Child Malnutrition and Recurrent Flooding in Rural Eastern India: A Community-Based Survey

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ABSTRACT

Objectives This study aims to improve the understanding of the relationship between exposure to floods and malnutrition in children aged 6 to 59 months in rural India. Research has focused exclusively on Bangladeshi children and few controlled epidemiological studies are available.

Method A community-based cross-sectional study of child nutritional status carried out in 14 flooded and 18 non-flooded villages of Jagatsinghpur district (Orissa) after the September 2008 floods, and similarly affected by flooding in August 2006. Face-to-face interviews were conducted in 785 households in the flooded villages and 816 in the non-flooded communities. Data used in this study were from those households with children 6 to 59 months. In total, 191 and 161 children were measured, respectively. The association between various malnutrition indicators and the exposure to floods was assessed by univariate and multivariate logistic regression.

Results Adjusted analyses revealed that children in flooded households were more likely stunted compared to those in non-flooded ones (APR, 1.60; 95% CI, 1.05-2.44). Children of the poorest families were also more chronically malnourished (APR, 1.85; 95% CI, 1.11-3.09) than those of the richest group. The prevalence of underweight was also higher in children living in the flooded communities (APR, 1.86; 95% CI, 1.04-3.30), those living with one or more under five children (APR, 1.69; 95% CI, 1.05-2.72) and born with lower weights (APR, 1.80; 95% CI, 1.11-2.92). Further analyses found the 26-36 months age group attained the highest levels of stunting and underweight within the flooded areas, thus those younger than one year during the precedent flood in August 2006.

Conclusion Exposure to floods is associated with long-term malnutrition in rural communities of Orissa, India. Children exposed to floods during their first year of life presented higher levels of chronic malnutrition. Long-term malnutrition prevention programs after floods should be implemented in flood-prone areas.

ARTICLE SUMMARY

Article focus

- Study of the connection between flood exposure and childhood malnutrition in rural communities of north eastern India

Key messages

- First study that addresses the health impacts of floods on child malnutrition in India, a country prone to multiple natural disasters
- Climate-related extreme events are projected to increase partly induced by climate change, leading to a higher burden of disaster-related diseases
- Exposure to floods is associated with chronic growth retardation in Indian children, especially in those exposed at very early stages in life

Strengths and limitations of this study

Strengths

- High and consistent survey response rates across flooded and non-flooded communities
- Use of standard methodology, including high precision WHO standards to assess malnutrition

Limitations

- The study does not establish causal relationship but an association between floods and childhood malnutrition
- Study only representative of the children 6 to 59 months living in 29 rural communities

INTRODUCTION

Floods are the most common reported natural disaster worldwide, [1] with important impact on the health of human populations. [2, 3] Their effects are especially dramatic in developing countries of south and south-east Asia. [4] Flooding has demonstrated serious impacts on crop productivity in the past, [5, 6] and the projected higher global temperatures may have nonlinear and increasingly negative impacts on existing agricultural activities [7], particularly on vulnerable countries of south Asia and southern Africa where insufficient adaptation measures are planned. [8] Crop yield variation induced by climate change has been suggested as one of the potential mechanisms leading to malnutrition. [9] Despite these presumed linkages, a recent review has pointed out limited evidence on the health effects of floods in controlled epidemiological studies, particularly of morbidity. [3] Though some studies have examined mortality, disease or mental health, there is little research on the association between floods and children's nutritional health, and this evidence is geographically restricted to flood-prone areas of Bangladesh. [10-13]

This is particularly worrying since children are vulnerable to environmental adversities because of their greater exposure, greater sensitivity to certain exposures, and their dependence on caregivers. [14, 15] For this reason, increased weather variability predicted by climatic models is expected to lead to a rise in the health risks of this age group, associated with more frequent extremes like droughts and floods. [14-16]

The deleterious consequences of poor nutrition are well recognized. Undernutrition is a primary cause of ill-health and premature mortality among children in developing countries. [17] Therefore, malnutrition affects children during critical phases of their early cognitive, social, motor and emotional development, and has been associated with poor school performance. [18, 19] Poverty and food security are also risk factors which have been found to be associated with poor early development in children. [20] Thus, these disadvantaged children are less likely to become productive adults, [18] perpetuating the cycle of poor human development. [20]

India is one of the most disaster-prone countries in the world. [1] The Indian state of Orissa, located by the Bay of Bengal, is vulnerable to multiple disasters, like tropical cyclones, storm surges, floods and tsunamis. Its densely populated coastal plains are the alluvial deposits of its river systems. These rivers, with heavy load of silt, have very little carrying capacity, what results in frequent floods. The state of Orissa suffered heavy loss of life and property during the cyclone Paradip that hit the state in October 1999. [21] As a consequence, an autonomous relief and coordination body was created in the state, the Orissa State Disaster Mitigation Authority (OSDMA). Since then, this agency has been actively working in disaster management, prevention, risk reduction and relief activities. [22] Complementary to long term poverty alleviation programs, there are also short term food aid governmental programs to help the victims of disasters within the country (SRD, personal communication).

Despite a rising awareness on understanding the health effects of extreme weather events, [14, 23, 24] limited evidence is available at present. [3, 10, 11, 12, 13] Specifically, without a better understanding of the mechanisms which produce and maintain high levels of malnutrition in developing countries, policy makers lack crucial information to design specific and effective intervention plans to reduce its prevalence among children. This is especially critical in the face of the foreseen long-lasting intensification of the water cycle [25] and the rise of human vulnerability to extreme weather events. [26]

The most recent floods occurring in Orissa in September 2008 provided an opportunity to compare the nutritional status in a representative sample of the children aged 6-59 months living in 13 flooded communities and those inhabiting 16 other non-flooded nearby villages. We aimed to identify other social, health and economic determinants of child malnutrition, including possible interactions with flood exposure, which may aggravate their situation.

MATERIALS AND METHODS

This study used a cross-sectional design to collect data on a representative sample of the children 6 to 59 months living in flooded and non-flooded communities of Orissa right after the September 2008 floods. We used anthropometric measurements to assess child malnutrition and face-to-face interviews to investigate their social, health and economic context.

Study area

The study site was Jagatsinghpur, a coastal district located in the state of Orissa, eastern India. The Devi, Mahanadi, Kathajodi and Biluakhai are the four main rivers in the area. The district covers a geographical area of 1 914.6 squared km. [22] The district is organized into one subdivision, four tehsils and eight blocks and has a population of 1 057 629 with 90% residing in rural areas (2001 census). [27] The district has been severely hit by five major floods in the last decade, the one following the cyclone Paradip (05B) in 1999, followed by heavy floods in 2001, 2003, and 2006. [22] The last floods, starting in mid September 2008, produced large devastation with 2.4 million people homeless and a death toll of 173. [1]

Data source

This study was conducted under the MICRODIS project, through a EC Framework 6 Research grant. The overall goal of this project was to strengthen preparedness, mitigation and prevention strategies in order to reduce the health, social and economic impacts of extreme events on communities. The consortium consists of a total of 19 academic institutions and grassroots organizations, administering empirical work in selected flood, storm and earthquake sites in Asia and Europe, along with the development of integrated assessment methods and tools. This specific research was led by the Voluntary Health Association of India (VHAI) in collaboration with the Centre for Research on the Epidemiology of Disasters – Université catholique de Louvain (CRED-UCL). The main objective of the present survey was to assess jointly the economic, social and health impact of floods in Orissa, India. The data presented here focuses on the impacts of floods on child malnutrition.

Sample selection

After discussions with the district administration, the 5 worst affected blocks (Kujanga, Biridi, Balikuda, Tirtol and Ersama) were selected for further sampling. The Orissa State Disaster Mitigation Authority (OSDMA), a governmental agency in charge of statewide disaster relief operations, provided the list of the flooded villages within the selected blocks. Logistic considerations limited our study to 14 accessible flooded villages. Eighteen non-flooded nearby villages of similar size were selected as comparison group. These 14 and 18 villages were also inundated and non-inundated, respectively, during previous floods occurring in August 2006. We cross-checked our survey data with OSDMA reports to validate this information. About 10% of households in each selected village were surveyed (Figure 1). In three small villages, one flooded and two non-flooded, none of the eligible children could be measured and consequently were excluded from the study population. The study population was defined as those children aged 6 to 59 months of the remaining 29 villages, which represented less than 5% of the total population and were present, overall, in less than 25% of the households surveyed (Table S1). The list of the children 6 to 59 months were obtained at the ICDS (Integrated Child Development Scheme) center at each village. A household was defined as a group of people who usually live under the same roof and share a common kitchen. If an adult member or any eligible children 6 to 59 months was not at home at the time of the survey, the survey team returned to the household later. The maximum number of visits per household was fixed at three. For household selection, we used a modified EPI 'random walk' method. [28, 29] At the centre of the village, a team member spun a pen, following the direction pointed by the pen up to the limit of the village. The same procedure was repeated from the new location to randomly choose a direction in which to conduct the survey. A random direction is selected each time that a bifurcation is encountered. Random numbers are generated to select the households. Overall, 85.2% of eligible children were measured and their parents interviewed. The response rate was consistent across the flooded (84%) and non-flooded communities (86.6%). Thirty-two children were not measured in the flooded households. Five of them have recently died and 27 stayed with relatives in different villages. In the non-flooded communities, twenty-two children were unavailable. Nineteen of these children moved with their parents elsewhere and other 3 died (Figure 1).

