household sanitation and drinking water conditions in their association with child  
12 stunting. The protective effect of mother/caregiver's reported practice of washing their hands  
13 with soap before food against child stunting was stronger among households with access to piped  
14 water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term  $P < 0.05$ )  
15 (Table 4). In addition, the inverse association between mother/caregiver's reported practices of  
16 washing their hands with soap after defecation and stunting was stronger among households with  
17 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  
18 shown).

19 CNSM

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

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

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

## 9 DISCUSSION

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

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



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

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

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

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

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

17 Few studies have explored the association between the mother/caregiver's personal  
18 hygiene practices and child stunting in India. We found that mothers/caregivers who reported  
19 washing their hands with soap either before meal or after defecation had a lower association with  
20 stunted children. This corresponds with the findings from a community-based cross-sectional  
21 study conducted in the rural State of Madhya Pradesh in which maternal hygiene practices were  
22 significantly associated with child undernutrition.<sup>26</sup> Our findings also suggest that the protective  
23 effects of mother/caregiver's reported personal hygiene practices were stronger when it was

1 accompanied by an improved household access to piped water and toilet facility. Clearly, efforts  
2 to improve hand washing practices of both mothers/caregivers and children themselves are  
3 essential to prevent diarrhea and other infections among children, which may in turn contribute  
4 to the reduction of stunting. These efforts should be accompanied by concrete actions to enhance  
5 household water and sanitation conditions. Further research is required to examine the impact of  
6 improved personal hygiene practices on child growth, especially as part of a multi-sectoral and  
7 convergent approach to effectively address child stunting.

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

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3 1 limitations, assessing the WASH association with child stunting using large representative  
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5 2 survey datasets coming from the local context is a critical step in strengthening the relevant  
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8 3 evidence base and developing multi-sectoral interventions for optimal child growth.  
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11 4 In conclusion, this analysis revealed that household sanitation and the  
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13 5 mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting  
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15 6 in India. This reinforces the growing evidence of the effects of WASH practices on child linear  
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17 7 growth. Large-scale randomized effectiveness trials of toilet provision (and use) and reported  
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19 8 handwashing at critical times, that include environmental enteropathy and child growth as  
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21 9 outcomes, are warranted to go beyond association in order to estimate causality. However, this  
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23 10 suggests the need for different programmatic responses by governments and development  
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25 11 partners. Optimizing nutrition outcomes for young children now requires a framework that is  
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27 12 broader than nutrition specific interventions alone. India's vulnerable children and mothers need  
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29 13 to benefit from additional, well targeted nutrition sensitive interventions especially leading up to  
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31 14 and during the first one thousand days. Children and mothers need basic WASH provision and  
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33 15 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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## REFERENCES

1. De Onis M, Dewey KG, Borghi E et al. The World Health Organization's global target for reducing child stunting by 2025: rationale and proposed actions. *Matern Child Nutr* 2013; 9 Supple 2: 6-26.
2. International Institute for Population Sciences (IIPS) and Macro International. National Family Health Survey (NFHS-3) 2005-6. Mumbai: IIPS; 2007.
3. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; 382: 427-51.
4. Victora CG, Adair L, Fall C et al. Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008; 371: 340-57.
5. Ruel MT. The natural history of growth failure: importance of intrauterine and postnatal periods. In: Martorell R, Haschke F, eds. *Nutrition and Growth*. Philadelphia, USA: Lippincott Williams and Wilkins, 2001: 123-158.
6. Dewey KG, Adu-Afarwuah S. Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Matern Child Nutr* 2008; 4 (Suppl 1): 24-85.
7. Victora CG, de Onis M, Hallal PC, et al. Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics* 2010; 125: e473-80.
8. Ngure FM, Reid BM, Humphrey JH, et al. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Ann NY Acad Sci* 2014; 1308: 118-28.

- 1  
2  
3 1 9. World Bank. Environmental health and child survival: epidemiology, economics,  
4  
5  
6 2 experience. Washington, DC: World Bank; 2008.
- 7  
8 3 10. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact?  
9  
10 4 *Matern Child Nutr* 2011; 7 Suppl 3: 129-42.
- 11  
12 5 11. Spears D, Ghosh A, Cumming O. Open defecation and childhood stunting in India: An  
13  
14 6 ecological analysis of new data from 112 districts. *Plos One* 2013; 8: e73784.
- 15  
16 7 12. The Naandi Foundation. The hunger and malnutrition survey report – 2011.  
17  
18 8 <http://naandi.org/HungamaBKDec11LR.pdf> (Accessed February 16, 2014).
- 19  
20 9 13. International Institute for Population Sciences (IIPS). Comprehensive nutrition survey in  
21  
22 10 Maharashtra 2012: IIPS; 2012.
- 23  
24 11 14. Gibson RS. Principles of Nutritional Assessment. New York, NY: Oxford University  
25  
26 12 Press, 1990.
- 27  
28 13 15. World Health Organization. WHO child growth standards: methods and development.  
29  
30 14 Geneva, Switzerland: WHO, 2006.
- 31  
32 15 16. World Health Organization and United Nations Children’s Fund Joint Monitoring  
33  
34 16 Programme for Water Supply and Sanitation. Types of drinking water and sanitation.  
35  
36 17 <http://www.wssinfo.org/definitions-methods/watsan-categories/> (Accessed February 17,  
37  
38 18 2014).
- 39  
40 19 17. World Health Organization. Drinking Water.  
41  
42 20 [http://www.who.int/water\\_sanitation\\_health/monitoring/water.pdf](http://www.who.int/water_sanitation_health/monitoring/water.pdf) (Accessed February 17,  
43  
44 21 2014).
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2  
3 1 18. De Pee S, Bloem MW. Assessing and communicating the impact of nutrition and health  
4  
5 2 programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries.  
6  
7 3 Totowa, NJ: Human Press, 2001: 483-506.  
8  
9  
10 4 19. Esrey SA. Water, waste, and well-being: a multi-country study. *Am J Epidemiol*. 1996;  
11  
12 5 143: 608-23.  
13  
14 6 20. Fink G, Gunther I, Hill K. The effect of water and sanitation on child health: evidence  
15  
16 7 from the demographic and health surveys 1986-2007. *Int J Epidemiol* 2011; 40: 1196-  
17  
18 8 1204.  
19  
20 9 21. Checkley W, Gilman RH, Black RE, et al. Effect of water and sanitation on childhood  
21  
22 10 health in a poor Peruvian peri-urban community. *Lancet* 2004; 363: 112-8.  
23  
24 11 22. Lin A, Arnold BF, Afreen S et al. Household environmental conditions are associated  
25  
26 12 with enteropathy and impaired growth in rural Bangladesh. *Am J Trop Med Hyg* 2013; 89:  
27  
28 13 130-7.  
29  
30 14 23. Prüss-üstün A, Bos R, Gore F, et al. Safe water, better health: costs, benefits and  
31  
32 15 sustainability of interventions to protect and promote health. World Health Organization,  
33  
34 16 Geneva, 2008.  
35  
36 17 24. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing.  
37  
38 18 *Lancet* 2009; 374:1032-5.  
39  
40 19 25. Merchant AT, Jones C, Kiure A, et al. Water and sanitation associated with improved  
41  
42 20 child growth. *Eur J Clin Nutr* 2003; 57: 1562-8.  
43  
44 21 26. Meshram II, Arlappa N, Balakrishna N et al. Influence of feeding practices and  
45  
46 22 associated factors on the nutritional status of infants in rural areas of Madhya Pradesh  
47  
48 23 State, India. *Asia Pac J Public Health* 2013 May 10.  
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10 3 Table 1. Characteristics of children 0-23 months included in the sample  
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	National Family Health Survey (NFHS) <sup>1</sup>	Hunger and Malnutrition Survey (HUNGaMA) <sup>2</sup>	Comprehensive Nutrition Survey in Maharashtra (CNSM) <sup>3</sup>
N	10,364	34,639	1,282
<b><i>Child Characteristics</i></b>			
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 (%) <sup>*</sup>	41	50	25
Wasted weight-for-height z-score, <-2 (%) <sup>*</sup>	27	16	17
Had diarrhea at least once in the past week(s) (%)	15	41	30

