Original Article

Association of maternal height and body mass index with nutrition of children under 5 years of age in India: Evidence from Comprehensive National Nutrition Survey 2016–18

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Background and Objectives: Child undernutrition remains an area of public health concern across the globe, particularly in developing countries like India. Previous studies have focused on the association of maternal nutrition with premature pregnancy and birthweight of child, with few establishing the intergenerational effect but limited to select populations and geography. **Methods and Study Design:** This study used data from 35,452 children aged under 5 years and their biological mother from nationally representative Comprehensive National Nutrition Survey (CNNS) in India. The outcome variables were anthropometric indices: height-for-age, weight-for-height, and weight-for-age. The exposure variables were maternal height and body mass index (BMI). Multivariate regression analysis was used to examine the association between maternal height and BMI with child undernutrition. **Results:** Out of total number of mothers, 11.1% were short in stature and 28% were underweight. Of total number of children, 33.9%, 17.3% and 32.7% were stunted, wasted, and underweight respectively. Children born to mother with short stature were more likely to be stunted (OR=1.73, 95% CI 1.59–1.89), wasted (OR=1.26, 95% CI 1.12–1.41) and underweight (OR=1.64, 95% CI 1.50–1.79). Similarly, children with underweight mother were more likely to be stunted (OR=1.63, 95% CI 1.53–1.73), wasted (OR=1.64, 95% CI 1.52–1.77) and underweight (OR=2.14, 95% CI 2.01–2.27). **Conclusions:** The study shows a strong association between maternal and child undernutrition demonstrating intergenerational linkage between the two. The national programme needs to focus on holistic and comprehensive nutrition strategy with targeted interventions to improve both maternal and child health.

Key Words: child undernutrition, mother's BMI, mother's height, intergeneration, CNNS, India

INTRODUCTION

Globally, one-third of children under 5 years of age are stunted, 112 million are underweight, and around 53 million are wasted, making undernutrition the most common 'disease' of children, and a major public health problem.[1] In India alone, an estimated 40.7 million children under 5 years of age were stunted, 20.3 million were wasted and 39.2 million were underweight.[2] Undernutrition is directly linked with premature mortality and morbidity and delayed cognitive development in early childhood with long-lasting physiological effects.[3,4] Further, it is also directly linked to adverse health outcomes such as increased tendency of fat accumulation, insulin resistance and hypertension among those children who survive to enter adulthood, contributing significantly to the global burden of disease.[5-7] The long-term impact of undernutrition is negatively associated with human capital, school achievement, economic productivity[8] and birthweight of the offspring.[9] As the effects are not limited to childhood but rather persist into adulthood and also affect newborn children of undernourished mothers, undernutrition propagates a vicious cycle of intergenerational effects.

The etiology of undernutrition is complex, influenced by multiple factors which are biological, economical, behavioral, and environmental in nature.[10-13] These factors are responsible for long-term chronic and short-term acute undernutrition. Stunting measured as height-for-age is an indicator of linear and cumulative growth which is not affected by short-term food inadequacy but is a result

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of long-term inadequate nutrition and recurrent chronic illness. Intrauterine growth retardation leading to low birth weight and premature childbirth with depleted nutrition is a proximate determinant of chronic undernutrition.[14,15] Studies suggest children born with low birth weight are more likely to endure growth failure in early childhood and are less likely to catch up in the later stages of life because of poverty and social conditions.[16] The effects of maternal stature and BMI as important factors that determine the intrauterine growth of a child is well documented.[17-19] Further, underweight mothers are at a higher risk of complications during childbirth and produce lower quantities of breast milk, resulting in poorer infant health.[20] Underweight measured as weight-for-age, an indicator of short-term acute undernutrition, is also associated with maternal undernutrition.[4]

Although India has recorded a reduction in the number of malnourished children over the last few decades, it still accounts for 23.8% of the global burden of malnutrition.[21] Furthermore, around 19% of women in the reproductive age group have a low BMI,[22,23] making the situation more critical given the association of maternal undernutrition with child undernutrition. In 2017–18, the Government of India launched the POSHAN Abhiyan programme with an aim to improve nutritional outcomes for children, pregnant women and lactating mothers using a holistic approach to nutrition.

The current evidence on the association between maternal and child undernutrition is largely limited to the study of low birth-weight children and premature pregnancies. Most of the studies have focused on maternal behavior, child-feeding practices, and economic and environmental conditions.[10,11] While a few studies have examined the concept of intergenerational effect of maternal and child undernutrition,[4] there is no recent study at the national level that assesses the nutritional status of the mother-child dyad to investigate intergenerational linkages. Using a nationally representative dataset, this paper reports the prevalence of maternal and child undernutrition and further examines the intergenerational linkages between maternal height and BMI with three child nutritional outcomes—underweight, wasting and stunting—among children aged under 5 years. The findings of this study are critical for evidence-based policy formulation and further strengthening of the POSHAN abhiyaan.