Instruments, training and pilot testing

Anthropometric measurements of children and adapted questionnaires were used to obtain the information on anthropometrics, household characteristics and other children variables. Fourteen interviewers, three supervisors and one data manager were specifically trained for this study during a three days workshop organized by the Voluntary Health Association of India (VHAI) under the supervision of The MICRODIS project university partners, local government officers and other local researchers. The questionnaires were pre-tested in 45 households to refine it before starting data collection. The questionnaire was translated to the local language in Orissa (Oriya) and then back translated into English by two different translators. Field work was carried out between 6 October and 19 November 2008.

Weight and height of every child were measured twice to minimize measurement errors and increase precision by using their average value. Weight measurements were undertaken to the nearest 100 grams using a 10 kg beam balance (Raman Surgical Co., Delhi-33, India) and a 50 kg standard electronic balance. For children younger than 2 years of age, length was measured to the nearest millimeter in the recumbent position using an infantometer (Narang Medical Ltd. Delhi - 110 028, India). Children older than 2 years were measured in a standing position using a measuring board. All instruments were calibrated daily.

Outcome measures, exposure and confounders

The outcomes of this study were three anthropometric indices, stunting (height-for-age), underweight (weight-for-age) and wasting (weight-for-height). Stunting is an indicator of chronic malnutrition whereas wasting often assesses acute nutritional stress within a population. Underweight combines the previous two, widely used for its operational value. The new World Health Organization (WHO) standard, based on healthy optimally fed children from different cultures, was used to calculate the z scores for these indicators. Malnutrition was a binary variable indicating whether a children is malnourished, z score <-2 (1) or not (0) at the time of the interview. The fundamental variable of this study was the level of children exposure to floods, measured as whether the village was flooded (1) or not (0), according to the list provided by the authorities (see Sample selection). Therefore, thirteen other variables included information at the household and individual (children) level (Table 1). In the first group, we recorded the number of persons residing in each household (household size) measured as a continuous variable, number of children younger than 5 years living in a household, dichotomized as one (0) or otherwise (1). The main occupation of the household was recorded in detailed categories and later recoded as non manual (reference), agricultural, manual and unemployed. Two religions were present in the study area, Hinduism, taken as the reference group, and Muslim. Caste of the household was based on the household head and was grouped as scheduled caste, other backward class or general class (reference category). The general class represents the higher caste status in India. The scheduled caste is the social group historically subject to the higher deprivation levels in the country. Monthly household income (in thousand Indian rupees INR) was collected from respondents as a continuous variable and recoded into four categories: ≤ 3, > 3-6, > 6-9 and > 9, chosen as the reference category. The household source of drinking water at the time of the interview was recorded in a detailed questionnaire (Table 1) and recoded as whether they were more secure sources, such as wells and taps (0) or unsecure such as surface water (1), consumed in the flooded areas (Table 2, 3 and S3). The storage of cooked food was also listed using a detailed questionnaire and dichotomized into closed containers (0) and open containers (1).

Within the second group, a number of individual variables were recorded. Birth weights were obtained from birth certificates and/or vaccination cards available and were coded as a binary variable above and below the median. Sex was a binary variable. Age was recorded from birth certificates and/or vaccination cards in most cases (85% of respondents). If these were not available, local calendars were used otherwise to approximate them. Children were classified by the reported age into the following groups (in months): 6 to 18, 18 to 26, 26 to 36, 36 to 46, and 46 to 59. This classification was purposive for analyses undertaken in this study. Children immunization coverage was obtained from vaccination cards available. Children fully vaccinated, proved with vaccination card, against Polio (3 doses), Tuberculosis (1 dose), Measles (1 dose), Hepatitis E (3 doses), Diphtheria and Tetanus toxoid and Pertussis (3 doses) were classified as those with full immunization coverage (0), otherwise partially immunized (1).

Power analysis

We calculated the sample size assuming a two thirds prevalence of malnutrition in non-flooded compared to flooded households, with α (error) = 0.05 and 1-β (power) = 0.80, using the average percentage of stunting in Orissa state (children < 5 years) as the prevalence for the flooded area (45) [30] and two thirds (30) as a conservative approximate for the non-flooded. A sample size of 328 children, 164 in flooded and 164 in non-flooded areas, was required.

Data analysis

Malnutrition indices were calculated using ENA for SMART version November 2008 (Erhardt and Golden 2008). The new World Health Organization (WHO) standard, based on healthy optimally fed children from different cultures, was used to calculate z scores. Statistical analyses were conducted in R version 2.10.1 (R Development Core Team 2008). [31] Missing data were rare. Data were missing on underweight and wasting in 1 and 5 respondents, respectively. In 1 respondent, data were missing on income, number of children under five and household size. Data were missing on caste in 2 respondents, and on food storage in 1 respondent.

In cross-sectional epidemiological research studying rare outcomes, the odds ratio (OR) is very close to the relative risk (RR). If the outcome is common as it is the case in this study (i.e. prevalence > 10%), ORs tend to differ from RRs. Prevalence ratios (PR), as named in this study, were then used instead of prevalence odds ratio (POR), to avoid confusion in the interpretation of the results. [32, 33] Quasi-binomial models were used to avoid overdispersion. Additionally, starting values and increasing the number of iterations were necessary to fit these models. [34] GLM quasi-binomial models were used to explore bivariate associations between malnutrition and independent variables, reported as crude (unadjusted) PRs with their associated 95% confidence intervals (CIs). Multivariate (adjusted) models were used to identify variables predictive of malnutrition, controlling for all other variables in the model. Two-way interactions were examined for significant parameters in the adjusted models ($p<0.05$). Alpha level was set at 5% and all statistical tests were two sided.

RESULTS

Demographic Characteristics

Table 1 reports characteristics of the sample by exposure group. More nonmanual (18.4%) and less agricultural work (31.6%) were reported by the respondents in the flooded communities compared to the non-flooded (11.8% and 40.4%, respectively). The higher proportion of Muslim in the flooded group (27.8%) was due to a large Muslim population living in a single village. More individuals from the scheduled caste were living in the flooded communities (21.9%) compared to the non-flooded (12.1%). The access to safe drinking water was limited right after the floods and 32.3% of the respondents affirmed to drink surface water.

Table 1 Characteristics of 294 Households and 352 Children in 29 Study Villages in Orissa, India*

Characteristics	Flooded (n = 13)	Non-Flooded (n = 16)
Household variables		
No. of households with any children 6-59 mo measured	158	136
Total No. of persons residing in household, mean (SD)	7.2 (2.8)	7.5 (2.9)
No. of children younger than 5 y		
1	116 (73.9)	97 (71.3)
≥ 2	41 (26.1)	39 (28.7)
Occupation		
Not working	14 (8.9)	16 (11.8)
Nonmanual	29 (18.4)	16 (11.8)
Agricultural	50 (31.6)	55 (40.4)
Manual	65 (41.1)	49 (36.0)
Religion		
Hindu	114 (72.2)	135 (99.3)
Muslim	44 (27.8)	1 (0.7)
Caste		
Scheduled caste	33 (21.9)	17 (12.1)
Other backward class	82 (54.3)	81 (58.1)
General class	36 (23.8)	42 (29.8)
Monthly income, thousand INR		

≤ 3	18 (11.5)	16 (11.8)
> 3-6	63 (40.1)	67 (49.3)
> 6-9	24 (15.3)	30 (22.1)
> 9	52 (33.1)	23 (16.9)
Source of drinking water		
Tap in house	1 (0.6)	7 (5.1)
Tube well	103 (65.2)	111 (81.6)
Communal tap	2 (1.3)	8 (5.9)
Protected dug well	1 (0.6)	10 (7.4)
Surface water	51 (32.3)	0 (0)
Storage of cooked food		
Open container	15 (9.5)	14 (10.4)
Closed container	140 (88.6)	119 (88.1)
Refrigerator	3 (1.9)	2 (1.5)
Child variables		
No. of children 6-59 mo measured	191	161
Birth weight, kg		
< 2.7	87 (45.5)	86 (53.4)
≥ 2.7	104 (54.5)	75 (46.6)
Sex		
Female	81 (42.4)	76 (47.2)
Male	110 (57.6)	85 (52.8)
Age, mo[a]	30.0 (1.0)	32.1 (1.1)
Immunization coverage[b]		
Total	22 (11.5)	42 (26.1)
Partial	169 (88.5)	119 (73.9)

Abbreviations: INR, Indian rupee

*Information for income, household size and number of children younger than 5 y could not be determined in 1 household of a flooded village. The caste of 1 household in a flooded village and 1 household in a non-flooded village could not be determined. The type of storage of cooked food in 1 household of a non-flooded village could not be obtained. Description of variables is the absolute number of household or children associated to each characteristic (percentage of the total) except where otherwise indicated.

[a]Child age is reported as mean (SE).

[b]Total immunization includes children vaccinated, confirmed with vaccination card, against Polio (OPV - 3 doses), Tuberculosis (BCG - 1 dose), Measles (MCV - 1 dose), Hepatitis B (HEPB - 3 doses), Diphtheria and Tetanus toxoid and Pertussis (DPT - 3 doses).