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Breastfeeding started within 1 hour of birth (%)	22	42	67
<b><i>Maternal Characteristics</i></b>			
Age, year (mean $\pm$ SE)	25.0 $\pm$ 0.08	26.8 $\pm$ 0.04	23.6 $\pm$ 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 <sup>2</sup> (%)	44	-	40
<b><i>Household Characteristics</i></b>			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
$\geq$ 7	47	50	41
Place of defecation			
Improved sanitation facility <sup>†</sup>	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			

Pipe water	9	24	30
Other improved source <sup>‡</sup>	74	-	57

<sup>1</sup> 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)

<sup>2</sup> 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)

<sup>3</sup> 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

<sup>†</sup> 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

<sup>‡</sup> 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<sup>§</sup>

	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

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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<sup>§</sup>

	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)	
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† 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)

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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<sup>§</sup>

	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 <sup>†</sup>						
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	

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		(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)

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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<sup>§</sup>

	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 <sup>†</sup>	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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3 1 **Household sanitation and personal hygiene practices are associated with child stunting in**  
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6 2 **rural India: A cross sectional analysis of surveys**  
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12 4 Jee Hyun Rah<sup>1</sup>, Aidan A. Cronin<sup>2</sup>, Bhupendra Badgaiyan<sup>1</sup>, Victor M. Aguayo<sup>3</sup>, Suzanne Joan  
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## 1 ABSTRACT

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

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

11 **Findings:** The prevalence of stunting ranged from 25% to 50%. Compared with open defecation,  
12 household access to toilet facility was associated with a 16-39% reduced odds of stunting among  
13 children aged 0-23 months, after adjusting for all potential confounders [NFHS-3 (OR=0.84,  
14 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM (OR=0.61, 95%CI:0.44-  
15 0.85)]. Household access to improved water supply or piped water was not in itself associated  
16 with stunting. The caregiver's self-reported practices of washing hands with soap before meals  
17 (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86, 95%CI:0.80-0.93) were inversely  
18 associated with child stunting. However, the inverse association between **reported** personal  
19 hygiene practices and stunting was stronger among households with access to toilet facility or  
20 piped water (all interaction terms,  $P<0.05$ ).

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

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

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## 1 INTRODUCTION

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

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

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

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

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

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

22



## 1 METHODS

### 2 Data

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

13 The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect  
14 district level data on the nutritional status of Indian children below five years of age.<sup>12</sup> The  
15 survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh,  
16 Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this,  
17 100 districts were those with the poorest indicators of child wellbeing in the country, and the  
18 remaining 12 districts were selected among those with some of the best indicators of child  
19 wellbeing for the purpose of within-state comparison. The selected areas represent about one-  
20 sixth of India's population and one-fifth of India's children under-five. A stratified cluster  
21 sampling was employed to identify a representative sample of 73,670 households from which a  
22 total of 109,903 children under-five were included in the survey. Information on child nutritional

1 status was collected together with relevant maternal, household and environmental  
2 determinants.<sup>12</sup>

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

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

## 16 Data Collection

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

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

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

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

### 19 **Statistical Analysis**

20 This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural  
21 India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than  
22 one child under-two was assessed in a given household, only the youngest child from each

1 household was included in the analysis. All analyses were weighted according to the population  
2 size and adjusted for the multistage cluster design of the surveys.

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

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

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

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

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

## 1 RESULTS

### 2 NFHS-3

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

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

### 17 HUNGaMA

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

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

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

12 There was a significant interaction between mother/caregiver's **reported hygiene**  
13 **practices** and household sanitation and drinking water conditions in their association with child  
14 stunting. The protective effect of mother/caregiver's reported practice of washing their hands  
15 with soap before food against child stunting was stronger among households with access to piped  
16 water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term  $P < 0.05$ )  
17 (Table 4). In addition, the inverse association between mother/caregiver's reported practices of  
18 washing their hands with soap after defecation and stunting was stronger among households with  
19 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  
20 shown).

21 **CNSM**

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

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

## 12 DISCUSSION

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

21 Overall, our results of the inverse association between stunting and household access to  
22 toilet facility tend to confirm the findings of previous non-randomized research carried out in



1 different parts of the world.<sup>19-22</sup> Using data from multiple countries in Africa, Asia and Latin  
2 America, Esrey showed that improved sanitation was associated with a 0.06-0.62 and 0.26-0.65  
3 increment in HAZ in children living in rural and urban areas, respectively.<sup>19</sup> Similarly, in a cross-  
4 sectional analysis of 171 Demographic and Health Surveys conducted worldwide (India not  
5 included), access to improved sanitation was shown to be associated with a 27% lower risk of  
6 child stunting.<sup>20</sup> Recently, in an ecological analysis, Spears et al. found that differences in open  
7 defecation could statistically account for 35-55% of the average difference in stunting between  
8 districts in India.<sup>11</sup> The findings of our analysis based on three large survey datasets collected at  
9 the household level, reinforce the notion that poor sanitation may indeed greatly increase the  
10 likelihood of child stunting in rural India where open defecation is pervasive and the burden of  
11 child stunting is massive.

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

21 Household access to an improved source of drinking water or piped water was not  
22 associated with child stunting. This corroborates earlier findings from non-randomized studies  
23 which indicate that the potential effects of improved water supply on child linear growth tend to

1 be much smaller than those of improved sanitation.<sup>19</sup> This lack of association in our analysis may  
2 be explained by the current predominant use of an improved drinking water source in India,  
3 reflecting source only, not on water safety. The NFHS and CNSM showed that ~83% and ~74%  
4 of the households in rural areas, respectively, have access to improved drinking water sources.<sup>2,13</sup>  
5 About a quarter of households reported having water piped into the dwelling, plot or yard.<sup>2,13</sup>  
6 Although household access to piped water was significantly associated with stunting in bivariate  
7 analyses, it was not a predictor of stunting in multivariate analysis adjusting for all potential  
8 confounders.

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

20 Few studies have explored the association between the mother/caregiver's personal  
21 hygiene practices and child stunting in India. We found that mothers/caregivers who reported  
22 washing their hands with soap either before meal or after defecation **had a lower association**  
23 **with** stunted children. This corresponds with the findings from a community-based cross-

1 sectional study conducted in the rural State of Madhya Pradesh in which maternal hygiene  
2 practices were significantly associated with child undernutrition.<sup>26</sup> Our findings also suggest that  
3 the protective effects of **mother/caregiver's reported personal hygiene practices** were  
4 stronger when it was accompanied by an improved household access to piped water and toilet  
5 facility. Clearly, efforts to improve **hand washing practices** of both mothers/caregivers and  
6 children themselves are essential to prevent diarrhea and other infections among children, which  
7 may in turn contribute to the reduction of stunting. These efforts should be accompanied by  
8 concrete actions to enhance household water and sanitation conditions. Further research is  
9 required to examine the impact of improved personal hygiene practices on child growth,  
10 especially as part of a multi-sectoral and convergent approach to effectively address child  
11 stunting.

