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RESEARCH ARTICLE

# A success story of reduction in childhood stunting and underweight in India: analysis of pooled data from three rounds of Indian Demographic and Health Surveys (1998–2016)

Swati Srivastava and Ashish Kumar Upadhyay*

International Institute for Population Sciences, Mumbai, India
*Corresponding author. Email: ashu100789@gmail.com

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**Abstract**

This study used a series of individual-level datasets from National Family Health Surveys conducted in 1998–99, 2005–06 and 2015–16 to assess the factors behind the reduction in childhood stunting and underweight in India between the years 1998–99 and 2015–16. A multivariable decomposition regression analysis was performed. Results showed that the prevalence of childhood stunting declined from 49.4% in 1998–99 to 34.9% in 2015–16. Over the same period, the prevalence of childhood underweight declined from 41.9% in 1998–99 to 33.1% in 2015–16. The reduction in the prevalence of stunting was found to be contributed largely by a reduction in the combined prevalence of stunting and underweight (60%), followed by stunted only (21%) and the combined prevalence of stunting, underweight and wasting (19%). Likewise, the reduction in the prevalence of underweight was contributed by a reduction in the combined prevalence of stunting and underweight and the combined prevalence of stunting, underweight and wasting. Results of the decomposition analysis showed that over the period 1998–99 to 2015–16, improvement in wealth status and maternal education led to 13% and 12% declines, respectively, in childhood stunting and to 31% and 19% declines, respectively, in childhood underweight. Furthermore, reductions in childhood stunting and underweight were due to an increased average number of antenatal care visits, lower average birth order, decreased share of children with below-average birth size, increased use of clean fuel for cooking and a reduction in the practice of open defecation. These findings suggest that further reduction in the prevalence of childhood stunting and underweight could be attained through more equitable household economic growth, investment in girl's education, greater access to improved toilet facilities, more widespread use of clean fuel for cooking, reduction in average birth order, increased antenatal care visits and greater consumption of IFA tablets by pregnant women. Policymakers need to prioritize these measures to further reduce malnutrition among Indian children.

**Keywords:** Stunting; Underweight; Demographic and Health Survey

## Introduction

Nutritional deficiency is one of the underlying causes of childhood illness with severe implications such as childhood mortality. It is responsible for about half of the child deaths in the world. Globally, about 149 million children under the age of 5 are stunted, 49 million wasted and 40 million underweight (UNICEF, 2019; WHO, 2019). Several global and country-level efforts have been introduced to reduce the burden of childhood malnutrition. In India, the prevalence of childhood stunting declined from 52% in 1992 to 36% in 2016. Over the same period, the Government of India launched several maternal and childcare programmes aimed at improving

the health status of mothers and children, including the Child Survival and Safe Motherhood (CSSM) and Reproductive and Child Health (RCH) programmes. The Universal Immunization Programme, which was made a part of the CSSM programme in 1992, was integrated with the RCH programme in 1997. The Government of India launched its most ambitious programme – the National Rural Health Mission (NRHM) – in 2005 with a strong focus on maternal and child health, food and nutrition and universal immunization (NRHM, 2007). Given the governmental effort put into improving the nutritional status of children, it is important to understand the factors that have led to the improvement in the nutritional measures of children in India since the 1990s.

Over the past two decades India has experienced a decline in infant and under-five mortality (IIPS & ICF, 2017; SRS, 2017). Since childhood malnutrition is considered to be the primary cause of death among children in India, it is highly probable that improvement in the nutritional status of children is a significant factor in the decline in child death in the country. To make further improvements in child nutritional measures, it is necessary to understand the role of other associated factors in childhood undernutrition.

In India, the problem of childhood stunting is an eternal enigma (MDS, 2010). According to Horton (1999), stunting is a significant concern for development and has enormous human and economic consequences. Studies of the possible determinants of childhood undernutrition across the regions of India have shown women's poorer nutritional status, shorter height, low BMI, low educational attainment, low economic status, rural residence and food insecurity to be important factors (Fotso, 2007; Bishwakarma, 2011; Amugsi *et al.*, 2013; Di Cesare *et al.*, 2015; Chowdhury *et al.*, 2016). Other determinants, such as road accessibility and food production, have also been found to be significant risk factors for poor child health status (Bishwakarma, 2011). Adair and Guilkey (1997) determined the age-specific factors related to stunting in Filipino children. They found that diarrhoea, febrile respiratory infection, early supplemental feeding and low birth weight were the main risk factors for stunting. Some studies have systematically examined the pattern of, and trends in, childhood malnutrition in India and reported that improvement in the nutritional status of children is primarily driven by growth in economic status and increase in maternal education (Khan & Mohanty, 2018; Singh *et al.*, 2019b). However, few studies in India have examined the contribution of factors that play a significant role in reducing the burden of stunted children in India (Singh *et al.*, 2017). Therefore, the present study used data from three rounds of the National Family Health Survey (NFHS-2, NFHS-3 and NFHS-4) to assess the factors associated with the reduction in childhood stunting and underweight in India from 1998 to 2016.