Child Malnutrition

Overall prevalences of stunting, underweight and wasting were 31.5%, 17.4% and 12.1%, respectively (Table S2). However, the prevalence of stunting was 38.7% in the flooded cohort compared to 23.0% in the non-flooded cohort. Similarly, the prevalence of underweight was more important in the children living in flooded communities (20.9%) compared to those inhabiting non-flooded villages (13.1%). Wasting was very similar in children experiencing flooding and those populating non-flooded areas, with 12.2% and 11.9%, respectively (Table S2).

Factors Associated with Stunting

Table 2 shows the crude and adjusted associations between stunting and exposure to floods, household size, number of children younger than 5 years, occupation, religion, caste, monthly family income, source of drinking water (at the time of the interview), storage of cooked food, child birth weight, sex, age and immunization coverage. In the bivariate model, exposure to floods, religion and family income were associated with stunting. Muslim children were at higher risk of being stunted, but this difference did not remain statistically significant in the multivariate model. In the adjusted analysis, controlling for all variables in the table, children living in flooded households were more likely stunted compared to those living in non-flooded communities (adjusted PR [APR], 1.60; 95% CI, 1.05-2.44). The children of the poorest families (those reporting to earn equal or less than three thousand rupees a year) were also more likely stunted compared to those in the higher income class (APR, 1.85; 95% CI, 1.11-3.09). The interaction between monthly household income and exposure to floods was not significant.

Table 2 Factors Associated with Stunting in Children Aged 6 to 59 Months in 29 Study Villages in Orissa, India (N=352)[a]

Factor		Stunting			
		Crude PR (95% CI)	P Value	Adjusted PR (95% CI)	P Value
Flood exposure level					
	Household in non-flooded village	1 [Reference]		1 [Reference]	
	Household in flooded village	1.69 (1.21-2.36)	0.002	1.60 (1.05-2.44)	0.031
Household size		0.99 (0.94-1.04)	0.74	1.00 (0.94-1.06)	0.96
No. of children younger than 5 y					
	1	1 [Reference]		1 [Reference]	
	≥ 2	1.14 (0.74-1.39)	0.93	0.91 (0.64-1.28)	0.58
Occupation					
	Nonmanual	1 [Reference]		1 [Reference]	
	Agricultural	0.89 (0.55-1.45)	0.65	1.10 (0.63-1.94)	0.73
	Manual	1.03 (0.64-1.66)	0.89	1.18 (0.69-2.01)	0.55
	Not working	1.12 (0.62-2.15)	0.70	1.33 (0.72-2.45)	0.37
Religion					
	Hindu	1 [Reference]		1 [Reference]	
	Muslim	1.46 (1.03-2.07)	0.036	1.30 (0.76-2.22)	0.34
Caste					
	General class	1 [Reference]		1 [Reference]	
	Scheduled caste	1.29 (0.80-2.07)	0.30	1.16 (0.70-1.91)	0.56
	Other backward class	1.16 (0.79-1.70)	0.46	1.08 (0.69-1.68)	0.74
Monthly income, thousand INR					
	> 9	1 [Reference]		1 [Reference]	
	> 6-9	0.84 (0.49-1.44)	0.52	1.02 (0.58-1.81)	0.94
	> 3-6	1.11 (0.74-1.65)	0.61	1.20 (0.77-1.88)	0.42
	≤ 3	1.65 (1.04-2.36)	0.032	1.85 (1.11-3.09)	0.019

Source of drinking water (at the time of the interview)					
	Well and tap	1 [Reference]		1 [Reference]	
	Surface water	1.41 (0.99-2.00)	0.052	1.02 (0.72-1.45)	0.92
Storage of cooked food					
	Closed container	1 [Reference]		1 [Reference]	
	Open container	1.03 (0.61-1.72)	0.91	0.99 (0.59-1.66)	0.96
	Refrigerator	1.27 (0.43-3.79)	0.66	1.23 (0.46-3.25)	0.68
Birth weight, kg					
	≥ 2.7	1 [Reference]		1 [Reference]	
	< 2.7	1.17 (0.86-1.60)	0.31	1.17 (0.85-1.62)	0.34
Sex					
	Male	1 [Reference]		1 [Reference]	
	Female	1.26 (0.93-1.72)	0.14	1.34 (0.97-1.84)	0.075
Age, mo					
	> 6-18	1 [Reference]		1 [Reference]	
	> 18-26	1.07 (0.65-1.77)	0.80	1.06 (0.63-1.78)	0.82
	> 26-36	1.15 (0.73-1.83)	0.54	1.18 (0.72-1.92)	0.51
	> 36-46	1.03 (0.63-1.68)	0.91	1.05 (0.64-1.69)	0.85
	> 46-60	1.07 (0.66-1.75)	0.78	1.05 (0.65-1.72)	0.83
Immunization coverage					
	Total	1 [Reference]		1 [Reference]	
	Partial	1.23 (0.79-1.91)	0.36	0.92 (0.58-1.46)	0.73

Abbreviations: CI, confidence interval; PR, prevalence ratio.

[a]One observation with missing data on household size, number of children younger than 5 y, income, storage of cooked food, birthweight and sex, and two observations with missing data on caste were deleted in the univariate analyses. Four observations with missing data were deleted from the adjusted analysis. APRs were adjusted for the effect of household size, number of children younger than 5 years, occupation, religion, caste, monthly income, source of drinking water and storage of cooked food, and child birth weight, sex, age and immunization coverage.

Factors Associated with Underweight and Wasting

Underweight was associated with the number of children younger than 5 years living in a household, monthly family income and child birth weight in the univariate analyses (Table 3). Family monthly income was not significant in the multivariate model (APR, 1.76; 95% CI, 0.78-3.99). Contrarily, exposure to floods was not statistically significant in the bivariate model (PR, 1.60; 95% CI, 0.98-2.59) but it became significant in the multivariate model, controlling for all other variables. Children living in flooded communities were at higher risk of being underweight compared to those living in non-flooded households (APR, 1.86; 95% CI, 1.04-3.30). Therefore, children living in a household with one or more under 5 children presented a higher risk of underweight than those living without other under 5 counterparts (APR, 1.69; 95% CI, 1.05-2.72). Low-birth weight children (< 2.7 kg) were at higher risk of being underweight compared to those born with higher weights (APR, 1.80; 95% CI, 1.11-2.92). The interaction between exposure to floods and low-birth weight and number of under five children were not significant. Wasting was not associated to any of the factors considered in this study neither in bivariate nor multivariate models (see Table S3).

Table 3 Factors Associated with Underweight in Children Aged 6 to 59 Months in 29 Study Villages in Orissa, India (N=351)[a]

Factor	Underweight			
	Crude PR (95% CI)	P Value	Adjusted PR (95% CI)	P Value
Flood exposure level				
Household in non-flooded village	1 [Reference]		1 [Reference]	
Household in flooded village	1.60 (0.98-2.59)	0.060	1.86 (1.04-3.30)	0.036
Household size	0.96 (0.88-1.04)	0.35	0.93 (0.85-1.03)	0.16
No. of children younger than 5 y				
1	1 [Reference]		1 [Reference]	
≥ 2	1.71 (1.08-2.71)	0.021	1.69 (1.05-2.72)	0.031
Occupation				
Nonmanual	1 [Reference]		1 [Reference]	
Agricultural	1.52 (0.66-3.50)	0.33	1.52 (0.60-3.83)	0.38
Manual	1.67 (0.73-3.82)	0.23	1.86 (0.77-4.47)	0.17
Not working	1.07 (0.34-3.26)	0.91	1.10 (0.33-3.65)	0.87
Religion				
Hindu	1 [Reference]		1 [Reference]	
Muslim	1.03 (0.56-2.59)	0.92	1.10 (0.49-2.48)	0.82
Caste				
General class	1 [Reference]		1 [Reference]	
Scheduled caste	1.11 (0.59-2.08)	0.75	0.97 (0.53-1.77)	0.91
Other backward class	0.73 (0.43-1.23)	0.24	0.68 (0.37-1.24)	0.21
Monthly income, thousand INR				
> 9	1 [Reference]		1 [Reference]	
> 6-9	1.74 (0.84-3.59)	0.14	2.01 (0.89-4.54)	0.095
> 3-6	1.35 (0.69-2.61)	0.38	1.22 (0.57-2.59)	0.60
≤ 3	2.14 (1.01-4.56)	0.049	1.76 (0.78-3.99)	0.18
Source of drinking water (at the time of the interview)				
Well and tap	1 [Reference]		1 [Reference]	
Surface water	1.31 (0.76-2.28)	0.33	0.99 (0.58-1.71)	0.98
Storage of cooked food				
Closed container	1 [Reference]		1 [Reference]	
Open container	1.03 (0.61-1.72)	0.91	1.22 (0.59-2.52)	0.60
Refrigerator	NA	NA	NA	NA
Birth weight, kg				
≥ 2.7	1 [Reference]		1 [Reference]	
< 2.7	1.82 (1.13-2.95)	0.015	1.80 (1.11-2.92)	0.017
Sex				
Male	1 [Reference]		1 [Reference]	
Female	0.99 (0.63-1.57)	0.97	0.90 (0.57-1.42)	0.65
Age, mo				
> 6-18	1 [Reference]		1 [Reference]	
> 18-26	0.67 (0.24-1.89)	0.45	0.75 (0.27-2.12)	0.59

> 26-36	1.60 (0.76-3.36)	0.22	2.05 (0.98-4.28)	0.056
> 36-46	1.76 (0.84-3.68)	0.13	1.94 (0.94-4.02)	0.076
> 46-60	1.99 (0.97-4.12)	0.063	1.99 (0.98-4.04)	0.057
Immunization coverage				
Total	1 [Reference]		1 [Reference]	
Partial	1.26 (0.66-2.43)	0.48	1.08 (0.58-1.99)	0.81

Abbreviations: CI, confidence interval; PR, prevalence ratio.