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

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

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

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For peer review only

## 1 REFERENCES

- 1 1. De Onis M, Dewey KG, Borghi E et al. The World Health Organization's global target  
2 for reducing child stunting by 2025: rationale and proposed actions. *Matern Child Nutr*  
3 2013; 9 Suppl 2: 6-26.
- 4 2. International Institute for Population Sciences (IIPS) and Macro International. National  
5 Family Health Survey (NFHS-3) 2005-6. Mumbai: IIPS; 2007.
- 6 3. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and  
7 overweight in low-income and middle-income countries. *Lancet* 2013; 382: 427-51.
- 8 4. Victora CG, Adair L, Fall C et al. Maternal and child undernutrition: consequences for  
9 adult health and human capital. *Lancet* 2008; 371: 340-57.
- 10 5. Ruel MT. The natural history of growth failure: importance of intrauterine and postnatal  
11 periods. In: Martorell R, Haschke F, eds. *Nutrition and Growth*. Philadelphia, USA:  
12 Lippincott Williams and Wilkins, 2001: 123-158.
- 13 6. Dewey KG, Adu-Afarwuah S. Systematic review of the efficacy and effectiveness of  
14 complementary feeding interventions in developing countries. *Matern Child Nutr* 2008; 4  
15 (Suppl 1): 24-85.
- 16 7. Victora CG, de Onis M, Hallal PC, et al. Worldwide timing of growth faltering: revisiting  
17 implications for interventions. *Pediatrics* 2010; 125: e473-80.
- 18 8. Ngure FM, Reid BM, Humphrey JH, et al. Water, sanitation, and hygiene (WASH),  
19 environmental enteropathy, nutrition, and early child development: making the links. *Ann*  
20 *NY Acad Sci* 2014; 1308: 118-28.
- 21 9. World Bank. *Environmental health and child survival: epidemiology, economics,*  
22 *experience*. Washington, DC: World Bank; 2008.

- 1  
2  
3  
4 10. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact?  
5  
6 2 *Matern Child Nutr* 2011; 7 Suppl 3: 129-42.  
7  
8  
9 3 11. Spears D, Ghosh A, Cumming O. Open defecation and childhood stunting in India: An  
10  
11 4 ecological analysis of new data from 112 districts. *Plos One* 2013; 8: e73784.  
12  
13 5 12. The Naandi Foundation. The hunger and malnutrition survey report – 2011.  
14  
15 6 <http://naandi.org/HungamaBKDec11LR.pdf> (Accessed February 16, 2014).  
16  
17  
18 7 13. International Institute for Population Sciences (IIPS). Comprehensive nutrition survey in  
19  
20 8 Maharashtra 2012: IIPS; 2012.  
21  
22 9 14. Gibson RS. Principles of Nutritional Assessment. New York, NY: Oxford University  
23  
24 10 Press, 1990.  
25  
26  
27 11 15. World Health Organization. WHO child growth standards: methods and development.  
28  
29 12 Geneva, Switzerland: WHO, 2006.  
30  
31  
32 13 16. World Health Organization and United Nations Children’s Fund Joint Monitoring  
33  
34 14 Programme for Water Supply and Sanitation. Types of drinking water and sanitation.  
35  
36 15 <http://www.wssinfo.org/definitions-methods/watsan-categories/> (Accessed February 17,  
37  
38 16 2014).  
39  
40  
41 17 17. World Health Organization. Drinking Water.  
42  
43 18 [http://www.who.int/water\\_sanitation\\_health/monitoring/water.pdf](http://www.who.int/water_sanitation_health/monitoring/water.pdf) (Accessed February 17,  
44  
45 19 2014).  
46  
47  
48 20 18. De Pee S, Bloem MW. Assessing and communicating the impact of nutrition and health  
49  
50 21 programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries.  
51  
52 22 Totowa, NJ: Human Press, 2001: 483-506.  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 1 19. Esrey SA. Water, waste, and well-being: a multi-country study. *Am J Epidemiol*. 1996;  
4  
5 2 143: 608-23.  
6  
7  
8 3 20. Fink G, Gunther I, Hill K. The effect of water and sanitation on child health: evidence  
9  
10 4 from the demographic and health surveys 1986-2007. *Int J Epidemiol* 2011; 40: 1196-  
11  
12 1204.  
13  
14 5  
15 6 21. Checkley W, Gilman RH, Black RE, et al. Effect of water and sanitation on childhood  
16  
17 7 health in a poor Peruvian peri-urban community. *Lancet* 2004; 363: 112-8.  
18  
19  
20 8 22. Lin A, Arnold BF, Afreen S et al. Household environmental conditions are associated  
21  
22 9 with enteropathy and impaired growth in rural Bangladesh. *Am J Trop Med Hyg* 2013; 89:  
23  
24 10 130-7.  
25  
26  
27 11 23. Prüss-üstün A, Bos R, Gore F, et al. Safe water, better health: costs, benefits and  
28  
29 12 sustainability of interventions to protect and promote health. World Health Organization,  
30  
31 13 Geneva, 2008.  
32  
33  
34 14 24. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing.  
35  
36 15 *Lancet* 2009; 374:1032-5.  
37  
38  
39 16 25. Merchant AT, Jones C, Kiure A, et al. Water and sanitation associated with improved  
40  
41 17 child growth. *Eur J Clin Nutr* 2003; 57: 1562-8.  
42  
43  
44 18 26. Meshram II, Arlappa N, Balakrishna N et al. Influence of feeding practices and  
45  
46 19 associated factors on the nutritional status of infants in rural areas of Madhya Pradesh  
47  
48 20 State, India. *Asia Pac J Public Health* 2013 May 10.  
49  
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52 21  
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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS) <sup>1</sup>	Hunger and Malnutrition Survey (HUNGaMA) <sup>2</sup>	Comprehensive Nutrition Survey in Maharashtra (CNSM) <sup>3</sup>
N	10,364	34,639	1,282
<b><i>Child Characteristics</i></b>			
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 (%) <sup>*</sup>	41	50	25
Wasted weight-for-height z-score, <-2 (%) <sup>*</sup>	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

<b><i>Maternal Characteristics</i></b>			
Age, year (mean $\pm$ SE)	25.0 $\pm$ 0.08	26.8 $\pm$ 0.04	23.6 $\pm$ 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 <sup>2</sup> (%)	44	-	40
<b><i>Household Characteristics</i></b>			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
$\geq 7$	47	50	41
Place of defecation			
Improved sanitation facility <sup>†</sup>	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source <sup>‡</sup>	74	-	57

1 <sup>†</sup> 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)