METHODS

Dataset and sample covered

Data for this study was taken from CNNS, conducted under the aegis of the Ministry of Health and Family Welfare (MoHFW) in collaboration with UNICEF and the Population Council, with approval from the National Statistical Commission. This cross-sectional household survey was designed to provide nationally representative and comprehensive nutritional profiling of preschoolers (under 5 years), school-age children (5–9 years) and adolescents (10–19 years). Anthropometric measurements were taken from 38,060 children aged under 5 years, 38,355 children aged 5–9 years and 35,830 adolescents from 2,035 primary sampling units (PSUs) across the country between February 24, 2016, and October 26, 2018. This paper is focused on children aged under 5 years and their biological mothers.

Study sampling and participants

CNNS used a multi-stage stratified sampling design in order to obtain a nationally representative sample of households and individuals aged 0–19 years across all 29 states of India and the capital Delhi. In each state, the sample was selected in two stages. The first stage was the selection of PSUs using probability proportional to size (PPS) sampling and the second stage was a systematic random selection of households within each PSU. In large PSUs, the sampling design involved three stages, with the addition of a segmentation procedure to reduce enumeration areas to manageable sizes. Children with a chronic illness, physical deformity, mental illness, cognitive disability, or an ongoing current illness (high fever, infection) were not included in the study. The overall study design and methods have been described elsewhere.[24] For children aged under 5 years, caregivers (mostly the mother) were interviewed, and anthropometric measurements of eligible children and biological mother were recorded. Weight was recorded in kilograms and height in centimeters using a digital SECA scale and three-piece wooden height/length board, respectively. Before measuring, the instrument was set up on a portable wooden square and spirit level was used to ensure even measurement surface. Recumbent length was measured in children who were either less than 2 years of age or 85 cm in length and for the remaining children, standing height was measured.25 Standard protocols for recruitment and training of investigators and measurers were used in the survey. The interviewers and measurers were university graduates with previous experience in survey data collection. Before data collection, all interviewers completed a four-week training on conducting the survey and all measurers underwent extensive training and practice sessions on anthropometric measurements. At the end of the training period, written and oral tests were conducted, and the final selection of data collectors was based on their performance during the training period, in the field practice and in the written and oral tests. To access the accuracy and precision of each trainee, their measures were compared to those of the master trainers. Intra-observer technical error of measurement (TEM) and reliability were calculated using the difference between the two measures of the trainee. Inter-observer TEM and reliability were calculated by comparing the trainee's two measures to the trainer's measure. Trainees with excess bias or unacceptable TEM scores were either dismissed or retrained until they were able to make accurate measurements. In the survey, primary caregiver of 38060 children aged under 5 years were interviewed. Of these, for this analysis, we used data from 35,452 children who had biological mother as primary caregiver. In rest of the cases (2608), respondent was not the biological mother but another caregiver. All those cases were excluded for this analysis. Samples for which mother's educational status was not known and flagged cases for mothers' BMI were excluded from this analysis. Selection of analytical sample is given in Table 1.

Table 1. Selection of analytical sample for children aged under 5 years in India, CNNS 2016-18

Criteria	N
Total sample collected from children under 5 years of age	38060
Respondent is not the biological mother	2608
Mother's education, age or schooling not known	113
Flagged and missing BMI of mother	3387
Sample analyzed for mother	31952
Sample with plausible values for HAZ for children	31267
Sample with plausible values for WHZ for children	30729
Sample with plausible values for WAZ for children	31638

Outcome measures for the nutritional status of children

Three anthropometric indices—height-for-age, weight-for-height, and weight-for-age—were used to assess the nutritional status of under-five children. The WHO MGRS was used to calculate the three anthropometric indices in order to evaluate the nutritional status.[25] The three indices were expressed in standard deviation (SD) units from the reference population median. Children with Z-scores, below -2SD from the WHO reference population median, for height-for-age (HAZ), weight-for-height (WHZ) and weight-for-age (WAZ) were considered stunted, wasted, and underweight, respectively.[26] Outcome variables were expressed in dichotomous category to examine the factors linked with nutritional status of children under 5 years of age. The variables included category 0 [not stunted (>−2SD), not wasted (>−2SD to +2SD) and not underweight (>−2SD)] and category 1 [stunted (<−2SD), wasted (<−2SD) and underweight (<−2SD)].

Exposure variable

The exposure variables included in this study were maternal height and BMI. Maternal height was recorded in centimeters and was categorized into tall (>150 cm), normal (145 cm–149.9 cm) and short (<145 cm) stature.[26-29] Maternal BMI was calculated from height in meters (m) and weight measured in kilograms (kg) using the formula,

$$BMI = Weight\ (kg) / Height^2\ (m)$$

Maternal BMI was further categorized into underweight (<18.5 kg/m^2), normal (18.5 – 24.9 kg/m^2), overweight or obese (≥25.0 kg/m^2).[26,27]

Covariates

Covariates were selected based on a review of existing literature and only those variables showing an association with the nutritional status of children were included in the current analysis.[30-32] Maternal covariates included age, education, employment status, mass media exposure and parity. Child covariates included age, sex, morbidity in the past two weeks (diarrhea, respiratory infection, or fever) and ever breastfed status. Wealth index was computed using data on the household's ownership of selected assets, such as televisions and bicycles, materials used for housing construction, access to and type of water and sanitation facilities and the number and kind of consumer goods they owned. The index was included as a household-level covariate. Households were given scores derived using principal component analysis adjusted for national and state-level weights. Wealth quintiles were computed by dividing the weighted distribution into five equal categories, each with 20% of the sample population. Other household-level covariates included caste and place of residence. The list of selected covariates and construction plan is provided in Table 2.