[a]One observation with missing data on underweight was deleted from all the analyses. One observation with missing data on household size, number of children younger than 5 y, income, storage of cooked food, birthweight and sex and two observations with missing data on caste were deleted in the univariate analyses. Four observations with missing data were deleted from the adjusted analysis. APRs were adjusted for the effect of household size, number of children younger than 5 years, occupation, religion, caste, monthly income, source of drinking water and storage of cooked food, and child birth weight, sex, age and immunization coverage.

Malnutrition and Recurrent Flooding

In this study, higher prevalence of chronic malnutrition was found in children living in flooded communities compared to those inhabiting the non-flooded ones. Given that this survey started within a month after the flooding onset, it is very unlikely that these malnutrition levels were exclusively related to the most recent flood. Instead, the inundation that took place in August 2006 and affected the same villages might be a more plausible explanation to these findings. We hypothesized that children being less than one year old during 2006 floods (>26-36 months) may have been exposed to nutritional stresses at a very critical age in their development. A separate adjusted analysis of flooded and non-flooded areas by age category revealed important differences between ages in the flooded cohort but not in the non-flooded. Children aged 26 to 36 months presented higher levels of stunting than any other age group (Table 4). Despite the analysis did not show a statistically significant difference between this age group and the reference category, 6-18 months (APR, 1.41; 95% CI, 0.81-2.44) it did for underweight (APR, 2.93; 95% CI, 1.09-7.88), which followed a similar pattern that stunting, with the higher prevalence of underweight concentrated in children 26 to 36 months.

Table 4 Factors Associated with Malnutrition in Children Aged 6 to 59 Months in 13 Flooded and 16 Non-Flooded Study Villages in Orissa, India[a]

	Stunting				Underweight			
	Flooded (n=191)		Non-Flooded (n=161)		Flooded (n=191)		Non-Flooded (n=161)	
Factor	APR (95% CI)	*P* Value	APR (95% CI)	*P* Value	APR (95% CI)	*P* Value	APR (95% CI)	*P* Value
Age, mo								
> 6-18	1 [Reference]		1 [Reference]		1 [Reference]		1 [Reference]	
> 18-26	0.98 (0.51-1.94)	0.98	1.28 (0.45-3.62)	0.64	0.81 (0.21-3.17)	0.76	0.81 (0.15-4.29)	0.80
> 26-36	1.41 (0.81-2.44)	0.23	1.08 (0.40-2.92)	0.87	2.93 (1.09-7.88)	0.012	1.14 (0.21-6.25)	0.88
> 36-46	1.30 (0.70-2.41)	0.41	1.44 (0.55-3.76)	0.46	2.07 (0.86-4.98)	0.11	1.48 (0.33-5.85)	0.57

> 46-60	1.14 (0.63-2.06)	0.67	0.94 (0.34-2.58)	0.91	2.22 (0.92-5.34)	0.078	1.55 (0.40-6.12)	0.53

Abbreviations: CI, confidence interval; APR, adjusted prevalence ratio.

[a]Two observations with missing data were deleted for each of these analyses with the exception of the analysis of underweight in non-flooded areas in which three observations were removed. APRs were adjusted for the effect of household size, number of children younger than 5 years, occupation, religion, caste, monthly income, source of drinking water and storage of cooked food, and child birth weight, sex, age and immunization coverage. Source of drinking water was removed from the analysis of the non-flooded cohort due to lack of respondents reporting drinking surface water in these communities.

DISCUSSION

Our study represents a first attempt to understand the role of exposure to natural disasters as a risk factor for child malnutrition in India. Within one month after the floods, wasting did not differ among children inhabiting the flooded villages and those living in the non-flooded areas. In contrast, a higher risk of stunting was detected in children living in the flooded areas in bivariate and multivariate models. The risk of underweight was significantly higher only in the adjusted analyses. All villages under study in the flooded group were also inundated in previous floods happening in August 2006 (25 months earlier). In the absence of other disasters in the area, the chronic malnutrition detected in this study is related to previous flooding. The study also showed that the cohort of children aged less than one year during previous floods presented higher levels of underweight and stunting compared to the non-flooded group. This finding underlines the importance of early exposure to floods as a risk factor for anthropometric failure in children. Although none of the variables explained the variation in wasting, the analyses did reveal other factors associated with stunting and underweight. The lowest economic status was positively associated with stunting whereas underweight was influenced by low birth weight and the presence of at least one additional under five child in the household.

One evident limitation of this study is direct consequence of its cross-sectional design, which did not allow us to establish causal relationships. Second, we did not measure or control for other social and health conditions in the multivariate models for malnutrition. Third, a different instrument was used to weight children heavier than 10 kg, instead of a single balance. [35] Fourth, our power calculations did not take into consideration subgroup analyses. Probably further determinants of malnutrition would have been revealed using a larger sample size. Fifth, self-reported economic status, especially after disasters, can be subject to reporting bias. To minimize false reporting, field researchers informed the respondents about the purpose of the survey and cross-checked the economic information collected with the house type and assets. Finally, the findings of this study apply to a population of children living in 29 rural communities of Orissa. A population survey instead of a community survey will be required to extend the findings to larger populations, thus making easier to design wider interventions.

The striking similarity in wasting among both groups suggests that the flooded cohort was not subject to additional short-term nutritional stress compared to children living in the non-flooded, at least immediately after the flood. This is probably connected to the fact that government and NGOs were mobilized rapidly and provided supplies right after the onset of flooding (unpublished data). In floods occurring in Bangladesh in 1998, other authors found critical levels of malnutrition (i.e. >15%) during the flood period. [12] The exceptional long duration and magnitude of that flooding probably played an important role in causing a more dramatic situation than the observed in these communities of Orissa. Further research on the same flood event in Bangladesh using a comparison group failed to detect an effect of floods on wasting two months after the floods. [13] In another study on the same floods, the levels of wasting had gone down considerably four months later. [12] These results suggest that the recovery after floods seem to occur promptly in these populations. On the other hand, the absence of significant wasting in the flooded communities of Orissa together with simultaneous higher levels of underweight and stunting suggest that both reflect the long-term health and nutritional experience of the population. [36] These results from India are similar to those found in Bangladesh in which the long-term consequences of floods on nutrition are depicted. [13]

Links between low income and chronic malnutrition have been well described in the literature. [37-41] Low income proxies (such as landlessness) have been observed as a risk factor for acute malnutrition among flood affected children in Bangladesh [10]. More recently, another study has shown that the children of flood-affected families taking loans at very high rates did not improve their nutritional status compared to those having access to credits at very low or no interest. [12] However the latter studies only establish the short term effects of the disaster. None have established economic status as a risk factor for chronic malnutrition – a long term consequence, among flood affected children.

Finally, the lack of significant interaction between significant variables, such as exposure to floods and income, confirms that higher economic status is not protective against the impacts of floods on child malnutrition. More research is necessary to understand the complex dynamics of child malnutrition after severe flooding and its socio-economic and health determinants. Representative larger surveys are recommended, which should help to confirm these results and help policy makers in implementing appropriate measures.

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FOOTNOTES

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Patient consent Obtained.

Competing interest None declared.

Ethics approval Persons eligible to participate in the study were not offered a monetary incentive for participation. All the participants involved in the study were informed about the nature of the study, research objectives and about confidentiality of the data, with the assurance that non-participation would not lead to negative consequences. It was not possible to blind assessors, as they needed to visit households to conduct the interviews.

Written informed consent was obtained for every head of household visited. In case the respondent was an illiterate, we asked a literate person from the community to read out the consent form and explain it to the head of the family. Then we obtained the thumb impression of the respondent. In those case, the person who readout the consent form also signed as a witness. Research procedures were consistent with the Declaration of Helsinki.[42] Interviews were administered after obtaining informed consent. The protocol was reviewed by a small group of scientists who had experience working with survivors of natural disasters and amended based on their recommendations.

Contributors

Study concept and design: Guha-Sapir, Mukhopadhyay, Ranjan-Dash, Rodriguez-Llanes.
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Drafting of the manuscript: Rodriguez-Llanes.
Critical revision of the manuscript for important intellectual content: Rodriguez-Llanes, Guha-Sapir, Degomme, Ranjan-Dash, Mukhopadhyay.
Statistical analysis: Rodriguez-Llanes.
Administrative, technical or material support: Ranjan-Dash, Rodriguez-Llanes, Guha-Sapir, Mukhopadhyay.
Obtained funding: Guha-Sapir.
Study supervision: Ranjan-Dash, Mukhopadhyay.

Data sharing statement Statistical code available from the corresponding author.