## Methods

### *Survey data*

Data were from three rounds of the NFHS conducted during 1998–99 (NFHS-2), 2005–06 (NFHS-3) and 2015–16 (NFHS-4). The NFHS is a large-scale, cross-sectional, multi-round survey conducted in a nationally representative sample of households throughout India. To date, four rounds of the NFHS have been conducted in 1992–93, 1998–99, 2005–06 and 2015–16 under the stewardship of the Ministry of Health and Family Welfare, Government of India (IIPS & ORC Macro, 1995, 2000, 2007; IIPS & ICF, 2017). The NFHS-1 (1992–93) did not collect children's height measurements in five large states (Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu and West Bengal) so it was excluded from the analysis.

### *Outcome variables*

The outcome variables of interest were 'child stunting' and 'child underweight', which are measures of chronic nutritional status reflecting 'low height according to age' and 'low weight according to

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age', respectively. Wasting was not included as this increased in prevalence between 1998–99 and 2015–16, and the study's aim was to examine the key socioeconomic determinants of the reduction in child malnutrition.

In NFHS-2, anthropometric measures were taken for children under the age of 3 years: that is, those born in the 3 years preceding the survey. However, in NFHS-3 and NFHS-4, anthropometric measures were collected for children under age 5 years: that is, those born in the 5 years preceding the survey. To maintain consistency across survey rounds, the study only included children under the age of 3 years from all three survey rounds. Analysis was restricted to the index birth because some of the information corresponding to mothers and children was only collected for the latest (most recent) birth. After deleting flagged cases and missing observations, the final sample consisted of 182,732 children under the age of 3 years.

### Exposure variables

Only those covariates that could be consistently measured across the three survey rounds were included in the analysis. Several child-, mother- and household-level characteristics were included to assess their role in the reduction in childhood stunting and underweight in India.

Child characteristics included: age (continuous), sex (male, female), birth size (average and above, below average) and birth order (continuous). Maternal and child programme characteristics included: pregnant mother's consumption of IFA tablets (no, yes), ANC visits during pregnancy ($<4$ visits, $\geq 4$ visits) and breastfeeding status (within one hour, after one hour of birth). Maternal characteristics included: height ($<145$ cm, $\geq 145$cm), education (none, primary, secondary, higher) and mother's age at time of birth (continuous). Finally, household characteristics included: average household size (continuous), place of residence (rural, urban), use of piped water (no, yes), open defecation (no, yes), type of cooking fuel (unclean, clean) and household wealth score. The wealth score was available in all rounds of the NFHS, but these were not comparable. Therefore, the three data sets were pooled and a principal component analysis conducted using twelve durable assets and housing materials (Ikeda *et al.*, 2013). Since piped water, open defecation and cooking fuel were included as separate variables in the study, they were not used in the construction of the wealth score.

### Analysis

The analysis was done in two stages. In the first stage, changes in the outcome and exposure variables between 1998–99 and 2015–16 were examined. Stunting was examined with 'stunting only', 'stunting and underweight' combined and 'stunting, underweight and wasting' combined. Likewise, underweight prevalence was examined with 'underweight only', 'stunting and underweight' combined, 'underweight and wasting' combined and 'stunting, underweight and wasting' combined. This allowed the determination of which of these combinations explained most of the reduction in stunting and underweight over the study period. Next, a multivariable binary logistic regression analysis was used to assess the adjusted effect of the exposure variables on the outcome variables. Finally, a multivariable decomposition analysis for non-linear response outcomes was conducted (Powers *et al.*, 2011) to test whether the selected exposure variables were statistically associated with the reductions in childhood stunting and underweight in India between 1998–99 and 2015–16. Survey year was included as a fixed effect.

The multivariable decomposition divided the total decline in outcomes variables (stunting or underweight) into the two components 'endowment' and 'coefficient'. The 'endowment' effect shows that changes in outcome variables that can be attributed to the change in composition or coverage of a set of independent variables. The 'coefficient' effect indicates the changes in outcome variable that can be attributed to the change in the effect of indicators included in the analysis. The multivariable decomposition can be represented by:

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**Table 1.** Prevalence of childhood stunting, underweight and wasting and changes in prevalence of different combinations of stunting, underweight and wasting among children under age 3 years in India, NFHS 1998–99, 2005–06 and 2015–16

| | | Prevalence (%) | | | Percentage point change | |
|---|---|---|---|---|---|---|
| Group | Description | 1998–99 | 2005–06 | 2015–16 | Between 1998–99 and 2015–16 | Between 1998–99 and 2015–16 |
| A | No anthropometric failure | 37.6 | 40.1 | 45.3 | −7.7 | −5.2 |
| B | Stunting only | 16.4 | 13.9 | 13.4 | 3 | 0.5 |
| C | Underweight only | 2.4 | 2.4 | 2.3 | 0.1 | 0.1 |
| D | Wasting only | 4.1 | 5.8 | 8.2 | −4.1 | −2.5 |
| E | Stunting and underweight | 23.7 | 19.9 | 15.1 | 8.6 | 4.8 |
| F | Underweight and wasting | 6.8 | 8.2 | 9.5 | −2.7 | −1.3 |
| G | Stunting, underweight and wasting | 9.5 | 9.7 | 6.3 | 2.8 | 3.5 |
| | Prevalence of stunting | 49.4 | 43.5 | 34.9 | 14.5 | 9.6 |
| | Prevalence of underweight | 41.9 | 40.2 | 33.1 | 8.8 | 7.1 |

$$Y_A - Y_B = F(X_A\beta_A) - F(X_B\beta_B) = F(X_A\beta_A) - F(X_B\beta_A) + F(X_B\beta_A) - F(X_B\beta_B)$$

The term $Y_A - Y_B$ is the difference in outcome variable between 1998–99 and 2015–16. $F(X_A\beta_A) - F(X_B\beta_A)$ measure endowments, and $F(X_B\beta_A) - F(X_B\beta_B)$ account for coefficients. The decomposition procedure depends on two key factors: 1) the prevalence of each indicators at both points in time and 2) and the coefficient derived from the multivariable regression model predicting stunting or underweight estimated separately at both time points (Winter *et al.*, 2013).