Statistical analysis

Descriptive statistics were used to describe the study variables. Logistic regression was used to examine association of the mother's stature and BMI with the three indices of child nutritional status (stunting, wasting and underweight), using three separate regression models. Model 1 examined the bivariate association between child nutritional status and all independent study variables. Model 2 showed adjusted associations after including (i) maternal covariates: height, age, education, access to information, parity and employment status, (ii) child covariates: age, sex, morbidity and breastfeeding status, and (iii) household-level covariates: wealth index, place of residence and caste. In Model 3, adjusted associations were examined after including maternal BMI in place of maternal height and all other covariates included in Model 2. The results are presented as unadjusted odds ratios (UOR) and adjusted odds ratios (AOR) with 95% confidence intervals (CI). The prevalence estimates of undernutrition in the population and all regression models were adjusted to consider the complex sampling design of the CNNS 2016–18 by including the primary sampling units, sampling weights and strata in the models. The STATA 16.0 software was used for data analysis.

Ethical review

The CNNS received ethical clearance from the Ethical Review Board of the Post Graduate Institute for Medical Education and Research (PGIMER) and the Institutional Review Board of the Population Council in New York. All aspects of the survey were informed, following which written consent was obtained from caregivers of children aged under 5 years.

RESULTS

Table 1 presents the analytical sample for this study. A total of 31952 children aged under 5 years were included in the study. Of those, 31267, 30729 and 31638 participants had plausible values for HAZ, WHZ and WAZ, respectively, and were included in the analysis. Overall, 33.9%, children were stunted, 32.7% of the children were underweight, and 17.3% were wasted (Table 3). The proportion of children with severe stunting (12.7%), underweight (9.7%) and wasting (5%) was lower but comprised

Table 2. Description of selected study variables

Variable	Description	Constructed variable
Outcome variable		
Stunting (HAZ-height-for-age)	Height/Age standard deviation (Z-score based on WHO growth chart) (Continuous)	0=Not stunted (HAZ -2SD and above); 1=Stunted (HAZ <-2SD)
Wasting (WHZ-weight-for-height)	Weight/Height standard deviation (Z-score based on WHO growth chart) (Continuous)	0=Not wasted (WHZ -2SD and above); 1=Wasted (WHZ <-2SD)
Underweight (WAZ-weight-for-age)	Weight/Age standard deviation (Z-score based on WHO growth chart) (Continuous)	0=Not underweight (WAZ-2SD and above); 1=Underweight (WAZ <-2SD)
Covariates		
Mother's height (in cm)	Mother's height in centimeters (1 decimal) (Continuous)	1= Tall (>150 cm); 2=Normal (145cm-149.9cm); 3=Short (<145 cm)
Mother's BMI (kg/m^2)	Mother's Body Mass Index (Continuous, calculated using measured height and weight, kg/m^2)	1=Underweight (<18.5 kg/m^2); 2=Normal (18.5-24.5 kg/m^2); 3=Overweight or Obese (≥25.0 kg/m^2)
Mother's education	Mother's educational level (0=no education, 1=primary, 2=secondary, 3=higher)	Same variable used
Mother's employment status	Mother currently working (0=non-working, 1=working)	Same variable used
Mother's age	Mother's current age in completed years	1=≤18 years; 2=19-24 years; 3=25-34 years; 4=35 years or more
Mother's mass media exposure	1. Frequency of reading newspaper or magazine; 2. Frequency of listening to radio; 3. Frequency of watching television (0=not at all, 1=occasionally, 2=at least once a week, 3=daily)	0=No (No Access); 1, 2 & 3 as 1=Yes (Access to at least one of the information sources)
Mother's parity	Total children ever born (Continuous)	1= 1–2; 2=3 or more
Age of child (in years)	Child's current age in completed years	1=0-2 year; 2=3-4 year
Sex of child	Sex of child (1=male, 2=female)	Same variable used
Morbidity in past 2 weeks	1. Child suffered from diarrhea in last 2 weeks; 2. Child suffered from acute respiratory infection in last 2 weeks; 3. Child suffered from fever in last 2 weeks (0=no, 1=yes)	0=No; 1, 2 & 3 as 1=Yes (Suffered from at least one ailment)
Child breastfed ever	1=Yes, 0=No	Same variable used
Wealth index	Wealth index (1=poorest, 2=poorer, 3=middle, 4=richer, 5=richest)	Same variable used
Place of residence	Type of place of residence (1=rural, 2=urban)	Same variable used
Caste	1=Scheduled Caste, 2=Scheduled Tribe, 3=Other Backward Caste (OBC), 4=Others	1= 1 & 2 (Scheduled Caste/Tribe); 2=3 & 4 (OBC/others)