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FIGURES

Figure 1 Flow diagram of the sample obtained on 352 children aged 6 to 59 months in Jagatsinghpur district, Orissa, India

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3,4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5,6,7
Bias	9	Describe any efforts to address potential sources of bias	7,8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	None
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7, Fig 1
		(b) Give reasons for non-participation at each stage	7, Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11
		(*b*) Report category boundaries when continuous variables were categorized	9-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14,15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

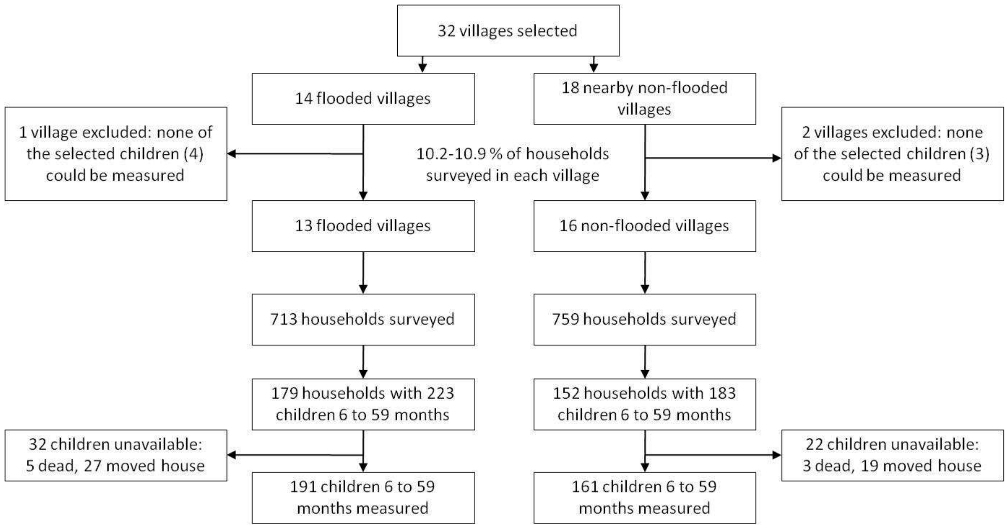

Figure 1 Flow diagram of the sample obtained on 352 children aged 6 to 59 months in Jagatsinghpur district, Orissa, India
234x122mm (150 x 150 DPI)

Child Malnutrition and Recurrent Flooding in Rural Eastern India: A Community-Based Survey

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Primary Subject Heading:	Epidemiology
Keywords:	stunting, chronic disease, nutritional status, natural disaster, development, climate change

Child Malnutrition and Recurrent Flooding in Rural Eastern India: A Community-Based Survey

ABSTRACT

Objectives This study aims to improve the understanding of the relationship between exposure to floods and malnutrition in children aged 6 to 59 months in rural India. Research has focused exclusively on Bangladeshi children and few controlled epidemiological studies are available.

Method A community-based cross-sectional study of child nutritional status carried out in 14 flooded and 18 non-flooded villages of Jagatsinghpur district (Orissa) after the September 2008 floods, and similarly affected by flooding in August 2006. Face-to-face interviews were conducted in 757 households in the flooded villages and 816 in the non-flooded communities. Data used in this study were from those households with children 6 to 59 months. In total, 191 and 161 children were measured, respectively. The association between various malnutrition indicators and the exposure to floods was assessed by univariate and multivariate logistic regression.

Results Adjusted analyses revealed that children in flooded households were more likely stunted compared to those in non-flooded ones (APR, 1.60; 95% CI, 1.05-2.44). The prevalence of underweight was also higher in children living in the flooded communities (APR, 1.86; 95% CI, 1.04-3.30). Further analyses found the 26-36 months flooded cohort, thus those children younger than one year during the precedent flood in August 2006, attained the largest difference in levels of stunting compared to theunexposed group of the same age.

Conclusion Exposure to floods is associated with long-term malnutrition in these rural communities of Orissa, India. Children exposed to floods during their first year of life presented higher levels of chronic malnutrition. Long-term malnutrition prevention programs after floods should be implemented in flood-prone areas.

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Deleted: , those living with one or more under five children (APR, 1.69; 95% CI, 1.05-2.72) and born with lower weights (APR, 1.80; 95% CI, 1.11-2.92)

Deleted: age group

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Deleted: and underweight within the flooded areas, thus those younger than one year during the precedent flood in August 2006

ARTICLE SUMMARY

Article focus

- Study of the connection between flood exposure and childhood malnutrition in rural communities of north eastern India

Key messages

- First study that addresses the health impacts of floods on child malnutrition in India, a country prone to multiple natural disasters
- Climate-related extreme events are projected to increase partly induced by climate change, leading to a higher burden of disaster-related diseases
- Exposure to floods is associated with chronic growth retardation in Indian children, especially in those exposed at very early stages in life

Strengths and limitations of this study

Strengths

- High and consistent survey response rates across flooded and non-flooded communities
- Use of standard methodology, including high precision WHO standards to assess malnutrition

Limitations

- The study does not establish causal relationship but an association between floods and childhood malnutrition
- Study only representative of the children 6 to 59 months living in 29 rural communities

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INTRODUCTION

Floods are the most common reported natural disaster worldwide, [1]with important impact on the health of human populations.[2, 3] Their effects are especially dramatic in developing countries of south and south-east Asia.[4]Epidemiological studies in low-income rural areas show evidence for increased risk of disease associated to flooding, such as diarrhea [5, 6], cholera [7], respiratory infection [5], leptospirosis [8] or posttraumatic stress disorder, PTSD [9]. However, little and geographically restricted evidence is available on the nutritional impacts of floods on children [10-13].

Flooding has demonstrated serious impacts on crop productivity in the past, [14, 15]and the projected higher global temperatures may have nonlinear and increasingly negative impacts on existing agricultural activities [16],particularly on vulnerable countries of south Asia and southern Africa where insufficient adaptation measures areplanned. [17] Crop yield variation induced by climate change has been suggested as one of the potential mechanisms leading to malnutrition. [18]

This is particularly worrying since children are especially vulnerable to environmental adversities because of their greater exposure, greater sensitivity to certain exposures, and their dependence on caregivers.[19,20]For this reason, increased weather variability predicted by climatic models is expected to lead to a rise in the health risks of this age group, associated with more frequent extremes like droughts and floods.[19-21]

The deleterious consequences of poor nutrition are well recognized. Undernutrition is a primary cause of ill-health and premature mortality among children in developing countries.[22] Therefore,malnutrition affects children during critical phases of their early cognitive, social, motor and emotional development, and has been associated with poor school performance. [23, 24] Poverty and food security are also risk factors which have been found to be associated with poor early development in children. [25] Thus, these disadvantaged children are less likely to become productive adults, [23] perpetuating the cycle of poor human development. [25]

India is one of the most disaster-prone countries in the world. [1] The Indian state of Orissa, located by the Bay of Bengal, is vulnerable to multiple disasters, like tropical cyclones, storm surges, floods and tsunamis. The state of Orissa suffered heavy loss of life and property during the cycloneParadip that hit the state in October 1999. [26] As a consequence, an autonomous relief and coordination body was created in the state, the Orissa State Disaster Mitigation Authority (OSDMA). Since then, this agency has been actively working in disaster management, prevention, risk reduction and relief activities. Complementary to long term poverty alleviation programs, there are also short term food aid governmental programs to help the victims of disasters within the country (SRD, personal communication).

Despite a rising awareness on understanding the health effects of extreme weather events, [19, 27, 28]without a better understanding of the mechanisms which produce and maintain high levels of malnutrition in developing countries, policy makers lack crucial information to

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Deleted: Despite these presumed linkages,a recent review has pointed out limited evidence on the health effects of floods in controlled epidemiological studies, particularly of morbidity. [3]Though some studies have examined mortality, disease or mental health, there is little research on the association between floods and children's nutritional health, and this evidence is geographically restricted to flood-prone areas of Bangladesh.[10-13]

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Deleted: limited evidence is available at present.[3, 10, 11, 12, 13]Specifically, design specific and effective intervention plans to reduce its prevalence among children. This is especially critical in the face of theforeseen long-lasting intensificationof the water cycle [29] and therise of human vulnerability to extreme weather events. [30] In Orissa, climate models predict an intensification of precipitation events, including monsoons, and increased sea level pressure by the end of the 21st century. [31] Additionally,vulnerability-resilience analysisshows Orissa as oneof the most vulnerable Indianstates to climate change. [32]

The most recent floods occurring in Orissa in September 2008 provided an opportunity to explore the strengths of association between flooding and the prevalence of undernutrition while taking other variables that directly affect nutrition into account.

MATERIALS AND METHODS

This study used a cross-sectional stratified (by village) design with sampling at the household level to collect data on a representative sample of thechildren aged 6 to 59 months living in 13 flooded communities and 16 nearbynon-flooded villages within a month after the September 2008 floods. We used anthropometric measurements to assess child malnutrition and face-to-face interviews to investigate the exposure to floods as a risk factor for malnutrition and the potential confounding effect of social, health and economic variables.