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4 1 <sup>2</sup> Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209),  
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6 2 breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438),  
7  
8 3 household size (n=257), source of drinking water (n=3395)  
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11 4 <sup>3</sup> Missing values existing in the CNSM sample, including the following: maternal age (n=10),  
12  
13 5 maternal education (n=10), maternal height (n=12), maternal BMI (n=14)  
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17 6 \* Estimated by using 2006 WHO growth reference  
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20 7 † Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit  
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22 8 latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet  
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25 9 ‡ Improved water sources other than piped water included public tap or standpipe, tube well or  
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27 10 borehole, protected dug well, protected spring, and rainwater  
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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<sup>§</sup>

	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<sup>§</sup>

	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)	
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† 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)

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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<sup>§</sup>

	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 <u>reported</u> 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 <sup>†</sup>						
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)

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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<sup>§</sup>

	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 <sup>†</sup>	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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# BMJ Open

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

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3 1 **Household sanitation and personal hygiene practices are associated with child stunting in**  
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6 2 **rural India: A cross sectional analysis of surveys**  
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12 4 Jee Hyun Rah<sup>1</sup>, Aidan A. Cronin<sup>2</sup>, Bhupendra Badgaiyan<sup>1</sup>, Victor M. Aguayo<sup>3</sup>, Suzanne Joan  
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## 1 ABSTRACT

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

6 **Setting:** India

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

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

13 **Results:** The prevalence of stunting ranged from 25% to 50% across the three studies. Compared  
14 with open defecation, household access to toilet facility was associated with a 16-39% reduced  
15 odds of stunting among children aged 0-23 months, after adjusting for all potential confounders  
16 [NFHS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM  
17 (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was  
18 not in itself associated with stunting. The caregiver's self-reported practices of washing hands  
19 with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86,  
20 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse  
21 association between reported personal hygiene practices and stunting was stronger among  
22 households with access to toilet facility or piped water (all interaction terms,  $P<0.05$ ).

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3 1 **Conclusions:** Improved conditions of sanitation and hygiene practices are associated with  
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5 2 reduced prevalence of stunting in rural India. Policies and programming aiming to address child  
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7 3 stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-  
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9 4 specific to nutrition-sensitive programming. Future randomized trials are warranted to validate  
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11 5 the causal association.  
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### 7 **Article Summary**

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

### 13 *Strengths and limitations of this study*

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

## 1 INTRODUCTION

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

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

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

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3 1 of fecal bacteria from both human and animal sources by infants and young children through  
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5 2 mouthing soiled fingers and household items, and the exploratory ingestion of soil and poultry  
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8 3 feces are common in many rural low income environments. This leads to intestinal infections  
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11 4 which affect a child's nutritional status by diminishing appetite, impairing nutrient absorption,  
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13 5 and increasing nutrient losses.<sup>10</sup>

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16 6 In India, approximately 53% of households and 624 million people defecate in the open.<sup>2</sup>  
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18 7 Open defecation is more pervasive in rural versus urban areas (74% vs. 17%). Recently, an  
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21 8 ecological analysis of data from 112 rural districts of India demonstrated a strong association  
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23 9 between the prevalence of open defecation and stunting, after adjusting for potential  
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26 10 confounders.<sup>11</sup> This analysis added to a growing body of suggestive evidence on the effect of  
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28 11 open defecation on child linear growth. However, further evidence is needed to corroborate the  
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31 12 findings, as ecological studies are prone to ecological fallacy and other errors, and are often used  
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33 13 to generate hypotheses for additional investigation employing more rigorous methods.<sup>11</sup>

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36 14 Strengthening the evidence base on the linkages between child linear growth and WASH  
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38 15 practices in Indian population will help support informed development of policy and guidelines  
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41 16 that inform optimal programmatic strategies, actions, and monitoring. This study therefore  
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43 17 sought to determine whether improved WASH conditions are associated with reduced child  
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46 18 stunting in rural India. Specifically, the analysis aimed to determine the association between  
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48 19 stunting and household access to sanitation facilities, water supply, and personal hygiene  
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51 20 practices using multiple logistic regression analyses.

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56 22 **METHODS**  
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## 1 Data

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

12 The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect  
13 district level data on the nutritional status of Indian children below five years of age.<sup>12</sup> The  
14 survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh,  
15 Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this,  
16 100 districts were those with the poorest indicators of child wellbeing in the country, and the  
17 remaining 12 districts were selected among those with some of the best indicators of child  
18 wellbeing for the purpose of within-state comparison. The selected areas represent about one-  
19 sixth of India's population and one-fifth of India's children under-five. A stratified cluster  
20 sampling was employed to identify a representative sample of 73,670 households from which a  
21 total of 109,903 children under-five were included in the survey. Information on child nutritional  
22 status was collected together with relevant maternal, household and environmental  
23 determinants.<sup>12</sup>

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

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

#### 14 Data Collection

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

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

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

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

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

## 16 Statistical Analysis

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

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

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

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

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3 1 maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5  
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5 2 kg/m<sup>2</sup>); and household composition (2-6, ≥7).  
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9 3 Although children 0-5 and 6-23 months of age have predominantly different feeding  
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11 4 practices, analyses for the two age groups were merged, because age was not a significant effect  
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13 5 modifier for indicators examined in predicting stunting. Multiple logistic regression analyses  
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15 6 were used to examine the association between the risk of stunting and WASH practices adjusting  
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17 7 for potential confounders. Stunting was included as the dependent variable and household  
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19 8 sanitation facilities, source of drinking water, and reported personal hygiene practices as the  
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21 9 independent variables, together with the potential confounding factors.  
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26 10 Confounding factors included the major determinants of child stunting based on  
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28 11 UNICEF's conceptual framework<sup>17, 18</sup>. These were associated with each WASH indicator in the  
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30 12 bivariate analyses using  $\chi^2$  test ( $P < 0.05$ ). The interactions between household sanitation  
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32 13 facilities, source of drinking water, and personal hygiene were created to examine the synergistic  
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34 14 effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and  
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36 15 corresponding 95% confidence intervals (CI) were estimated with statistical significance defined  
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38 16 as  $P < 0.05$ . All analyses were performed using STATA version 13.0 (Stat Corp., College Station,  
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40 17 TX, USA).  
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## 49 **RESULTS**

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52 20 NFHS-3  
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1 The mean ( $\pm$  standard error (SE)) age of children in the analysis was  $11.5 \pm 0.05$  months  
2 and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15%  
3 were reported to have had diarrhea in the past two weeks. The mean ( $\pm$  SE) age of the mothers of  
4 under-twos was  $25.0 \pm 0.08$  years. More than half the mothers had no education and 41% had  
5 short stature ( $<150$  cm). About 83% of the households had access to improved drinking water  
6 sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation  
7 facilities, whereas 77% had no toilet facility.

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

#### 15 HUNGaMA

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

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

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

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

10 There was a significant interaction between mother/caregiver's reported hygiene  
11 practices and household sanitation and drinking water conditions in their association with child  
12 stunting. The protective effect of mother/caregiver's reported practice of washing their hands  
13 with soap before food against child stunting was stronger among households with access to piped  
14 water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term  $P < 0.05$ )  
15 (Table 4). In addition, the inverse association between mother/caregiver's reported practices of  
16 washing their hands with soap after defecation and stunting was stronger among households with  
17 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  
18 shown).