Table 3. Prevalence of different forms of undernutrition among children aged under 5 years, India, CNNS 2016–18

Variable	%	Mean (SD)
Stunting (HAZ), N	31267	
Below -2SD (moderately stunted)	33.9	-2.95 (0.81)
Below -3SD (severely stunted)	12.7	-3.79 (0.68)
Mean Z-score (SD)		-1.38 (1.56)
Wasting (WHZ), N	30729	
Below -2SD (moderately wasted)	17.3	-2.78 (0.71)
Below -3SD (severely wasted)	5.0	-3.72 (0.58)
Mean Z-score (SD)		-0.96 (1.24)
Underweight (WAZ), N	31638	
Below -2SD (moderately underweight)	32.7	-2.77 (0.65)
Below -3SD (severely underweight)	9.7	-3.59 (0.55)
Mean Z-score (SD)		-1.47 (1.21)

around a third in all three categories. Maternal, child and socio-demographic characteristics of the study population are presented in Table 4. Overall, 62% of the mothers were classified as tall and 28% were underweight. Further, 76% of the mothers were not working, 30% of the mothers had no formal education and 40% of them had no exposure to mass media. 60% of the children in the study were under 2 years of age, 52% were males and 49% reported morbidity (episode of respiratory infection or diarrhea) in the 2 weeks prior to survey. Further, 24% of the children resided in households from urban areas.

Maternal education, mass media exposure and parity were significantly associated with all the three indices of child undernutrition. Higher odds of child undernutrition were found among children with working mothers, those with lower education levels, higher parity and those belonging to Scheduled Castes/Tribes and with no mass media exposure. Similarly, higher odds of child undernutrition were found among children who reported morbidity in the two weeks preceding the survey, poor and rural households (Model 1) Table 5, 6 and 7. Sex segregated analyses was conducted to explore the association of mother's BMI and stature with all the three anthropometric indices. No significant sex differential was observed in association of all the three anthropometric indices with mother's BMI and stature (Supplementary Table 1, 2 and 3).

Association of Mother's height and BMI with child undernutrition

Stunting

Table 5 presents the results multivariate analysis with child stunting as dependent variable. Adjusted analysis highlighted that the mother's stature and BMI were associated with child's undernutrition. Short maternal stature was significantly associated with stunting (AOR:1.60, 95% CI: 1.46–1.75) (Model 1). Similarly, the association between underweight mothers and child stunting (Model 2) was significantly associated (AOR:1.36, 95% CI: 1.28–1.46) (Model 2).

Wasting

The results from multivariate analyses with child wasting as the dependent variable are shown in Table 6. Child wasting remained significantly associated with the mother's short stature (AOR: 1.19, 95% CI: 1.06–1.34) after adjusting for maternal, child and household covariates (Model 1). Similarly, the association between underweight mothers and wasted children (Model 2) remained significant (AOR:1.54, 95% CI: 1.42–1.66) after adjusting for covariates.

Underweight

Results of multivariate analysis with child underweight as a dependent variable are shown in Table 7. The association between the mother's short stature and underweight children (AOR: 1.52, 95%CI: 1.39–1.66) remained significant (Model 1) as did the association between underweight mothers (BMI <18.5 kg/m^2) and underweight children (AOR: 1.84, 95% CI: 1.73–1.97) (Model 2) after adjusting for maternal, child and household covariates.

Association of covariates with child undernutrition

Other maternal factors like education, employment status, mass media exposure and parity were significantly associated with all the three anthropometric indices of child's undernutrition. Similarly, child level covariates like age and sex were significantly associated with all three indices. However, morbidity in past 2 weeks prior to survey was significantly associated with underweight after adjusting for covariates. At the household level, wealth index and caste of the respondent were associated with all the three indices Table 5, 6 and 7.

DISCUSSION

The present study examined the association between two maternal anthropometric characteristics—stature and BMI—and child undernutrition. Maternal stature and BMI were found to be associated with all the three nutritional indices in children. Mothers with short stature and low BMI had higher odds of having undernourished children: underweight, stunted or wasted. Results of this study are similar to those reported by Subramanian et al (2009) who used data from the 2005–06 National family health survey.[29] Similarly, a recent study conducted in North Bengal reported a significant correlation between maternal BMI Z-scores and child Z-scores for height-for-age and weight-for-age.[33] Findings of this study are also aligned with previous studies conducted in low- and middle-income countries. Pooled analysis of 5 low-to middle-income countries, including India, showed that short statured mothers were more likely to have stunted children at 2 years of age.[34] A study on 54 low-to middle-income countries that used DHS data, found a weak association

Table 4. Percentage of children aged under 5 years who were stunted, wasted, and underweight by their maternal, birth and socio-demographic characteristics, India, CNNS 2016–18