Study area

The study site wasJagatsinghpur, a coastal district located in the state of Orissa, eastern India. The district is organized into eight blocks and has a population of 1 057 629, with 90% residing in rural areas. [33] The district has been severely hit by five major floods in the last decade, the one following thecycloneParadip(05B) in 1999, followed byheavy floods in 2001, 2003, and 2006. Thelast floods, starting in mid-September 2008, produced large devastation. [1]

Sample selection

The villages in this study were selected from the 5 worst affected blocks in the district(Kujanga, Biridi, Balikuda, Tirtol and Ersama) according toOSDMA. This agency provided the list of the flooded and non-flooded villages, definedas those with all households inundated by the floods and those with none of the households flooded, respectively. Logistic considerationslimitedour study to 14 accessibleflooded villages. Eighteen non-flooded nearby villages of similar size and demographic characteristics were selected as comparison group(Table S1). These 14 and 18 villages were also inundated and non-inundated, respectively, during previous floods occurring in August 2006. We validated this information using the survey household data. All respondents interviewed in the 14 flooded villages (n=757) confirmed that their household were exposed to only these two

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This study was conducted under the MICRODISproject, through a EC Framework 6 Research grant. The overall goal of this project was to strengthen preparedness, mitigation and prevention strategies in order to reduce the health, social and economic impacts of extreme events on communities. The consortium consists of a total of 19 academic institutions and grassroots organizations, administering empirical work in selected flood, storm and earthquake sites ... [1]

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floods and the cyclone Paradip in October 1999. Most respondents considered the 2008 floods 'very severe' (84.6%) in contrast with the 2006 floods which most households categorized as 'mild' (79.5%).

Stratified samplingat the village level was used. In each village,10% of households were surveyed (Figure 1). This allowed us to obtain a sample with a distribution of households across villages comparable to that in the population. The list of the children 6 to 59 months were obtained at the ICDS center (Integrated Child Development Scheme) at each village and were used as a check of the information given by the head of the households. In total, 757households were surveyed in the 14 flooded communities and 816 in the 18 non-flooded villages. In surveyed households with more thanonechild 6 to 59 months, all eligible children were selected.In three small villages, one flooded and two non-flooded,all the 7 eligible children selected moved home and consequently these villages were excluded from furtheranalyses (Figure 1). The study population was defined as those children aged 6 to 59 months of the remaining 29 villages, which represented less than 5% of the total populationand were present, overall, in less than 25% of the households surveyed (Table S1).

A household was defined as a group of people who usually live under the same roof and share a common kitchen. If an adult member or any eligible children 6 to 59 monthswas not at home at the time of the survey, the interviewersreturned to the household later. The maximum number of visits per household was fixed at three. For selection of the households, we used a modified EPI 'random walk' method. [34, 35]At the centre of the village, a team member spun a pen, following the direction pointed by the pen up to the limit of the village. The same procedure was repeated from the new location to randomly choose a direction in which to conduct the survey. A random direction is selected each time that a bifurcation is encountered. Random numbers are generated toselect the households. The nesteddata used in this study were from those households with children 6 to 59 months. Thus the final sample was 179 households with 223 children in the 13 flooded villages, and 152 households with 183 children in the 16 non-flooded communities.Overall, 85.2% of these eligible children were measured and their parents interviewed.The response rate was consistent across the flooded (84%) and non-flooded communities (86.6%). Thirty-two children were not measured in the flooded households. Five of them have recently died and 27 stayed with relatives in different villages. In the non-flooded communities, twenty-two children were unavailable. Nineteen of these children moved with their parents elsewhere and other 3 died (Figure 1).

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Instruments, training and pilot testing

Anthropometric measurements of children and adapted questionnaires were used to obtain the information on anthropometrics, household characteristics and other children variables. Fourteen interviewers, three supervisors and one data manager were specifically trained for this study during a three days workshop organized by the Voluntary Health Association of

India (VHAI) under the supervision of The MICRODIS project university partners, local government officers and other local researchers. Thequestionnaires were pre-tested in 45 households. The questionnaire was translated to the local language in Orissa (Oriya) and then back translated into English by two different translators. Field work was carried out between 6 October and 19 November 2008.

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Weight and height of every child were measured twice to minimize measurement errors and increase precision by using their average value. Weight measurements were undertaken to the nearest 100 grams using a 10 kg beam balance (Raman Surgical Co., Delhi-33, India) and a 50 kg standard electronic balance. For children younger than 2 years of age, length was measured to the nearest millimeter in the recumbent position using an infantometer (Narang Medical Ltd.Delhi - 110 028, India). Children older than 2 years were measured in a standing position using a measuring board. All instruments were calibrated daily.

Outcome measures, exposure and confounders

The outcomes of this study were three anthropometric indices, stunting (height-for-age), underweight (weight-for-age) and wasting (weight-for-height). Stunting is an indicator of chronic malnutrition whereas wasting often assesses acute nutritional stress within a population. Underweight combines the previous two, widely used for its operational value.The new World Health Organization (WHO) standard was used to calculate the z scores for these indicators. Malnutrition was a binary variable indicating whether a children is malnourished, z score <-2 (1) or not (0) at the time of the interview. The fundamental variable of this study was the level of children exposure to floods, measured as whether the village was flooded (1) or not (0). Therefore, thirteen other variables included information at the household and individual (children) level (Table 1). In the first group, we recorded the number of persons residing in each household (household size) measured as a continuous variable, number of children younger than 5 years living in a household,dichotomized as one (0) or otherwise (1). The main occupation of the household was recorded in detailed categories and later recoded as non manual (reference), agricultural, manual and unemployed.Two religions were present in the study area, Hinduism, taken as the reference group, and Muslim.Caste of the household was based on the household head and was grouped as scheduled caste, other backward class or general class (reference category). The general class represents the higher caste status in India. The scheduled caste is the social group historically subject to the higher deprivation levels in the country. Monthly household income (in thousand Indian rupees INR) was collected from respondents as a continuous variable and recoded into four categories: ≤ 3, > 3-6, > 6-9 and > 9, chosen as the reference category.The household source of drinking water at the time of the interview was recorded in a detailed questionnaire (Table 1) and recoded as whether they were more secure sources, such as wells and taps (0) or unsecure such as surface water (1), consumed in the flooded areas. The storage of cooked food was also listed using a detailed questionnaire and dichotomized into closed containers (0) and open containers (1).

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Within the second group, a number of individual variables were recorded. Birth weights were obtained from birth certificates and/or vaccination cards available and were coded as a binary variable above and belowthe median.Sex was a binary variable. Age was recorded from birth certificates and/or vaccination cards in most cases (85% of respondents). If these were not available, local calendars were used. Children were classifiedby the reported age into the following groups (in months): 6 to 18, 18 to 26, 26 to 36, 36 to 46, and 46 to 59. This classification was used tocompare theprevalence of malnutrition in those children younger than 1 year exposed to the 2006 floods(aged 26 to 36 months at the time of this study), with those of the non-flooded cohort in the same age group. Children immunization coverage was obtained from vaccination cards available. Children fully vaccinated, proved with vaccination card, against Polio (3 doses), Tuberculosis (1 dose), Measles (1 dose), Hepatitis E (3 doses), Diphtheria and Tetanus toxoid and Pertussis (3 doses)were classified as those with full immunization coverage (0), otherwise partially immunized (1).

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Power analysis

Considering that 10% of 14 948households (7248 flooded and 7700 non-flooded) were planned to be surveyed and that the expectation of getting a household with at least 1 eligible child is ¼, the expected number of households containing children in our samplewas 181 and 192.Assuminga two thirds prevalence of malnutrition in non-flooded compared to flooded households, with α (error) = 0.05, using the average percentage of stunting in Orissa state (children < 5 years) as the prevalence for the flooded area (45) [36] and two thirds (30) as a conservative approximate for the non-flooded, a power of 84% would be achieved. The minimum sample size, with power 80%, would be 164 in each group.

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Data analysis

Malnutrition indices were calculated using ENA for SMART version November 2008 (Erhardt and Golden 2008). The new World Health Organization (WHO) standard was used to calculate z scores.Statistical analyses were conducted in R version 2.10.1 (R Development Core Team 2008). [37] Missing data were rare.Data were missing on underweight and wasting in 1 and 5 respondents, respectively. In 1 respondent, data were missing on income, number of children under five and household size. Data were missing on caste in 2 respondents, and on food storage in 1 respondent.

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In cross-sectional epidemiological research studying rare outcomes, the odds ratio (OR) is very close to the relative risk (RR). If the outcome is common as it is the case in this study (i.e. prevalence > 10%), ORs tend to differ from RRs. Prevalence ratios (PR), as named in this study, were then used instead of prevalence odds ratio (POR), to avoid confusion in the interpretation of the results. [38, 39]Quasi-binomial models were usedto avoid overdispersion. Additionally, starting values and increasing the number of iterations were necessary to fit these models. [40]GLM quasi-binomial models were used to explore

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bivariate associations between malnutrition and independent variables, reported as crude (unadjusted) PRs with their associated 95% confidence intervals (CIs). Multivariate (adjusted) models were used to identify variables predictive of malnutrition, controlling for all other variables in the model. ANOVA models were used to test the difference between Z-scores (a continuous variable) of the flooded and non-flooded cohortsin each of the age groups previously defined.Two-way interactions were examined for significant parameters in the adjusted models ($p<0.05$). Alpha level was set at 5% and all statistical tests were two sided.

RESULTS

Demographic Characteristics

Table 1 reports characteristics of the sample by exposure group. More nonmanual (18.4%) and less agricultural work (31.6%) were reported by the respondents in the flooded communities compared to the non-flooded (11.8% and 40.4%, respectively).The higher proportion of Muslim in the flooded group (27.8%) was due to a large Muslim population living in a single village.More individuals from the scheduled caste were living in the flooded communities (21.9%) compared to the non-flooded (12.1%). The access to safe drinking water was limited right after the floods and 32.3% of the respondents affirmed to drink surface water.