All the exposure variables were tested for possible multicollinearity before putting them into the regression model. Appropriate sampling weights were used in the estimations. Analysis also adjusted estimates for the complex survey design. Analysis was performed using STATA 14.0.

## Results

### *Trend in the distribution of outcome and exposure variables*

The prevalences of childhood stunting and underweight for the period of 1998–99, 2005–06 and 2015–16 are presented in Table 1. The prevalence of childhood stunting declined from 49.4% in 1998–99 to 34.9% in 2015–16 (a reduction of 14.5 percentage points). Likewise, the prevalence of underweight declined from 41.9% in 1998–99 to 33.1% in 2015–16 (a reduction of 8.8 percentage points). The changes in prevalence of different combinations of stunting, underweight and wasting are also shown in Table 1. The prevalence of stunted only (Group B) declined from 16.4% in 1998–99 to 13.4% in 2015–16 (a reduction of 3.0 percentage points). Over the same period, the combined prevalence of stunting and underweight (Group E) declined sharply from 23.7% to 15.1% (a reduction of 8.6 percentage points). Between 1998–99 and 2015–16, a reduction of 2.8 percentage points was observed for the combined prevalence of stunting, underweight and wasting (Group G). The prevalence of underweight only (Group C) was almost constant between 1998–99 and 2015–16. Surprisingly, the combined prevalence of underweight and wasting (Group F) increased from 6.8% to 9.5% between 1998–99 and 2015–16 (an increase of 2.7 percentage points).

The percentage contributions of different combinations of stunting, underweight and wasting to the overall reduction in the prevalence of stunting and underweight are presented in Figure 1. Between period 1998–99 and 2015–16, about 60% of the reduction in the prevalence of stunting was due to a reduction in the combined prevalence of stunting and underweight (Group E), about

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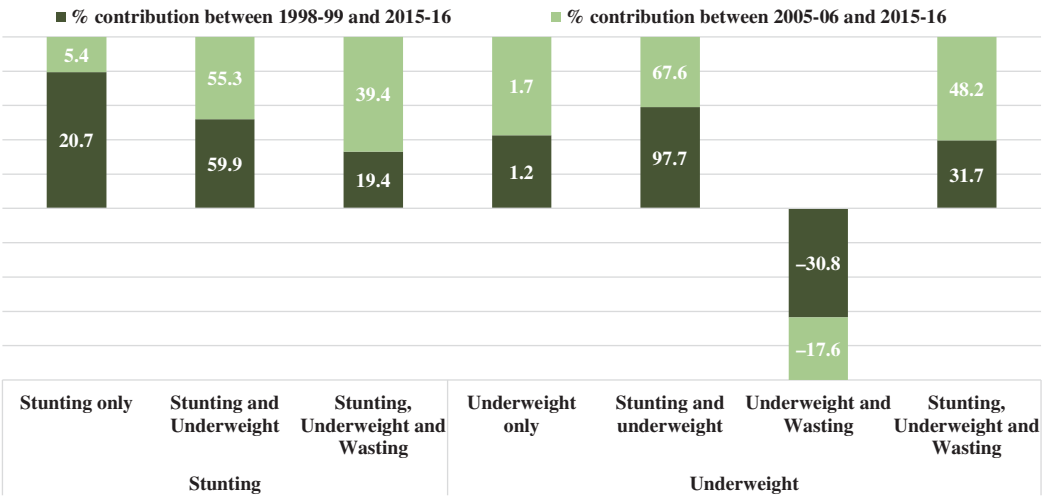


**Figure 1.** Percentage contribution of different combinations of stunting, underweight and wasting to the overall reduction in the prevalence of stunting and underweight among children under the age of 3 years in India in 1998–1999, 2005–06 and 2015–16.

21% was due to a reduction in the prevalence of stunting only (Group B) and about 19% was due to a reduction in the combined prevalence of stunting, underweight and wasting (Group G). Likewise, the reduction in the prevalence of underweight was mainly due to the combined prevalence of stunting and underweight (98.0%), followed by the combined prevalence of stunting, underweight and wasting (32%) and the prevalence of underweight only (1%). As the combined prevalence of underweight and wasting increased over the study period, it was negatively associated with the reduction in the prevalence of underweight (−31%).