Covariates	Stunting (<-2SD)		Wasting (<-2SD)		Underweight (<-2SD)		Total	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Maternal covariates								
Height								
Tall	20936	26.9 (25.5-28.3)	20539	16.2 (15.1-17.4)	21188	27.2 (25.8-28.6)	21414	62.0 (60.6-63.4)
Normal	7418	42.0 (39.7-44.3)	7330	17.5 (15.9-19.2)	7496	38.7 (36.5-41.0)	7554	26.9 (25.8-28.1)
Short	2913	53.5 (50.5-56.5)	2860	22.4 (19.7-25.5)	2954	48.8 (45.8-51.8)	2984	11.1 (10.2-12.0)
Body mass index (BMI)								
Underweight	5789	42.7 (40.6-44.9)	5722	23.3 (21.3-25.3)	5839	44.7 (42.5-47.0)	5884	28.0 (26.7-29.3)
Normal	18174	32.8 (31.3-34.2)	17815	15.9 (14.7-17.3)	18440	30.6 (29.0-32.3)	18629	56.8 (55.6-57.9)
Overweight/ obese	7304	21.9 (20.0-23.9)	7192	11.1 (9.70-12.7)	7359	18.1 (16.4-20.0)	7439	15.3 (14.2-16.4)
Education								
No education	5746	45.3 (43.2-47.4)	5657	19.0 (17.0-21.1)	5802	42.8 (40.3-45.3)	5854	30.2 (28.1-32.3)
Primary	3738	40.0 (37.1-42.9)	3669	18.1 (15.4-21.0)	3780	36.2 (33.0-39.5)	3827	14.0 (13.0-15.0)
Secondary	12090	30.2 (28.7-31.8)	11884	17.5 (16.2-18.9)	12238	30.0 (28.4-31.7)	12353	34.3 (32.8-35.8)
Higher	9693	19.7 (18.0-21.5)	9519	13.9 (12.4-15.5)	9818	20.5 (18.7-22.3)	9918	21.6 (20.1-23.1)
Employment status								
Not working	23843	31.5 (30.2-32.8)	23456	17.3 (16.2-18.4)	24151	30.2 (28.7-31.8)	24371	76.0 (74.3-77.6)
Working	7424	41.4 (39.3-43.5)	7273	17.2 (15.6-19.0)	7487	40.4 (38.3-42.5)	7581	24.0 (22.4-25.7)
Age (in years)								
≤ 18	384	25.8 (18.8-34.2)	379	15.0 (10.0-21.9)	391	18.6 (13.0-25.9)	396	1.2 (1.0-1.6)
19-24	8250	33.7 (31.9-35.7)	8145	17.6 (16.0-19.3)	8361	32.2 (30.3-34.1)	8431	32.0 (30.9-33.2)
25-34	18884	33.8 (32.2-35.4)	18535	17.4 (16.3-18.6)	19095	32.9 (31.2-34.8)	19296	58.5 (57.4-59.6)
35 or more	3749	36.4 (33.2-39.8)	3670	15.0 (12.9-17.4)	3791	34.8 (31.8-37.9)	3829	8.2 (7.7-8.8)
Mass media exposure								
No	7154	42.7 (40.9-44.6)	7052	19.6 (17.8-21.5)	7248	41.1 (39.1-43.3)	7319	39.5 (36.9-42.2)
Yes	24113	28.1 (26.9-29.4)	23677	15.7 (14.8-16.8)	24390	27.1 (25.7-28.5)	24633	60.5 (57.8-63.1)
Parity								
1-2	24451	31.0 (29.8-32.3)	24034	16.8 (15.8-17.9)	24750	30.4 (29.1-31.7)	25003	72.4 (70.9-73.7)
3 or more	6816	41.4 (39.3-43.6)	6695	18.5 (16.7-20.4)	6888	38.7 (36.4-41.0)	6949	27.6 (26.3-29.1)
Child covariates								
Age (in years)								
0-2	18363	32.8 (31.2-34.5)	18136	18.5 (17.3-19.8)	18747	30.0 (28.5-31.6)	18899	59.6 (58.6-60.7)
2-4	12904	35.5 (33.6-37.3)	12593	15.4 (14.2-16.8)	12891	36.6 (34.6-38.6)	13053	40.4 (39.3-41.4)
Sex								
Male	16520	34.8 (33.2-36.5)	16188	18.1 (16.9-19.4)	16716	32.0 (30.5-33.6)	16891	52.3 (51.1-53.5)
Female	14747	32.9 (31.2-34.6)	14541	16.3 (15.1-17.6)	14922	33.3 (31.5-35.3)	15061	47.7 (46.5-48.9)

Table 4. Percentage of children aged under 5 years who were stunted, wasted, and underweight by their maternal, birth and socio-demographic characteristics, India, CNNS 2016–18 (cont.)