Table 1 Characteristics of 294 Households and 352 Children in 29 Study Villages in Orissa, India*

Characteristics	Flooded (n = 13)	Non-Flooded (n = 16)
Household variables		
No. of households with any children 6-59 mo measured	158	136
Total no. of persons residing in household, mean (SD)	7.2 (2.8)	7.5 (2.9)
No. of children younger than 5 y		
1	116 (73.9)	97 (71.3)
≥ 2	41 (26.1)	39 (28.7)
Occupation		
Not working	14 (8.9)	16 (11.8)
Nonmanual	29 (18.4)	16 (11.8)
Agricultural	50 (31.6)	55 (40.4)
Manual	65 (41.1)	49 (36.0)
Religion		
Hindu	114 (72.2)	135 (99.3)
Muslim	44 (27.8)	1 (0.7)
Caste		
Scheduled caste	33 (21.9)	17 (12.1)
Otherbackward class	38 (25.2)	81 (57.4)
General class	36 (23.8)	42 (29.8)
Other	44 (29.1)	1 (0.7)
Annualincome, thousand INR		

≤ 3	18 (11.5)	16 (11.8)
> 3-6	63 (40.1)	67 (49.3)
> 6-9	24 (15.3)	30 (22.1)
> 9	52 (33.1)	23 (16.9)
Source of drinking water (at the time of the interview)		
Tap in house	1 (0.6)	7 (5.1)
Tube well	103 (65.2)	111 (81.6)
Communal tap	2 (1.3)	8 (5.9)
Protecteddugwell	1 (0.6)	10 (7.4)
Surface water	51 (32.3)	0 (0)
Storage of cookedfood		
Open container	15 (9.5)	14 (10.4)
Closed container	140 (88.6)	119 (88.1)
Refrigerator	3 (1.9)	2 (1.5)
Child variables		
No. of children 6-59 mo measured	191	161
Height-for-age, no. (%)		
Stunting, Z-score < -2	74 (38.7)	37 (23.0)
Severestunting, Z-score < -3	29 (15.2)	14 (8.7)
Weight-for-age[a],no. (%)		
Underweight, Z-score < -2	40 (20.9)	21 (13.1)
Severeunderweight, Z-score < -3	11 (5.8)	7 (4.4)
Weight-for-height[b], no. (%)		
Wasting, Z-score < -2	23 (12.2)	19 (11.9)
Severewasting, Z-score < -3	8 (4.3)	8 (5.0)
Birthweight, kg		
< 2.7	87 (45.5)	86 (53.4)
≥ 2.7	104 (54.5)	75 (46.6)
Sex		
Female	81 (42.4)	76 (47.2)
Male	110 (57.6)	85 (52.8)
Age, mo[c]	30.0 (1.0)	32.1 (1.1)
Immunizationcoverage[d]		
Total	22 (11.5)	42 (26.1)
Partial	169 (88.5)	119 (73.9)

Abbreviations: INR, Indianrupee; CI, confidence interval.

*Information for income, household size and number of children younger than 5 y could not be determined in 1 household of a flooded village. The caste of 1 household in a flooded village and 1 household in a non-flooded village could not be determined. The type of storage of cooked food in 1 household of a non-flooded village could not be obtained. Description of variables is the absolute number of household or children associated to each characteristic (percentage of the total) except where otherwise indicated.

[a]One observation with missing data was excluded from the analyses in the non-flooded cohort.

[b]Four observations with missing data were excluded from the analyses in the flooded cohort and one in the non-flooded cohort.

[c]Child age is reported as mean (SE).

[d]Total immunization includes children vaccinated, confirmed with vaccination card, against Polio (OPV - 3 doses), Tuberculosis (BCG - 1 dose), Measles (MCV - 1 dose), Hepatitis B (HEPB - 3 doses), Diphtheria and Tetanus toxoid and Pertussis (DPT - 3 doses).

Child Malnutrition

Overallprevalences of stunting, underweight and wasting were 31.5%, 17.4% and 12.1%, respectively (Table 1). However, the prevalence of stunting was 38.7% in the flooded cohort compared to23.0% in the non-flooded cohort. Similarly, the prevalence of underweight was more important in the children living in flooded communities (20.9%) compared to those inhabiting non-flooded villages (13.1%). Wasting was very similar in children experiencing flooding and those populating non-flooded areas, with 12.2% and 11.9%, respectively (Table 1).

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Factors Associated with Stunting

Table S2 shows the crude and adjusted associations between stunting andexposure to floods, household size, number of children younger than 5 years, occupation, religion, caste, monthly family income, source of drinking water, storage of cooked food, child birth weight,sex, age and immunization coverage. In the bivariate model, exposure to floods, religion and family income were associated with stunting. Muslim children were at higher risk of being stunted, but this difference did not remain statistically significant in the multivariate model. Table 2 shows the significant determinants of stuntingin the adjusted analyses.Children living in flooded households were more likely stunted compared to those living in non-flooded communities (adjusted PR [APR], 1.60; 95% CI, 1.05-2.44). The children of the poorest families (those reporting to earn equal or less than three thousand rupees a year)were also more likely stunted compared to those in the higher income class (APR, 1.85; 95% CI, 1.11-3.09). The interaction between monthly household income and exposure to floods was not significant.

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Table 2Factors Associated with Malnutrition in Children Aged 6 to 59 Months in 29 Study Villages in Orissa, India

Factor	Stunting[a]		Underweight[b]		Wasting[c]	
	APR (95% CI)	P Value	APR (95% CI)	P Value	APR (95% CI)	P Value
Flood exposurelevel						
Household in non-flooded village	1 [Reference]		1 [Reference]		1 [Reference]	
Household in flooded village	1.60 (1.05-2.44)	0.031	1.86 (1.04-3.30)	0.036	1.21 (0.61-2.42)	0.58
No. of children younger than 5 y						
1	1 [Reference]		1 [Reference]		1 [Reference]	
≥ 2	0.91 (0.64-1.28)	0.58	1.69 (1.05-2.72)	0.031	1.29 (0.68-2.45)	0.43
Annualincome, thousand INR						

> 9	1 [Reference]		1 [Reference]		1 [Reference]	
> 6-9	1.02 (0.58-1.81)	0.94	2.01 (0.89-4.54)	0.095	1.27 (0.42-3.86)	0.67
> 3-6	1.20 (0.77-1.88)	0.42	1.22 (0.57-2.59)	0.60	1.41 (0.56-3.54)	0.47
≤ 3	1.85 (1.11-3.09)	0.019	1.76 (0.78-3.99)	0.18	2.13 (0.76-6.02)	0.15
Birthweight, kg						
≥ 2.7	1 [Reference]		1 [Reference]		1 [Reference]	
< 2.7	1.17 (0.85-1.62)	0.34	1.80 (1.11-2.92)	0.017	1.28 (0.69-2.38)	0.46

Abbreviations: CI, confidence interval; APR, adjustedprevalence ratio.

[a]Four observations with missing data were deleted from the analysis.

[b]One observation with missing data on underweight was deleted from the analyses. Four additional observations with missing data were deleted from the analysis.

[c]Five observations with missing data on wasting were deleted from all the analyses. Four additional observations with missing data were deleted from the analysis. APRs were adjusted for the effect of all the other variables shown in the table and household size, occupation, religion, caste, source of drinking water and storage of cooked food, sex, age and immunization coverage.

Factors Associated with Underweight and Wasting

Underweight was associated with the number of children younger than 5 years living in a household, monthly family income and child birth weight in the univariate analyses (Table S3). Family monthly income was not significant in the multivariate model (APR, 1.76; 95% CI, 0.78-3.99). Contrarily,exposure to floods was not statistically significant in the bivariate model (PR, 1.60; 95% CI, 0.98-2.59) but it became significant in the multivariate model(APR, 1.86; 95% CI, 1.04-3.30 - seeTables 2 and S3). Therefore, children living in a household with one or more under 5 children presented a higher risk of underweight than those living without other under 5 counterparts (APR, 1.69; 95% CI, 1.05-2.72). Low-birth weightchildren (< 2.7 kg) were at higher risk of being underweight compared to those born with higher weights (APR, 1.80; 95% CI, 1.11-2.92). The interaction between exposure to floods and low-birth weight and number of under five children were not significant.Wasting was not associated to any of the factors considered in this study neither in bivariate nor multivariate models (Tables 2 andS4).

Malnutrition and Recurrent Flooding

ANOVA analyses were used totestthe differences in Z-scores for stunting and underweight by age categorybetween the flooded and non-flooded cohorts. Thechildren aged 26 to 36 months of the flooded cohort presentedthelargestdifferencein stunting with those of the non-flooded compared to otherage groups, except for the 6 to 18 months cohort (Table 3). The difference was only significant for the group 26 to 36 (p<0.001).These differences were less evident for underweight (see Table 3).

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Deleted: In this study, higher prevalence of chronic malnutrition was found in children living inflooded communities compared to those inhabiting the non-flooded ones. Given that this survey started within a month after the flooding onset,it is very unlikely that these malnutrition levels were exclusively related to the most recent flood. Instead, the inundation that took place in August 2006 and affected the same villages might be a more plausible explanation tothese findings.We hypothesized that childrenbeing less than one year old during 2006 floods (>26-36 months) may have been exposed to nutritional stresses at a very critical age in their development.