The descriptive statistics of the child-, maternal- and household-level characteristics for the three NFHS surveys are presented in Table 2. The proportion of children born with below average birth size declined by 12.2 percentage points over the study period – from 24.3% in 1998–99 to 12.1% in 2015–16. Substantial improvements in maternal and child programme indicators such as the consumption of IFA tablets and use of ANC services were observed between 1998–99 and 2015–16. Initiation of breastfeeding within one hour of birth also showed an improvement, with an upward trend that nearly tripled during the last two decades from 22.3% in 1998–99 to 68.9% in 2015–16. Broken down by level of education, about 54% of the women had no formal education in 1998–99. However, this percentage decreased by nearly half and reached 27% in 2015–16. Other improvements in different household characteristics by survey year were seen, including a substantial improvement in household characteristics, including higher urban residence, less open defecation, more availability of piped water and increased use of clean cooking fuel. The trend in non-modifiable factors like age and sex of children suggested no difference over the period.

### *Socioeconomic and demographic determinants of childhood stunting and underweight*

Tables 3 and 4 portray the results of the multivariable regression analysis to examine the factors associated with childhood stunting and underweight in India in the last three rounds of the NFHS. First, looking at the regional variations, children from the North region were more likely to be malnourished compared with those from the South region, but were less likely to be malnourished compared with children in the West region in each round of the survey. The practice of open defecation was associated with an increased likelihood of childhood stunting and underweight in all rounds of the survey. Availability of clean fuel for cooking, access to piped water and

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**Table 2.** Characteristics of children, India, NFHS 1998–99, 2005–06 and 2015–16

| | 1998–99 (*N*=28,978) | 2005–06 (*N*=25,489) | 2015–16 (*N*=128,265) |
|---|---|---|---|
| **Child characteristics** | | | |
| Age (mean, in months) | 15.75 | 16.14 | 16.49 |
| Female (%) | 47.41 | 47.01 | 47.04 |
| Below average birth size (%) | 24.29 | 22.08 | 12.09 |
| Average birth order | 2.88 | 2.75 | 2.20 |
| **Maternal and child programme characteristics** | | | |
| Consumption of IFA tablets (%) | 58.07 | 65.29 | 78.24 |
| ≥4 ANC visits during pregnancy (%) | 29.97 | 36.31 | 50.61 |
| Breastfed within 1 hour of birth (%) | 22.97 | 24.03 | 68.94 |
| **Maternal characteristics** | | | |
| Height (cm) | 151.07 | 151.62 | 151.66 |
| Age at time of birth | 23.81 | 24.12 | 24.55 |
| Education (%) | | | |
| None | 54.44 | 47.45 | 27.03 |
| Primary | 15.46 | 13.79 | 13.34 |
| Secondary | 21.94 | 32.98 | 47.72 |
| Higher | 8.17 | 5.79 | 11.91 |
| **Household characteristics** | | | |
| Average household members | 7.61 | 7.01 | 6.52 |
| Urban residence (%) | 22.09 | 25.85 | 28.08 |
| Open defecation (%) | 70.06 | 55.33 | 42.48 |
| Piped water (%) | 16.87 | 17.32 | 25.08 |
| Clean cooking fuel (%) | 12.37 | 18.49 | 34.74 |
| Mean wealth score | −0.7968 | −0.6686 | 0.3371 |

children belonging to wealthier households were significantly associated with a lower risk of childhood stunting and underweight. Mothers who made at least four ANC visits during pregnancy, were more than 145 cm tall and who had secondary or higher schooling had a significantly lower risk of having a child with stunting and underweight in all the three rounds of the survey. Children of higher birth order (continuous) and those of below average birth size were more likely to experience childhood stunting and underweight in all the survey years.

### *Multivariable decomposition results*

Tables 5 and 6 present the detailed decomposition results and the contribution of each explanatory variable to the noticeable decline in the prevalence of childhood stunting and underweight over the study period. Figure 2 shows the percentage contributions of key factors to the overall reduction in the prevalence of stunting and underweight from 1998–99 to 2015–16. Childhood stunting declined by 14 percentage point from 1998–99 to 2015–16 and by 8 percentage points from 2005–06 to 2015–16 (Table 5). Childhood underweight declined by 9 percentage points from

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**Table 3.** Association of variables with childhood stunting in India, NFHS 1998–99, 2005–06 and 2015–16