Covariates	Stunting (<-2SD)		Wasting (<-2SD)		Underweight (<-2SD)		Total	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Morbidity in past 2 weeks								
No	17897	32.8 (31.4-34.3)	17527	15.9 (14.9-17.0)	18136	30.3 (28.8-31.9)	18322	50.8 (49.3-52.3)
Yes	13370	35.0 (33.2-36.8)	13202	18.6 (17.2-20.2)	13502	35.1 (33.2-37.0)	13630	49.2 (47.7-50.7)
Breastfed ever								
No	1483	39.6 (34.5-45.0)	1436	18.4 (14.0-23.9)	1488	36.4 (31.4-41.7)	1511	3.9 (3.4-4.5)
Yes	29784	33.7 (32.4-34.9)	29293	17.2 (16.3-18.2)	30150	32.5 (31.2-33.8)	30441	96.1 (95.5-96.6)
Household covariates								
Wealth index								
Poorest	2443	48.8 (46.1-51.5)	2409	20.6 (17.7-23.7)	2469	47.4 (44.3-50.5)	2488	19.5 (17.3-21.9)
Poor	3693	40.3 (37.4-43.2)	3650	19.4 (17.2-21.8)	3752	37.5 (34.6-40.6)	3789	19.9 (18.5-21.3)
Middle	5904	34.8 (32.4-37.2)	5789	17.5 (15.9-19.3)	5979	33.2 (30.9-35.6)	6044	20.1 (19.0-21.2)
Rich	8124	27.4 (25.6-29.4)	7982	16.4 (14.9-17.9)	8210	27.2 (25.4-28.9)	8287	20.1 (18.8-21.4)
Richest	11103	19.0 (17.5-20.6)	10899	12.6 (11.5-13.7)	11228	18.8 (17.3-20.4)	11344	20.5 (18.9-22.2)
Place of residence								
Rural	16941	36.2 (34.8-37.7)	16676	17.5 (16.3-18.8)	17164	34.9 (33.3-36.5)	17328	76.3 (73.7-78.8)
Urban	14326	26.4 (24.8-28.0)	14053	16.6 (15.4-17.8)	14474	25.4 (24.0-26.9)	14624	23.7 (21.2-26.3)
Caste								
Scheduled Caste/Tribe	11676	38.9 (37.0-40.8)	11440	17.7 (16.2-19.4)	11842	36.7 (34.9-38.6)	11971	35.5 (33.2-38.0)
Others/OBC	19591	31.1 (29.7-32.6)	19289	17.0 (15.8-18.2)	19796	30.4 (28.8-32.0)	19981	64.5 (62.0-66.8)

Table 5. Association of maternal height and BMI with stunting of children aged under 5 years adjusted for maternal and other covariates showing unadjusted and adjusted odds ratio with 95% confidence intervals

Covariates	Stunting (<-2SD)	
	Model 1† (95% CI)	Model 2‡ (95% CI)
Maternal covariates		
Mother's Height		
Normal	Ref	
Tall	0.59 (0.56-0.63)***	
Short	1.60 (1.46-1.75)***	
Mother's BMI		
Normal		Ref
Underweight		1.36 (1.28-1.46)***
Overweight		0.79 (0.74-0.85)***
Mother's education		
No education	1.80 (1.64-1.98)***	1.88 (1.71-2.07)***
Primary	1.55 (1.41-1.71)***	1.63 (1.48-1.80)***
Secondary	1.40 (1.30-1.51)***	1.44 (1.34-1.55)***
Higher	Ref	Ref
Mother's employment status		
Not working	Ref	Ref
Working	1.12 (1.05-1.19)***	1.11 (1.04-1.18)***
Mother's age		
≤ 18 years	1.05 (0.82-1.35)	1.01 (0.79-1.30)
19-24	1.32 (1.20-1.46)***	1.21 (1.10-1.34)***
25-34	1.16 (1.07-1.27)***	1.12 (1.03-1.22)**
35+	Ref	Ref
Mother's mass media exposure		
No	Ref	Ref
Yes	0.88 (0.82-0.95)***	0.89 (0.83-0.96)***
Mother's parity		
1-2	Ref	Ref
3 or more	1.23 (1.15-1.32)***	1.21 (1.13-1.29)***
Child covariates		
Age (in years)		
0-2	Ref	Ref
3-4	1.11 (1.05-1.18)***	1.11 (1.05-1.17)***
Sex		
Male	1.12 (1.06-1.18)***	1.12 (1.06-1.18)***
Female	Ref	Ref
Morbidity in past 2 weeks		
No	Ref	Ref
Yes	1.02 (0.97-1.08)	1.03 (0.97-1.08)
Breastfed ever		
No	Ref	Ref
Yes	0.98 (0.86-1.10)	0.96 (0.85-1.08)
Household characteristics		
Wealth index		
Richest	Ref	Ref
Rich	1.33 (1.23-1.43)***	1.36 (1.26-1.47)***
Middle	1.47 (1.34-1.61)***	1.50 (1.37-1.65)***
Poor	1.76 (1.57-1.97)***	1.78 (1.59-2.00)***
Poorest	2.07 (1.81-2.38)***	2.11 (1.84-2.42)***
Place of residence		
Rural	Ref	Ref
Urban	0.96 (0.91-1.02)	1.01 (0.96-1.07)
Caste		
Scheduled Caste/Tribe	1.11 (1.05-1.17)***	1.14 (1.08-1.20)***
Others/OBC	Ref	Ref

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

†Model 1: (excluding mother's BMI): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste ‡Model 2: (excluding mother's height): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste.

between maternal height and wasting.[4] Wasting reflects acute growth failure that is more likely to be influenced by factors or events occurring around the time of the survey.[4] This is in contrast with the results of this study and those reported by Subramanian et al in 2009.[29] Future studies should include information on contemporaneous environmental events and household food security in the months around the survey.