19 CNSM

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

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

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

## 9 DISCUSSION

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

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



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

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

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

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

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

22 Few studies have explored the association between the mother/caregiver's personal  
23 hygiene practices and child stunting in India. We found that mothers/caregivers who reported

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

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

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3 1 NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with  
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5 2 soap was determined in the CNSM. Although an important variable to consider, the birth weight  
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7 3 of children was not included in the multivariate analysis, as the information was collected from a  
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9 4 small proportion of the sample. However, we did control for maternal height, BMI, dietary intake  
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11 5 and other relevant factors which are strong predictors of child birth weight. Despite these  
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13 6 limitations, assessing the WASH association with child stunting using large representative  
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15 7 survey datasets coming from the local context is a critical step in strengthening the relevant  
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17 8 evidence base and developing multi-sectoral interventions for optimal child growth.  
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23 9 In conclusion, this analysis revealed that household sanitation and the  
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25 10 mother's/caregiver's reported personal hygiene practices are strong predictors of child stunting  
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27 11 in India. This reinforces the growing evidence of the effects of WASH practices on child linear  
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29 12 growth. Large-scale randomized effectiveness trials of toilet provision (and use) and reported  
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31 13 handwashing at critical times, that include environmental enteropathy and child growth as  
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33 14 outcomes, are warranted to go beyond association in order to estimate causality. However, this  
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35 15 suggests the need for different programmatic responses by governments and development  
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37 16 partners. Optimizing nutrition outcomes for young children now requires a framework that is  
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39 17 broader than nutrition specific interventions alone. India's vulnerable children and mothers need  
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41 18 to benefit from additional, well targeted nutrition sensitive interventions especially leading up to  
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43 19 and during the first one thousand days. Children and mothers need basic WASH provision and  
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45 20 behaviors to survive, grow and thrive.  
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3 **1 TRIAL REGISTRATION**  
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6 2 As this is a secondary analysis of publicly available survey data, no trial registration was  
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9 3 required  
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12 **4 CONTRIBUTORSHIP STATEMENT**  
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15 5 JHR and AC conceptualized, designed and wrote the paper; JHR and BB analyzed the datasets;  
16  
17 6 JHR, VMA, SC wrote the paper; All authors read the manuscript, made a substantial contribution  
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19 7 to the revision, and approved the final manuscript.  
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23 **8 COMPETING INTERESTS**  
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26 9 The authors declare no conflict of interest  
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37 **12 DATA SHARING**  
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40 13 No additional data available  
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## 1 REFERENCES

- 1 1. De Onis M, Dewey KG, Borghi E et al. The World Health Organization's global target  
2 for reducing child stunting by 2025: rationale and proposed actions. *Matern Child Nutr*  
3 2013; 9 Suppl 2: 6-26.
- 4 2. International Institute for Population Sciences (IIPS) and Macro International. National  
5 Family Health Survey (NFHS-3) 2005-6. Mumbai: IIPS; 2007.
- 6 3. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and  
7 overweight in low-income and middle-income countries. *Lancet* 2013; 382: 427-51.
- 8 4. Victora CG, Adair L, Fall C et al. Maternal and child undernutrition: consequences for  
9 adult health and human capital. *Lancet* 2008; 371: 340-57.
- 10 5. Ruel MT. The natural history of growth failure: importance of intrauterine and postnatal  
11 periods. In: Martorell R, Haschke F, eds. *Nutrition and Growth*. Philadelphia, USA:  
12 Lippincott Williams and Wilkins, 2001: 123-158.
- 13 6. Dewey KG, Adu-Afarwuah S. Systematic review of the efficacy and effectiveness of  
14 complementary feeding interventions in developing countries. *Matern Child Nutr* 2008; 4  
15 (Suppl 1): 24-85.
- 16 7. Victora CG, de Onis M, Hallal PC, et al. Worldwide timing of growth faltering: revisiting  
17 implications for interventions. *Pediatrics* 2010; 125: e473-80.
- 18 8. Ngure FM, Reid BM, Humphrey JH, et al. Water, sanitation, and hygiene (WASH),  
19 environmental enteropathy, nutrition, and early child development: making the links. *Ann*  
20 *NY Acad Sci* 2014; 1308: 118-28.
- 21 9. World Bank. *Environmental health and child survival: epidemiology, economics,*  
22 *experience*. Washington, DC: World Bank; 2008.

- 1  
2  
3 10. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact?  
4  
5  
6 2 *Matern Child Nutr* 2011; 7 Suppl 3: 129-42.  
7  
8 3 11. Spears D, Ghosh A, Cumming O. Open defecation and childhood stunting in India: An  
9  
10 4 ecological analysis of new data from 112 districts. *Plos One* 2013; 8: e73784.  
11  
12  
13 5 12. The Naandi Foundation. The hunger and malnutrition survey report – 2011.  
14  
15 6 <http://naandi.org/HungamaBKDec11LR.pdf> (Accessed February 16, 2014).  
16  
17  
18 7 13. International Institute for Population Sciences (IIPS). Comprehensive nutrition survey in  
19  
20 8 Maharashtra 2012: IIPS; 2012.  
21  
22  
23 9 14. Gibson RS. Principles of Nutritional Assessment. New York, NY: Oxford University  
24  
25 10 Press, 1990.  
26  
27  
28 11 15. World Health Organization. WHO child growth standards: methods and development.  
29  
30 12 Geneva, Switzerland: WHO, 2006.  
31  
32 13 16. World Health Organization and United Nations Children’s Fund Joint Monitoring  
33  
34 14 Programme for Water Supply and Sanitation. Types of drinking water and sanitation.  
35  
36 15 <http://www.wssinfo.org/definitions-methods/watsan-categories/> (Accessed February 17,  
37  
38 16 2014).  
39  
40  
41 17 17. World Health Organization. Drinking Water.  
42  
43 18 [http://www.who.int/water\\_sanitation\\_health/monitoring/water.pdf](http://www.who.int/water_sanitation_health/monitoring/water.pdf) (Accessed February 17,  
44  
45 19 2014).  
46  
47  
48 20 18. De Pee S, Bloem MW. Assessing and communicating the impact of nutrition and health  
49  
50 21 programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries.  
51  
52 22 Totowa, NJ: Human Press, 2001: 483-506.  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 1 19. Esrey SA. Water, waste, and well-being: a multi-country study. *Am J Epidemiol*. 1996;  
4  
5 2 143: 608-23.  
6  
7  
8 3 20. Fink G, Gunther I, Hill K. The effect of water and sanitation on child health: evidence  
9  
10 4 from the demographic and health surveys 1986-2007. *Int J Epidemiol* 2011; 40: 1196-  
11  
12 1204.  
13  
14  
15 6 21. Checkley W, Gilman RH, Black RE, et al. Effect of water and sanitation on childhood  
16  
17 7 health in a poor Peruvian peri-urban community. *Lancet* 2004; 363: 112-8.  
18  
19  
20 8 22. Lin A, Arnold BF, Afreen S et al. Household environmental conditions are associated  
21  
22 9 with enteropathy and impaired growth in rural Bangladesh. *Am J Trop Med Hyg* 2013; 89:  
23  
24 10 130-7.  
25  
26  
27 11 23. Prüss-üstün A, Bos R, Gore F, et al. Safe water, better health: costs, benefits and  
28  
29 12 sustainability of interventions to protect and promote health. World Health Organization,  
30  
31 13 Geneva, 2008.  
32  
33  
34 14 24. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing.  
35  
36 15 *Lancet* 2009; 374:1032-5.  
37  
38  
39 16 25. Merchant AT, Jones C, Kiure A, et al. Water and sanitation associated with improved  
40  
41 17 child growth. *Eur J Clin Nutr* 2003; 57: 1562-8.  
42  
43  
44 18 26. Meshram II, Arlappa N, Balakrishna N et al. Influence of feeding practices and  
45  
46 19 associated factors on the nutritional status of infants in rural areas of Madhya Pradesh  
47  
48 20 State, India. *Asia Pac J Public Health* 2013 May 10.  
49  
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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS) <sup>1</sup>	Hunger and Malnutrition Survey (HUNGaMA) <sup>2</sup>	Comprehensive Nutrition Survey in Maharashtra (CNSM) <sup>3</sup>
N	10,364	34,639	1,282
<b><i>Child Characteristics</i></b>			
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 (%) <sup>*</sup>	41	50	25
Wasted weight-for-height z-score, <-2 (%) <sup>*</sup>	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