| | | 1998–99 | | 2005–06 | | 2015–16 | |
|---|---|---|---|---|---|---|---|
| | | Odds ratio | [95% CI] | Odds ratio | [95% CI] | Odds ratio | [95% CI] |
| **Child characteristics** | | | | | | | |
| Sex | Male (Ref.) | | | | | | |
| | Female | 0.93* | [0.87, 1.00] | 0.89* | [0.82, 0.97] | 0.84* | [0.81, 0.88] |
| Age (months) | | 1.08* | [1.07, 1.08] | 1.07* | [1.06, 1.07] | 1.04* | [1.04, 1.05] |
| Size at birth | Average and above (Ref.) | | | | | | |
| | Below average | 1.36* | [1.26, 1.48] | 1.43* | [1.30, 1.58] | 1.50* | [1.42, 1.59] |
| Breastfeeding | After 1 hour (Ref.) | | | | | | |
| | Within 1 hour | 0.95 | [0.87, 1.04] | 1.01 | [0.92, 1.12] | 1.07* | [1.03, 1.12] |
| Birth order | | 1.08* | [1.05, 1.11] | 1.10* | [1.06, 1.14] | 1.08* | [1.06, 1.09] |
| **Maternal characteristics** | | | | | | | |
| Consumption of IFA tablets | No (Ref.) | | | | | | |
| | Yes | 0.88* | [0.81, 0.95] | 0.93 | [0.85, 1.02] | 0.96 | [0.92, 1.00] |
| ANC visits | <4 (Ref.) | | | | | | |
| | ≥4 | 0.71* | [0.64, 0.78] | 0.83* | [0.74, 0.92] | 0.87* | [0.83, 0.91] |
| Age at time of birth | | 0.97* | [0.96, 0.98] | 0.97* | [0.96, 0.98] | 0.98* | [0.97, 0.98] |
| Education | No education (Ref) | | | | | | |
| | Primary | 0.81* | [0.73, 0.90] | 0.94 | [0.83, 1.06] | 0.87* | [0.82, 0.92] |
| | Secondary | 0.66* | [0.59, 0.73] | 0.70* | [0.63, 0.78] | 0.73* | [0.69, 0.77] |
| | Higher | 0.47* | [0.40, 0.56] | 0.48* | [0.38, 0.60] | 0.57* | [0.52, 0.62] |
| Height | <145 cm (Ref.) | | | | | | |
| | >145 cm | 0.52* | [0.46, 0.58] | 0.52* | [0.46, 0.59] | 0.52* | [0.49, 0.55] |
| **Household characteristics** | | | | | | | |
| Household size | | 1 | [0.99, 1.01] | 1 | [0.99, 1.02] | 1 | [1.00, 1.01] |
| Place of residence | Rural (Ref.) | | | | | | |
| | Urban | 1.03 | [0.92, 1.14] | 1.11 | [0.99, 1.25] | 1.07* | [1.00, 1.13] |
| Piped water | No (Ref.) | | | | | | |
| | Yes | 0.94 | [0.84, 1.05] | 0.92 | [0.81, 1.04] | 0.98 | [0.92, 1.04] |
| Open defecation | No (Ref.) | | | | | | |
| | Yes | 1.48* | [1.33, 1.64] | 1.30* | [1.17, 1.45] | 1.21* | [1.15, 1.27] |
| Cooking fuel | Unclean (Ref.) | | | | | | |
| | Clean | 0.80* | [0.70, 0.93] | 0.67* | [0.58, 0.77] | 0.88* | [0.83, 0.94] |
| Household's wealth score | | 0.85* | [0.82, 0.89] | 0.85* | [0.81, 0.89] | 0.90* | [0.88, 0.91] |
| Region | North (Ref.) | | | | | | |
| | Central | 0.95 | [0.86, 1.05] | 1.38* | [1.21, 1.56] | 1.07* | [1.01, 1.13] |

(*Continued*)

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**Table 3.** (*Continued*)

| | | 1998–99 | | 2005–06 | | 2015–16 | |
|---|---|---|---|---|---|---|---|
| | | Odds ratio | [95% CI] | Odds ratio | [95% CI] | Odds ratio | [95% CI] |
| | East | 0.78* | [0.70, 0.86] | 1.10 | [0.97, 1.26] | 0.86* | [0.81, 0.91] |
| | North East | 0.80* | [0.68, 0.94] | 1.08 | [0.91, 1.30] | 0.76* | [0.70, 0.82] |
| | West | 0.89 | [0.79, 1.01] | 1.72* | [1.47, 2.01] | 1.06 | [0.97, 1.16] |
| | South | 0.68* | [0.61, 0.77] | 1.06 | [0.91, 1.23] | 0.94 | [0.87, 1.02] |

Regression results included time fixed effects.
*$p<0.05$.

1998–99 to 2015–16 and by 6 percentage points from 2005–06 to 2015–16 (Table 6). Both these declines were statistically significant.

Between 1998–99 and 2015–16, about 58% of the overall percentage change in childhood stunting was due to differences in the characteristics (compositional factors) and 41% to differences in the coefficient. For the period 2005–06 to 2015–16, about 76% of the overall percentage change in childhood stunting was due to differences in the characteristics (compositional factors) and 24% to differences in the coefficient. Similarly, between 1998–99 and 2015–16, about 97% of the overall percentage change in childhood underweight was due to differences in the characteristics (compositional factors) and 3% to differences in the coefficients. Between 2005–06 and 2015–16, 93% of the overall percentage change in childhood underweight was due to differences in the characteristics (compositional factors) and 7% to differences in the coefficients.

Among the compositional factors, a significant contribution to the decline in childhood stunting and underweight was associated with household socioeconomic status in both survey periods (Figure 2). Improvement in wealth scores over the years contributed to decreasing childhood stunting and underweight. Another significant contributor to the decline in childhood stunting and underweight was increased women's education. A decrease in average birth order helped reduce childhood stunting by 8% from 1998–99 to 2015–16 and by 14% from 2005–06 to 2015–16. This also helped to reduce childhood underweight by 13% between 1998–99 and 2015–16 and by 14% between 2005–06 and 2015–16. Apart from this, a decline in the proportion of children with below-average birth size, decline in the practice of open defecation, increase in ANC visits, increase in consumption of IFA tablets and increase in maternal age at time of birth also contributed to the reduction in childhood stunting and underweight over the survey periods. The increased availability of piped water contributed very little to the reduction in childhood stunting and underweight in the survey rounds. Surprisingly, the decrease in the number of members in the household over the years was associated with an increase in childhood stunting and underweight between NFHS-2 and NFHS-4, and also between NFHS-3 and NFHS-4.