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Table 3 Differences in Stunting and Underweight Z-scores Between Flooded and Non-Flooded Children by Age Groups in Orissa, India

	Stunting		Underweight	
Factor	Difference in Mean	P Value	Difference in Mean	P Value
Age, mo				
> 6-18	-1.1	0.17	-0.3	0.39
> 18-26	-0.02	0.95	0.1	0.74
> 26-36	-1.1	0.0006	-0.4	0.07
> 36-46	-0.5	0.29	-0.3	0.19
> 46-60	-0.2	0.62	-0.3	0.38

DISCUSSION

Our study represents a first attemptto understand the role of exposure to natural disastersas a risk factor for child malnutrition in India. Within one month after the floods, wasting did not differ among children inhabiting the flooded villages and those living in the non-flooded areas.In contrast, a higher risk of stunting was detected in children living in the flooded areas in bivariate and multivariate models. The risk of underweight was significantly higher only in the adjusted analyses. All villages under study in the flooded group were also inundated in previous floods happening in August 2006 (25 months earlier). In the absence of other disasters in the area,our results suggest an association of chronic malnutrition and previous flooding in these children. The study also showed that the exposedcohort of children aged less than one year during the 2006 floods presented thelargest difference in levels of stunting with thenon-flooded group of the same age. This finding underlinesthe importance of early exposureto floods as a risk factor for anthropometric failure in children.

One evident limitation of this study is direct consequence of its cross-sectional design, which did not allow us to establish causal relationships. Second, this study was conducted soon after waters start to recede in aheavily flooded areawhereroadblocks were commonplace.In consequence,thereexists selecting bias in the choice of the affected villages. Nevertheless, if the situation was even worst in more isolated villages not represented in the sample, it is remarkable that we already found increased risk for malnutrition among these exposed children. In contrast, wasting could have been more important than reflected in our results in the mostisolated communities. Thus,this community-based studylimits our findings to twosubpopulations of children living in 29 rural communities of Orissa. Apopulation survey would be necessary to assess health impacts and disease riskin a populationbetter representingthe one affected,and thus making easier to design wider interventions.Third,this study did notincludeother relevant conditions related to malnutrition, such as maternal education, variables onlosses,food insecurity and coping mechanismswhich mayimpact this association and further explain the mechanisms which

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Deleted: in the multivariate models for malnutrition lead to malnutrition after floods.Fourth, a different instrument was used to weight children heavier than 10 kg, instead of a single balance. [41] Fifth, our power calculations did not take into consideration subgroup analyses. Probably further determinants of malnutrition would have been revealed using a larger sample size. Sixth, self-reported economic status, especially after disasters, can be subject to reporting bias. To minimize false reporting, field researchers informed the respondents about the purpose of the survey and cross-checked the economic information collected with the house type and assets.

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Deleted: Finally, the findings of this study apply to a population of children living in 29 rural communities of Orissa. A population survey instead of a community survey will be required to extend the findings to larger populations, thus making easier to design wider interventions.

The striking similarity in wasting among both groups suggests that the flooded cohort was not subject to additional short-term nutritional stresscompared to children living in the non-flooded, at leastimmediatelyafter the flood. This is probably connected to the fact that government and NGOs were mobilized rapidly and provided supplies right after the onset of flooding (unpublished data) and this might be the case after the 2006 event. In floods occurring in Bangladesh in 1998, other authors found critical levels of malnutrition (i.e. >15%) during the flood period. [12] The exceptional long duration and magnitude of that flooding probably played an important role in causing a more dramatic situation than the observed in these communities of Orissa. Further research on the same flood event in Bangladesh using a comparison group failed to detect an effect of floods on wasting two months after the floods. [13] In another study on the same floods, the levels of wasting had gone down considerably four months later.[12] These results suggest that the recovery after floods seem to occur promptly in these populations.On the other hand, the absence of significant wasting in the flooded communities of Orissa together with simultaneous higher levels of underweight and stunting suggest that both reflect the long-term health and nutritional experience of the population. [42]These results from India are similar to those found in Bangladesh in which the long-term consequences of floods on nutrition are depicted. [13]

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Low income proxies (such as landlessness) have been observed as a risk factor for acute malnutrition among flood affected children in Bangladesh[10]. More recently, another study has shown that the children of flood-affected families taking loans at very high rates did not improve their nutritional status compared to those having access to credits at very low or no interest. [12] However the latter studies only establish the short term effects of the disaster.None have established economic status as a risk factor for chronic malnutrition – a long term consequence, among flood affected children.

Deleted: Links between low income and chronic malnutrition have been well described in the literature.[37-41]

Finally, the lack of significant interaction between significant variables, such as exposure to floods and income, supports that higher economic status is not protective against the impacts of floods on child malnutrition, at least in these communities.More research is necessaryto understandthe complex dynamics of child malnutrition after severe flooding and its socio-economic and health determinants. Representative larger surveys are recommended, which should help to confirm these results and help policy makers in implementing appropriate measures.

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FOOTNOTES

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Patient consent Obtained.

Competing interest None declared.

Ethics approval Persons eligible to participate in the study were not offered a monetary incentive for participation.All the participants involved in the study were informed about the nature of the study, research objectives and about confidentiality of the data, with the assurance that non-participation would not lead to negative consequences. It was not possible to blind assessors, as they needed to visit households to conduct the interviews.

Written informed consent was obtained for every head of household visited.In case the respondent was an illiterate, we asked a literate person from the community to read out the consent form and explain it to the head of the family. Then we obtained the thumb impression of the respondent. In those case, the person who readout the consent form also signed as a witness. Research procedures were consistent with the Declaration of Helsinki.[43] Interviews were administered after obtaining informed consent. The protocol was reviewed by a small group of scientists who had experience working with survivors of natural disasters and amended based on their recommendations.

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Contributors

DGS obtained the funding. DGS, AM, SRD, JRL conceived and designed the study. SRD and AM collected the data and supervised the study. JRL, DGS, OD analyzed and interpreted the data. JRL conducted the statistical analyses and drafted the manuscript. SRD, JRL, DGS and AM provided administrative, technical or material support.All authors critically revised the manuscript for important intellectual content.

Data sharingstatement Statistical code available from the corresponding author.

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FIGURES

Figure 1 Flow diagram of the sample obtained on 352 children aged 6 to 59 months in Jagatsinghpur district, Orissa, India

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Data source

This study was conducted under the MICRODISproject, through a EC Framework 6 Research grant. The overall goal of this project was to strengthen preparedness, mitigation and prevention strategies in order to reduce the health, social and economic impacts of extreme events on communities. The consortium consists of a total of 19 academic institutions and grassroots organizations, administering empirical work in selected flood, storm and earthquake sites in Asia and Europe, along with the development of integrated assessment methods and tools. This specific research was led by the Voluntary Health Association of India (VHAI) in collaboration with the Centre for Research on the Epidemiology of Disasters – Université catholique de Louvain (CRED-UCL). The main objective of the present survey was to assess jointly the economic, social and health impact of floods in Orissa, India. The data presented herefocuses on the impacts of floods on child malnutrition.

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a governmental agency in charge of statewide disaster relief operations,

STROBE 2007 (v4)Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3,4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5,6,7
Bias	9	Describe any efforts to address potential sources of bias	7,8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	None
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7, Fig 1
		(b) Give reasons for non-participation at each stage	7, Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11
		(*b*) Report category boundaries when continuous variables were categorized	9-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14,15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

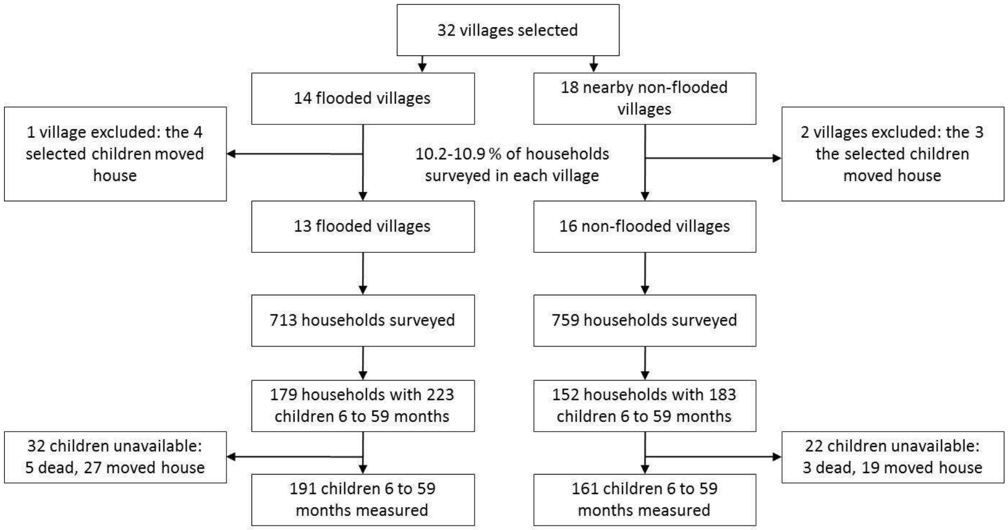

Figure 1 Flow diagram of the sample obtained on 352 children aged 6 to 59 months in Jagatsinghpur district, Orissa, India
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