<b><i>Maternal Characteristics</i></b>			
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 <sup>2</sup> (%)	44	-	40
<b><i>Household Characteristics</i></b>			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
≥7	47	50	41
Place of defecation			
Improved sanitation facility <sup>†</sup>	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source <sup>‡</sup>	74	-	57

1 <sup>†</sup> 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)

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4 1 <sup>2</sup> Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209),  
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6 2 breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438),  
7  
8 3 household size (n=257), source of drinking water (n=3395)  
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11 4 <sup>3</sup> Missing values existing in the CNSM sample, including the following: maternal age (n=10),  
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13 5 maternal education (n=10), maternal height (n=12), maternal BMI (n=14)  
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17 6 \* Estimated by using 2006 WHO growth reference  
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20 7 † Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit  
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22 8 latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet  
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25 9 ‡ Improved water sources other than piped water included public tap or standpipe, tube well or  
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27 10 borehole, protected dug well, protected spring, and rainwater  
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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<sup>§</sup>

	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<sup>§</sup>

	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)	
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† 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)

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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<sup>§</sup>

	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 <sup>†</sup>						
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	

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		(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)

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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<sup>§</sup>

	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 <sup>†</sup>	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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4 1 **Household sanitation and personal hygiene practices are associated with child stunting in**  
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6 2 **rural India: A cross sectional analysis of surveys**  
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12 4 Jee Hyun Rah<sup>1</sup>, Aidan A. Cronin<sup>2</sup>, Bhupendra Badgaiyan<sup>1</sup>, Victor M. Aguayo<sup>3</sup>, Suzanne Joan  
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48 16 Word Count: 3,652  
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3 1 **ABSTRACT**  
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6 2 **Objectives:** Increasing evidence suggests that water, sanitation and hygiene (WASH) practices  
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9 3 affect linear growth in early childhood. We determined the association between household access  
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11 4 to water, sanitation, and personal hygiene practices with stunting among children aged 0-23  
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13 5 months in rural India.

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17 6 **Setting:** India  
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20 7 **Participants:** A total of 10,364, 34,639, and 1,282 under-tuos who participated in the 2005-6  
21  
22 8 National Family Health Survey (NFHS-3), 2011 Hunger and Malnutrition Survey (HUNGaMA),  
23  
24 9 and 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM), respectively, were included  
25  
26 10 in the analysis.  
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30 11 **Primary outcome measures:** The association between WASH indicators and child stunting was  
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32 12 assessed using logistic regression models.  
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36 13 **Results:** The prevalence of stunting ranged from 25% to 50% across the three studies. Compared  
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38 14 with open defecation, household access to toilet facility was associated with a 16-39% reduced  
39  
40 15 odds of stunting among children aged 0-23 months, after adjusting for all potential confounders  
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42 16 [NFHS-3 (OR=0.84, 95%CI:0.71-0.99); HUNGaMA (OR=0.84, 95%CI:0.78-0.91); CNSM  
43  
44 17 (OR=0.61, 95%CI:0.44-0.85)]. Household access to improved water supply or piped water was  
45  
46 18 not in itself associated with stunting. The caregiver's self-reported practices of washing hands  
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48 19 with soap before meals (OR=0.85, 95% CI: 0.76-0.94) or after defecation (OR=0.86,  
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50 20 95%CI:0.80-0.93) were inversely associated with child stunting. However, the inverse  
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52 21 association between reported personal hygiene practices and stunting was stronger among  
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54 22 households with access to toilet facility or piped water (all interaction terms, P<0.05).  
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1 **Conclusions:** Improved conditions of sanitation and hygiene practices are associated with  
2 reduced prevalence of stunting in rural India. Policies and programming aiming to address child  
3 stunting should encompass WASH interventions, thus shifting the emphasis from nutrition-  
4 specific to nutrition-sensitive programming. Future randomized trials are warranted to validate  
5 the causal association.

### 7 **Article Summary**

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

### 13 *Strengths and limitations of this study*

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

## 1 INTRODUCTION

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

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

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

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

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

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

21

## 22 **METHODS**

## 1 Data

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

12 The HUNGaMA survey was conducted by the Naandi Foundation in 2011 to collect  
13 district level data on the nutritional status of Indian children below five years of age.<sup>12</sup> The  
14 survey covered 112 rural districts across nine states in India, namely Bihar, Himachal Pradesh,  
15 Jharkhand, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Tamil Nadu. Of this,  
16 100 districts were those with the poorest indicators of child wellbeing in the country, and the  
17 remaining 12 districts were selected among those with some of the best indicators of child  
18 wellbeing for the purpose of within-state comparison. The selected areas represent about one-  
19 sixth of India's population and one-fifth of India's children under-five. A stratified cluster  
20 sampling was employed to identify a representative sample of 73,670 households from which a  
21 total of 109,903 children under-five were included in the survey. Information on child nutritional  
22 status was collected together with relevant maternal, household and environmental  
23 determinants.<sup>12</sup>



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

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

#### 14 Data Collection

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

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

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3 1 nutritional status, morbidity, and reported personal hygiene practices. Information on household  
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5 2 composition, source of drinking water and sanitation facility, socioeconomic status, and  
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8 3 utilization of social safety net programs was also collected. All interviews were carried out using  
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10 4 a structured questionnaire.

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13 Anthropometric measurements were taken from the children and mothers following  
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15 5 standard procedures.<sup>14</sup> Height was measured using a height/length board to the nearest 0.1 cm.  
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17 6 Weight was assessed using an electronic weight scale to the nearest 0.1 kg. Age of the children  
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19 7 was determined using the immunization cards or home records of date of birth to the extent  
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21 8 possible. When these documents were unavailable, the local events calendar was used to help  
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23 9 with the recall of the child's age.  
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29 11 The field interviewers/anthropometrists were from local non-governmental organization  
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31 12 partners and were thoroughly trained before data collection. The performance of field staff  
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33 13 during data collection was continuously monitored by supervisors and quality control teams who  
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35 14 rechecked some of the data the following day to ensure data reliability. Non-response and refusal  
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37 15 to participate in the surveys were minimal.  
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#### 41 16 Statistical Analysis