## Discussion

Childhood stunting and underweight are widely used indicators to assess the deprivation in child health status. This study examined the determinants of the reduction in childhood stunting and underweight observed in India between 1998 and 2016. The study found that India has registered a remarkable decline in the prevalence of stunting and underweight between 1998–99 (NFHS-2) and 2015–16 (NFHS-4). The prevalence of stunting declined from 49.4% in 1998–99 to 34.9% in 2015–16, and that of underweight declined from 41.9% to 33.1% over the same period. Furthermore, analysis of different combinations of stunting, underweight and wasting indicated that the reductions in the prevalence of childhood stunting and underweight were mainly due to a

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**Table 4.** Association of variables with childhood underweight in India, NFHS 1998–99, 2005–06 and 2015–16

| | | 1998–99 | | 2005–06 | | 2015–16 | |
|---|---|---|---|---|---|---|---|
| | | Odds ratio | [95% CI] | Odds ratio | [95% CI] | Odds ratio | [95% CI] |
| **Child characteristics** | | | | | | | |
| Sex | Male (Ref.) | | | | | | |
| | Female | 0.90* | [0.84, 0.96] | 0.96 | [0.89, 1.04] | 0.85* | [0.82, 0.88] |
| Age (months) | | 1.04* | [1.03, 1.04] | 1.03* | [1.03, 1.04] | 1.03* | [1.02, 1.03] |
| Size at birth | Average and above (Ref.) | | | | | | |
| | Below average | 1.75* | [1.61, 1.90] | 1.73* | [1.57, 1.90] | 1.72* | [1.62, 1.81] |
| Breastfeeding | After 1 hour (Ref.) | | | | | | |
| | Within 1 hour | 0.96 | [0.88, 1.05] | 0.90* | [0.82, 0.99] | 1.09* | [1.04, 1.13] |
| Birth order | | 1.07* | [1.04, 1.10] | 1.07* | [1.03, 1.11] | 1.07* | [1.05, 1.09] |
| **Maternal characteristics** | | | | | | | |
| Consumption of IFA tablets | No (Ref.) | | | | | | |
| | Yes | 0.96 | [0.88, 1.04] | 0.92 | [0.84, 1.01] | 0.99 | [0.94, 1.03] |
| ANC visits | <4 (Ref.) | | | | | | |
| | ≥4 | 0.77* | [0.70, 0.85] | 0.87* | [0.78, 0.97] | 0.90* | [0.86, 0.94] |
| Age at time of birth | | 0.98* | [0.97, 0.99] | 0.99* | [0.98, 1.00] | 0.98* | [0.97, 0.98] |
| Education | No education (Ref.) | | | | | | |
| | Primary | 0.85* | [0.77, 0.94] | 0.91 | [0.81, 1.03] | 0.83* | [0.78, 0.88] |
| | Secondary | 0.69* | [0.62, 0.77] | 0.77* | [0.69, 0.86] | 0.72* | [0.69, 0.76] |
| | Higher | 0.63* | [0.52, 0.76] | 0.54* | [0.43, 0.70] | 0.54* | [0.49, 0.59] |
| Height | <145 cm (Ref.) | | | | | | |
| | >145 cm | 0.58* | [0.52, 0.64] | 0.58* | [0.52, 0.66] | 0.55* | [0.52, 0.58] |
| **Household characteristics** | | | | | | | |
| Household size | | 1.00 | [0.99, 1.01] | 1.01 | [1.00, 1.02] | 1.00 | [0.99, 1.00] |
| Place of residence | Rural (Ref.) | | | | | | |
| | Urban | 1.27* | [1.15, 1.42] | 1.05 | [0.94, 1.18] | 1.09* | [1.03, 1.16] |
| Piped water | No (Ref.) | | | | | | |
| | Yes | 0.97 | [0.86, 1.08] | 1.03 | [0.91, 1.17] | 0.99 | [0.93, 1.05] |
| Open defecation | No (Ref.) | | | | | | |
| | Yes | 1.41* | [1.27, 1.57] | 1.35* | [1.21, 1.51] | 1.33* | [1.27, 1.40] |
| Cooking fuel | Unclean (Ref.) | | | | | | |
| | Clean | 0.78* | [0.67, 0.91] | 0.73* | [0.63, 0.85] | 0.82* | [0.78, 0.87] |
| Household's wealth score | | 0.84* | [0.81, 0.88] | 0.88* | [0.84, 0.91] | 0.90* | [0.88, 0.91] |
| Region | North (Ref.) | | | | | | |
| | Central | 1.19* | [1.07, 1.31] | 1.34* | [1.18, 1.51] | 1.16* | [1.09, 1.22] |

(*Continued*)

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**Table 4.** (*Continued*)

| | | 1998–99 | | 2005–06 | | 2015–16 | |
|---|---|---|---|---|---|---|---|
| | | Odds ratio | [95% CI] | Odds ratio | [95% CI] | Odds ratio | [95% CI] |
| | East | 1.23* | [1.11, 1.37] | 1.36* | [1.19, 1.56] | 0.96 | [0.91, 1.02] |
| | North East | 0.67* | [0.57, 0.79] | 0.99 | [0.83, 1.19] | 0.65* | [0.60, 0.70] |
| | West | 1.49* | [1.32, 1.69] | 1.39* | [1.19, 1.63] | 1.24* | [1.14, 1.36] |
| | South | 0.93 | [0.83, 1.05] | 1.00 | [0.86, 1.17] | 0.99 | [0.91, 1.07] |

Regression results included time fixed effects.
*$p<0.05$.

reduction in the combined prevalence of stunting and underweight, followed by the combined prevalence of stunting, underweight and wasting.