Table 6. Association of maternal height and BMI with wasting of children aged under 5 years of age adjusted for maternal and other covariates showing unadjusted and adjusted odds ratio with 95% confidence intervals

Covariates	Wasting (<-2SD)	
	Model 1† (95% CI)	Model 2‡ (95% CI)
Maternal covariates		
Mother's Height		
Normal	Ref	
Tall	0.94 (0.87-1.01)*	
Short	1.19 (1.06-1.34)***	
Mother's BMI		
Normal		Ref
Underweight		1.54 (1.42-1.66)***
Overweight		0.64 (0.58-0.70)***
Mother's education		
No education	1.15 (1.02-1.30)**	1.13 (1.00-1.27)*
Primary	1.18 (1.04-1.33)**	1.17 (1.03-1.32)**
Secondary	1.18 (1.08-1.29)***	1.17 (1.07-1.27)***
Higher	Ref	Ref
Mother's employment status		
Not working	Ref	Ref
Working	0.97 (0.89-1.05)	0.95 (0.88-1.03)
Mother's age		
≤ 18 years	1.05 (0.78-1.42)	0.93 (0.69-1.25)
19-24	1.10 (0.97-1.24)	0.97 (0.86-1.10)
25-34	1.14 (1.03-1.28)**	1.08 (0.97-1.21)
35+	Ref	Ref
Mother's mass media exposure		
No	Ref	Ref
Yes	0.88 (0.8-0.96)***	0.89 (0.82-0.98)**
Mother's parity		
1-2	Ref	Ref
3 or more	0.99 (0.91-1.08)	0.99 (0.91-1.08)
Child covariates		
Age (in years)		
0-2	Ref	Ref
3-4	0.87 (0.81-0.93)***	0.88 (0.82-0.95)***
Sex		
Male	1.09 (1.02-1.17)**	1.09 (1.03-1.17)**
Female	Ref	Ref
Morbidity in past 2 weeks		
No	Ref	Ref
Yes	1.06 (0.99-1.13)*	1.06 (0.99-1.13)*
Breastfed ever		
No	Ref	Ref
Yes	1.21 (1.03-1.43)**	1.19 (1.01-1.40)**
Household characteristics		
Wealth index		
Richest	Ref	Ref
Rich	1.17 (1.06-1.28)***	1.11 (1.01-1.23)**
Middle	1.26 (1.12-1.41)***	1.14 (1.02-1.28)**
Poor	1.49 (1.29-1.72)***	1.32 (1.15-1.53)***
Poorest	1.78 (1.51-2.11)***	1.53 (1.29-1.81)***
Place of residence		
Rural	Ref	Ref
Urban	1.15 (1.07-1.24)***	1.21 (1.13-1.30)***
Caste		
Scheduled Caste/Tribe	0.90 (0.84-0.96)***	0.90 (0.84-0.96)***
Others/OBC	Ref	Ref

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

†Model 1: (excluding mother's BMI): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste.

‡Model 2: (excluding mother's height): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste.

Table 7. Association of maternal height and BMI with underweight of children aged under 5 years adjusted for maternal and other covariates showing unadjusted and adjusted odds ratio with 95% confidence intervals