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44 17 This analysis included 10,364, 34,639, and 1282 children 0-23 months of age in rural  
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46 18 India who participated in the NFHS-3, HUNGaMA, and CNSM, respectively. When more than  
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48 19 one child under-two was assessed in a given household, only the youngest child from each  
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50 20 household was included in the analysis. All analyses were weighted according to the population  
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52 21 size and adjusted for the multistage cluster design of the surveys.  
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1 Stunting and wasting were defined as height-for-age (HAZ) and weight-for-height z-  
2 scores less than -2, respectively, using the WHO growth standards in AnthroPlus 2009  
3 software.<sup>15</sup> Maternal body mass index (BMI) was defined as weight divided by the square of  
4 height (kg/m<sup>2</sup>). In the analysis of data obtained from the NFHS and CNSM, sources of drinking  
5 water were classified into improved water sources including water piped into a dwelling, plot or  
6 yard, public tap or standpipe, tube well or borehole, protected dug well, protected spring, and  
7 rainwater vs. unimproved water.<sup>16, 17</sup> Improved sanitation facilities included flush toilet, piped  
8 sewer system, septic tank, flush to pit latrine, ventilated improved pit latrine, pit latrine with slab,  
9 and composting toilet.<sup>16</sup> A comparison was also made between piped water vs. other sources of  
10 drinking water and any toilet facility vs. open defecation. The HUNGaMA categorized source of  
11 drinking water only as hand pump and piped water and others and sanitation as defecating in the  
12 open vs. any toilet.<sup>12</sup>

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

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

1  
2  
3 1 maternal age (<20, 20-29, ≥30); maternal height (< or ≥150 cm); maternal BMI (< or ≥18.5  
4  
5 2 kg/m<sup>2</sup>); and household composition (2-6, ≥7).  
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9 3 Although children 0-5 and 6-23 months of age have predominantly different feeding  
10  
11 4 practices, analyses for the two age groups were merged, because age was not a significant effect  
12  
13 5 modifier for indicators examined in predicting stunting. Multiple logistic regression analyses  
14  
15 6 were used to examine the association between the risk of stunting and WASH practices adjusting  
16  
17 7 for potential confounders. Stunting was included as the dependent variable and household  
18  
19 8 sanitation facilities, source of drinking water, and reported personal hygiene practices as the  
20  
21 9 independent variables, together with the potential confounding factors.  
22  
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26 10 Confounding factors included the major determinants of child stunting based on  
27  
28 11 UNICEF's conceptual framework<sup>17,18</sup>. These were associated with each WASH indicator in the  
29  
30 12 bivariate analyses using  $\chi^2$  test ( $P < 0.05$ ). The interactions between household sanitation  
31  
32 13 facilities, source of drinking water, and personal hygiene were created to examine the synergistic  
33  
34 14 effects of WASH indicators on the risk of child stunting. The odds ratios (OR) and  
35  
36 15 corresponding 95% confidence intervals (CI) were estimated with statistical significance defined  
37  
38 16 as  $P < 0.05$ . All analyses were performed using STATA version 13.0 (Stat Corp., College Station,  
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## 49 RESULTS

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52 20 NFHS-3  
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1 The mean ( $\pm$  standard error (SE)) age of children in the analysis was  $11.5 \pm 0.05$  months  
2 and 52% were male (Table 1). Approximately 41% were stunted, 27% were wasted, and 15%  
3 were reported to have had diarrhea in the past two weeks. The mean ( $\pm$  SE) age of the mothers of  
4 under-twos was  $25.0 \pm 0.08$  years. More than half the mothers had no education and 41% had  
5 short stature ( $<150$  cm). About 83% of the households had access to improved drinking water  
6 sources, and ~9% had access to piped water. One-fifth of the households had improved sanitation  
7 facilities, whereas 77% had no toilet facility.

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

#### 15 HUNGaMA

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

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

1  
2  
3 1 CI: 0.78-0.91) (Table 3). Household access to a piped water source was not associated with  
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5  
6 2 stunting. There were no synergistic effects of household sanitation and water supply on child  
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8 3 stunting.  
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10  
11 4 The mother/caregiver's reported hygiene practices appeared to predict the risk of child  
12  
13 5 stunting. In the multivariate analysis, the caregiver's reported practice of washing their hands  
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15 6 with soap after defecation was associated with a 14% reduced risk of stunting among children  
16  
17 7 aged 0-23 months (OR=0.86, 95% CI: 0.80-0.93) (Table 3). Likewise, the caregiver's reported  
18  
19 8 practice of washing their hands with soap before food was associated with a 15% lower odds of  
20  
21 9 stunting among children aged 0-23 months (OR=0.85, 95% CI: 0.76-0.94) (data not shown).  
22  
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26 10 There was a significant interaction between mother/caregiver's reported hygiene  
27  
28 11 practices and household sanitation and drinking water conditions in their association with child  
29  
30 12 stunting. The protective effect of mother/caregiver's reported practice of washing their hands  
31  
32 13 with soap before food against child stunting was stronger among households with access to piped  
33  
34 14 water (OR=0.77, 95% CI: 0.66-0.90 vs. OR=0.89, 95% CI: 0.80-0.99, interaction term  $P<0.05$ )  
35  
36 15 (Table 4). In addition, the inverse association between mother/caregiver's reported practices of  
37  
38 16 washing their hands with soap after defecation and stunting was stronger among households with  
39  
40 17 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  
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42 18 shown).  
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48 19 CNSM

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52 20 The mean ( $\pm$  SE) age of the children was  $11.0 \pm 0.24$  months and about 56% were male  
53  
54 21 (Table 1). About a quarter (25%) of the children were stunted, 17% were wasted, and 30% had  
55  
56 22 had diarrhea in the past two weeks. The mean ( $\pm$  SE) age of the mothers was  $23.6 \pm 0.12$  years  
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1 and 14% had no education. Approximately 87% of the households had improved sources of  
2 drinking water, and about 30% had access to piped water. Twenty seven percent of the  
3 households had access to improved sanitation facilities.

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

## 8

## 9 DISCUSSION

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

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

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

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

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



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

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

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

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

1 having access to an improved source of drinking water and sanitation facilities could not be  
2 determined using the HUNGaMA data. Data on personal hygiene was not collected from the  
3 NFHS and only the proportion of mothers/caregivers reporting that they washed their hands with  
4 soap was determined in the CNSM. Although an important variable to consider, the birth weight  
5 of children was not included in the multivariate analysis, as the information was collected from a  
6 small proportion of the sample. However, we did control for maternal height, BMI, dietary intake  
7 and other relevant factors which are strong predictors of child birth weight. Despite these  
8 limitations, assessing the WASH association with child stunting using large representative  
9 survey datasets coming from the local context is a critical step in strengthening the relevant  
10 evidence base and developing multi-sectoral interventions for optimal child growth.