The multivariate decomposition analysis revealed that the most significant contribution to the decline in stunting, as well as underweight, came from an improvement in household economic status, followed by the increase in mother's education. Improvement in household economic status improves child nutritional status by increasing access to food and health-related services. The present study also found a positive influence of improved household economic status on child health. However, supporting evidence for this relationship is inconclusive (Haddad *et al.*, 2003; Subramanyam *et al.*, 2011). Many previous studies have claimed that improved economic status facilitates the improvement in child health indicators. However, other studies have pointed out that economic development alone is not enough to improve the nutritional status of children, and have suggested that the equitable allocation of funds to public health, education and development should be done on a priority basis to keep children healthy (Haddad *et al.*, 2003; Subramanyam *et al.*, 2011). An educated woman has the skills, information, knowledge and self-confidence to be a better parent and ensure the health of her offspring. Investment in women's education promotes economic and agricultural productivity and, thereby, economic growth. Consequently, improved economic status helps to improve child nutritional status by allowing good access to food and health-related services (Smith & Haddad, 2002). The association between maternal education and improved child health has been made by several earlier studies (Cleland & Van Ginneken, 1988; Case *et al.*, 2002; Hasan *et al.*, 2016; Dessie *et al.*, 2019; Singh *et al.*, 2019a).

The other main factors that have significantly contributed to the reduction in stunting and underweight are an increase in the use of piped water, improvements in sanitation facilities and an increase in the use of clean fuel for cooking. The practice of open defecation in India declined from 70% in 1998 to 42% in 2016, and this has been shown to be associated with stunting and underweight in other parts of the world (Esrey, 1996; Checkley *et al.*, 2004; Fink *et al.*, 2011; Lin *et al.*, 2013). One possible reason may be that as children start crawling, walking, exploring and putting objects in their mouths, they become prone to ingesting fecal bacteria from human and animal sources. This leads to repeated episodes of diarrhoea and intestinal worms, which in turn deteriorates the nutritional status of children (WHO, 2008). Another possible explanation could be mother/household characteristics; previous studies have shown an association between mother's or caregiver's personal hygiene practices and childhood malnutrition (Meshram *et al.*, 2015; Rah *et al.*, 2015). It is very clear that efforts to maintain personal hygiene at the level of both mother/household and child helps prevent diarrhoea and other infectious diseases, which in turn helps reduce malnutrition among children.

As far as improved water sources are concerned, the study found a negligible contribution of access to piped water to improvement in child nutritional status. The use of piped water increased only slightly, from 17% in 1998–99 to 25% in 2015–16. Prior studies have also found inconclusive

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**Table 5.** Multivariable decomposition of childhood stunting for children under 3 years in India, NFHS 1998–99, 2005–06 and 2015–16

| | | 2015/16–1998/99 | | | | 2015/16–2005/06 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Endowment | | Coefficient | | Endowment | | Coefficient | |
| Variable | | Coeff. | % | Coeff. | % | Coeff. | % | Coeff. | % |
| **Child characteristics** | | | | | | | | | |
| Size at birth | Average and above (Ref.) | | | | | | | | |
| | Below average | −0.0104* | 7.0375 | 0.0093* | −6.2753 | −0.0081* | 9.6839 | 0.005 | −6.452 |
| Breastfeeding | After 1 hour (Ref.) | | | | | | | | |
| | Within 1 hour | 0.0078* | −5.2801 | 0.0073 | −4.9262 | 0.0061* | −7.2942 | 0.001 | −1.320 |
| Birth order | | −0.0130* | 8.8568 | 0.0000 | 0.0139 | −0.0118* | 14.0780 | −0.009 | 10.580 |
| **Maternal characteristics** | | | | | | | | | |
| Consumption of IFA tablets | No (Ref.) | | | | | | | | |
| | Yes | −0.0028* | 1.8666 | 0.0036 | −2.4291 | −0.0018 | 2.1985 | 0.003 | −3.028 |
| ANC visits | <4 (Ref.) | | | | | | | | |
| | ≥4 | −0.0055* | 3.7147 | 0.0126 | −8.5476 | −0.0045 | 5.3712 | 0.000 | 0.350 |
| Age at time of birth | | −0.0036* | 2.4436 | 0.0326 | −22.1570 | −0.0023* | 2.7916 | 0.044 | −52.336 |
| Mother's education | No education (Ref.) | | | | | | | | |
| | Primary | 0.0008* | −0.5553 | 0.0018 | −1.2223 | 0.0000 | 0.0203 | −0.0004 | 0.5235 |
| | Secondary | −0.0141* | 9.5990 | 0.0000 | −0.0041 | −0.0089* | 10.6410 | −0.003 | 3.184 |
| | Higher | −0.0029* | 1.9780 | −0.0006 | 0.4100 | −0.0065* | 7.7587 | 0.0000 | −0.0003 |
| Maternal height | <145 cm (Ref.) | | | | | | | | |
| | ≥145 cm | 0.0019* | −1.3273 | −0.0325 | 17.3700 | −0.0007* | 0.8465 | 0.035 | −41.829 |
| **Household characteristics** | | | | | | | | | |
| Household size | | 0.0030* | −2.0582 | 0.0022 | −1.6405 | 0.7980* | −0.9516 | −0.018 | 21.488 |
| Piped water | No (Ref.) | | | | | | | | |