Covariates	Underweight (<-2SD)	
	Model 1† (95% CI)	Model 2‡ (95% CI)
Maternal covariates		
Mother's Height		
Normal	Ref	
Tall	0.64 (0.60-0.68)***	
Short	1.52 (1.39-1.66)***	
Mother's BMI		
Normal		Ref
Underweight		1.84 (1.73-1.97)***
Overweight		0.68 (0.63-0.74)***
Mother's education		
No education	1.66 (1.50-1.83)***	1.70 (1.54-1.87)***
Primary	1.47 (1.33-1.62)***	1.52 (1.37-1.68)***
Secondary	1.38 (1.28-1.48)***	1.39 (1.29-1.50)***
Higher	Ref	Ref
Mother's employment status		
Not working	Ref	Ref
Working	1.11 (1.04-1.18)***	1.09 (1.02-1.16)**
Mother's age		
≤ 18 years	0.87 (0.67-1.14)	0.79 (0.60-1.03)*
19-24	1.28 (1.15-1.42)***	1.11 (1.00-1.23)*
25-34	1.20 (1.10-1.32)***	1.13 (1.03-1.24)**
35+	Ref	Ref
Mother's mass media exposure		
No	Ref	Ref
Yes	0.91 (0.85-0.98)**	0.93 (0.86-1.00)*
Mother's parity		
1-2	Ref	Ref
3 or more	1.07 (1.00-1.15)*	1.07 (0.99-1.14)*
Child covariates		
Age (in years)		
0-2	Ref	Ref
3-4	1.30 (1.23-1.38)***	1.32 (1.24-1.39)***
Sex		
Male	1.00 (0.95-1.05)	1.00 (0.95-1.05)
Female	Ref	Ref
Morbidity in past 2 weeks		
No	Ref	Ref
Yes	1.13 (1.07-1.19)***	1.13 (1.07-1.19)***
Breastfed ever		
No	Ref	Ref
Yes	1.04 (0.92-1.18)	1.01 (0.89-1.15)
Household characteristics		
Wealth index		
Richest	Ref	Ref
Rich	1.26 (1.17-1.37)***	1.25 (1.16-1.36)***
Middle	1.44 (1.31-1.58)***	1.38 (1.25-1.52)***
Poor	1.67 (1.49-1.87)***	1.58 (1.41-1.77)***
Poorest	2.51 (2.19-2.88)***	2.31 (2.01-2.66)***
Place of residence		
Rural	Ref	Ref
Urban	1.00 (0.94-1.06)	1.07 (1-1.13)**
Caste		
Scheduled Caste/Tribe	0.93 (0.87-0.98)**	0.95 (0.90-1.00)*
Others/OBC	Ref	Ref

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

†Model 1: (excluding mother's BMI): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste.

‡Model 2: (excluding mother's height): Adjusted for maternal covariates - age, education, access to information, parity and employment status. Child Covariates - age, sex, morbidity, and breastfeeding status. Household level covariates- wealth index, place of residence and caste.

The association of maternal stature and low BMI with child under nutritional status has multi-dimensional aspects. A mother's short stature highlights the importance of early life factors and nutritional deprivation during their formative years,[29] reflected in the stature attained, while low BMI reflects poor nutrition extending into adult life. These mothers are more likely to experience intrauterine growth retardation of the fetus and have preterm or low birth weight infants due to a smaller physical structure of the uterus and pelvis[35] and inadequate supply of nutrients to the fetus.[36] Low birth weight or pre-term infants are more susceptible to infections resulting in higher morbidity and mortality that impedes growth and are more likely to be stunted or underweight.[37,38] Short statured mothers are also more likely to have difficult labor requiring assisted deliveries or caesarean sections that further impact the infant's early days with limited breastfeeding and insufficient intake of colostrum.[39] The importance of socio-economic factors associated with child undernutrition cannot be overstated. Mothers who have experienced nutrition deprivation due to adverse social and economic circumstances, poverty and poor living conditions in their formative years are more likely to deliver small-for-gestational age (SGA) infants who consequently are at a higher risk of undernutrition, highlighting the intergenerational transfer of socio-economic adversities.[34] Adjusted analysis for behavioral and socio-economic factors in this study shows that the odds of children being stunted or underweight remain significantly associated with short maternal height and low BMI. The presence of a significant association even after adjusting for behavioral and socio-economic factors emphasizes the intergenerational linkage between maternal and child nutrition.

Although the primary objective of this study was to investigate the association of maternal and child nutrition, this study also documented other maternal, child and household factors associated with child undernutrition. The findings of this study suggest that no or lower maternal education, no exposure to mass media and high parity were associated with child undernutrition. Similarly, child morbidity and poor households were also associated with child undernutrition. These results corroborate findings from other studies that low maternal education and no exposure to mass media limit a mother's knowledge and consequently result in poorer child feeding practices leading to child undernutrition.[11,40] Furthermore, household characteristics indicative of poverty that serve as proxy indicators for food security and the availability of an adequate diet required for optimum growth of the child, were associated with a higher risk of child undernutrition.[41,42]

This study has certain limitations. The use of cross-sectional data limits the ability to draw causal inferences between maternal stature and BMI with child nutrition. However, the strong association observed supports the linkage between the stature and BMI of mothers with child nutrition. In addition, the genetic factors which might influence both mother and child nutritional status have not been assessed in this study.

Striving to achieve the WHO 2025 nutrition targets[43] and, subsequently, the Sustainable Development Goals (SGD)-2 to end all forms of malnutrition[44] by 2030, India has taken steps with an unprecedented investment in nutrition through the Poshan Abhiyaan Programme. This study provides evidence for tailored policies and intervention strategies focusing on both child and maternal health for long-term returns. The focus on maternal health as a starting point, will contribute to building a pool of mothers with adequate nutrition and thereby secure the nutrition of their children.

Conclusion

There is a strong association between maternal height and BMI with child undernutrition, demonstrating intergenerational linkages between the two. The national program needs to focus on holistic and comprehensive nutrition strategy with targeted interventions to improve both maternal and child health.

AUTHOR DISCLOSURES

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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