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

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3 1 The authors wish to thank Dr. Francis Odhiambo for his insightful comments on the manuscript  
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## 6 2 TRIAL REGISTRATION

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10 3 As this is a secondary analysis of publicly available survey data, no trial registration was  
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12 4 required  
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## 14 5 CONTRIBUTORSHIP STATEMENT

15  
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18 6 JHR and AC conceptualized, designed and wrote the paper; JHR and BB analyzed the datasets;  
19  
20 7 JHR, VMA, SC wrote the paper; All authors read the manuscript, made a substantial contribution  
21  
22 8 to the revision, and approved the final manuscript.  
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## 26 9 COMPETING INTERESTS

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30 10 The authors declare no conflict of interest  
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34  
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## 39 13 DATA SHARING

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42 14 No additional data available  
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## REFERENCES

1. De Onis M, Dewey KG, Borghi E et al. The World Health Organization's global target for reducing child stunting by 2025: rationale and proposed actions. *Matern Child Nutr* 2013; 9 Suppl 2: 6-26.
2. International Institute for Population Sciences (IIPS) and Macro International. National Family Health Survey (NFHS-3) 2005-6. Mumbai: IIPS; 2007.
3. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; 382: 427-51.
4. Victora CG, Adair L, Fall C et al. Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008; 371: 340-57.
5. Ruel MT. The natural history of growth failure: importance of intrauterine and postnatal periods. In: Martorell R, Haschke F, eds. *Nutrition and Growth*. Philadelphia, USA: Lippincott Williams and Wilkins, 2001: 123-158.
6. Dewey KG, Adu-Afarwuah S. Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Matern Child Nutr* 2008; 4 (Suppl 1): 24-85.
7. Victora CG, de Onis M, Hallal PC, et al. Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics* 2010; 125: e473-80.
8. Ngure FM, Reid BM, Humphrey JH, et al. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Ann NY Acad Sci* 2014; 1308: 118-28.

- 1  
2  
3 1 9. World Bank. Environmental health and child survival: epidemiology, economics,  
4  
5  
6 2 experience. Washington, DC: World Bank; 2008.
- 7  
8 3 10. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact?  
9  
10 4 *Matern Child Nutr* 2011; 7 Suppl 3: 129-42.
- 11  
12 5 11. Spears D, Ghosh A, Cumming O. Open defecation and childhood stunting in India: An  
13  
14 6 ecological analysis of new data from 112 districts. *Plos One* 2013; 8: e73784.
- 15  
16 7 12. The Naandi Foundation. The hunger and malnutrition survey report – 2011.  
17  
18 8 <http://naandi.org/HungamaBKDec11LR.pdf> (Accessed February 16, 2014).
- 19  
20 9 13. International Institute for Population Sciences (IIPS). Comprehensive nutrition survey in  
21  
22 10 Maharashtra 2012: IIPS; 2012.
- 23  
24 11 14. Gibson RS. Principles of Nutritional Assessment. New York, NY: Oxford University  
25  
26 12 Press, 1990.
- 27  
28 13 15. World Health Organization. WHO child growth standards: methods and development.  
29  
30 14 Geneva, Switzerland: WHO, 2006.
- 31  
32 15 16. World Health Organization and United Nations Children’s Fund Joint Monitoring  
33  
34 16 Programme for Water Supply and Sanitation. Types of drinking water and sanitation.  
35  
36 17 <http://www.wssinfo.org/definitions-methods/watsan-categories/> (Accessed February 17,  
37  
38 18 2014).
- 39  
40 19 17. World Health Organization. Drinking Water.  
41  
42 20 [http://www.who.int/water\\_sanitation\\_health/monitoring/water.pdf](http://www.who.int/water_sanitation_health/monitoring/water.pdf) (Accessed February 17,  
43  
44 21 2014).
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51  
52  
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54  
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57  
58  
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60

- 1  
2  
3 1 18. De Pee S, Bloem MW. Assessing and communicating the impact of nutrition and health  
4  
5 2 programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries.  
6  
7 3 Totowa, NJ: Human Press, 2001: 483-506.  
8  
9  
10 4 19. Esrey SA. Water, waste, and well-being: a multi-country study. *Am J Epidemiol*. 1996;  
11  
12 5 143: 608-23.  
13  
14 6 20. Fink G, Gunther I, Hill K. The effect of water and sanitation on child health: evidence  
15  
16 7 from the demographic and health surveys 1986-2007. *Int J Epidemiol* 2011; 40: 1196-  
17  
18 8 1204.  
19  
20 9 21. Checkley W, Gilman RH, Black RE, et al. Effect of water and sanitation on childhood  
21  
22 10 health in a poor Peruvian peri-urban community. *Lancet* 2004; 363: 112-8.  
23  
24 11 22. Lin A, Arnold BF, Afreen S et al. Household environmental conditions are associated  
25  
26 12 with enteropathy and impaired growth in rural Bangladesh. *Am J Trop Med Hyg* 2013; 89:  
27  
28 13 130-7.  
29  
30 14 23. Prüss-üstün A, Bos R, Gore F, et al. Safe water, better health: costs, benefits and  
31  
32 15 sustainability of interventions to protect and promote health. World Health Organization,  
33  
34 16 Geneva, 2008.  
35  
36 17 24. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing.  
37  
38 18 *Lancet* 2009; 374:1032-5.  
39  
40 19 25. Merchant AT, Jones C, Kiure A, et al. Water and sanitation associated with improved  
41  
42 20 child growth. *Eur J Clin Nutr* 2003; 57: 1562-8.  
43  
44 21 26. Meshram II, Arlappa N, Balakrishna N et al. Influence of feeding practices and  
45  
46 22 associated factors on the nutritional status of infants in rural areas of Madhya Pradesh  
47  
48 23 State, India. *Asia Pac J Public Health* 2013 May 10.  
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1 Table 1. Characteristics of children 0-23 months included in the sample

	National Family Health Survey (NFHS) <sup>1</sup>	Hunger and Malnutrition Survey (HUNGaMA) <sup>2</sup>	Comprehensive Nutrition Survey in Maharashtra (CNSM) <sup>3</sup>
N	10,364	34,639	1,282
<b><i>Child Characteristics</i></b>			
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 (%) <sup>*</sup>	41	50	25
Wasted weight-for-height z-score, <-2 (%) <sup>*</sup>	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



<b><i>Maternal Characteristics</i></b>			
Age, year (mean $\pm$ SE)	25.0 $\pm$ 0.08	26.8 $\pm$ 0.04	23.6 $\pm$ 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 <sup>2</sup> (%)	44	-	40
<b><i>Household Characteristics</i></b>			
Family size (%)			
2-3	7	7	7
4-6	46	43	52
$\geq 7$	47	50	41
Place of defecation			
Improved sanitation facility <sup>†</sup>	20	-	27
No toilet facility/bush/field	77	83	65
Source of drinking water			
Pipe water	9	24	30
Other improved source <sup>‡</sup>	74	-	57

1 <sup>†</sup> 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)

1  
2  
3 1 <sup>2</sup> Missing values existing in the HUNGaMA sample, including the following: wasting (n=2209),  
4  
5  
6 2 breastfeeding within 1 hour of birth (n=389), maternal age (n=186), maternal education (n=438),  
7  
8 3 household size (n=257), source of drinking water (n=3395)  
9

10  
11 4 <sup>3</sup> Missing values existing in the CNSM sample, including the following: maternal age (n=10),  
12  
13 5 maternal education (n=10), maternal height (n=12), maternal BMI (n=14)  
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17 6 \* Estimated by using 2006 WHO growth reference  
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20 7 † Improved sanitation facilities included flush toilet, piped sewer system, septic tank, flush to pit  
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22 8 latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet  
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25 9 ‡ Improved water sources other than piped water included public tap or standpipe, tube well or  
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27 10 borehole, protected dug well, protected spring, and rainwater  
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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<sup>§</sup>

	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

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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<sup>§</sup>

	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)	
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† 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)

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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<sup>§</sup>

	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 <sup>†</sup>						
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	

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		(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)

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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<sup>§</sup>

	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 <sup>†</sup>	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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