(*Continued*)

**Table 5.** (*Continued*)

| | | 2015/16–1998/99 | | | | 2015/16–2005/06 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Endowment | | Coefficient | | Endowment | | Coefficient | |
| Variable | | Coeff. | % | Coeff. | % | Coeff. | % | Coeff. | % |
| | Yes | −0.0004 | 0.2621 | −0.0013 | 1.0099 | −0.0003 | 0.3269 | 0.001 | −0.623 |
| Open defecation | No (Ref.) | | | | | | | | |
| | Yes | −0.0081* | 5.4783 | −0.0173 | 8.2070 | −0.0055 | 6.5703 | 0.010 | −12.459 |
| Cooking fuel | Unclean (Ref.) | | | | | | | | |
| | Clean | −0.0042* | 2.8818 | −0.0019 | 1.3071 | −0.0022 | 2.6544 | 0.002 | −2.766 |
| Household wealth score | | −0.0196* | 13.3410 | −0.0064 | 4.1762 | −0.01819* | 21.6970 | −0.0080* | 9.597 |
| Region | North (Ref.) | | | | | | | | |
| | Central | 0.0005* | −0.3403 | 0.0100* | −6.806 | −0.0003 | 0.4076 | −0.0150* | 17.898 |
| | East | −0.0007* | 0.4842 | 0.0107* | −7.307 | −0.00042* | 0.4980 | −0.0098 | 11.645 |
| | North East | −0.00007* | 0.0528 | 0.0008 | −0.565 | 0.0002* | −0.1959 | −0.0017 | 1.9994 |
| | West | −0.0004 | 0.2630 | 0.0087* | −5.958 | −0.0001 | 0.0616 | −0.01269* | 15.129 |
| | South | 0.0004 | −0.2520 | 0.0179* | −12.219 | −0.0002 | 0.1796 | −0.0067 | 7.9427 |
| Total | | −0.0801 | | −0.0673 | | −0.0635 | | −0.0204 | |
| Percentage | | 58.907 | | 41.093 | | 75.717 | | 24.283 | |
| *N** | | 153,793 | | | | 153,754 | | | |
| Total decline | | | | −0.14771 | | −0.083863 | | | |

*$p<0.05$.

**Table 6.** Multivariable decomposition of childhood underweight for children under 3 years in India, NFHS 1998–99, 2005–06 and 2015–16

| | | 2015/16–1998/99 | | | | 2015/16–2005/06 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Endowment | | Coefficient | | Endowment | | Coefficient | |
| Variable | | Coefficient | % | Coefficient | % | Coefficient | % | Coefficient | % |
| **Child characteristics** | | | | | | | | | |
| Size at birth | Average and above (Ref.) | | | | | | | | |
| | Below average | −0.0145* | 16.011 | 0.0002 | −0.272 | −0.0109* | 15.5400 | −0.0006 | 0.8247 |
| Breastfeeding | After 1 hour (Ref.) | | | | | | | | |
| | Within 1 hour | 0.0077 | −8.448 | 0.003 | −3.215 | 0.0069* | −10.0150 | −0.0058 | 8.3957 |
| Birth order | | −0.0115* | 12.570 | −0.002 | 2.680 | −0.0101* | 14.4700 | −0.0009 | 1.2620 |
| **Maternal characteristics** | | | | | | | | | |
| Consumption of IFA tablets | No (Ref.) | | | | | | | | |
| | Yes | −0.001 | 1.221 | 0.0016 | −1.804 | −0.0008 | 1.1820 | −0.0064 | 9.1478 |
| ANC visits | <4 (Ref.) | | | | | | | | |
| | ≥4 | −0.0057* | 5.335 | 0.0048 | −5.201 | −0.0037* | 5.3154 | −0.0017 | 2.4125 |
| Age at time of birth | | −0.0034* | 3.741 | 0.001 | −1.450 | −0.0021* | 3.0447 | 0.0318 | −45.7270 |
| Education | No education (Ref.) | | | | | | | | |
| | Primary | 0.0011* | −1.201 | −0.0004 | 4.802 | 0.0000 | −0.0289 | 0.0042 | −6.0735 |
| | Secondary | −0.0145* | 15.824 | 0.0010 | −1.483 | −0.0083* | 11.9440 | 0.0064 | −9.2549 |
| | Higher | −0.0033* | 3.621 | −0.0010 | 1.447 | −0.0065* | 9.4074 | 0.0001 | −0.1879 |
| Height | <145 cm (Ref.) | | | | | | | | |
| | ≥145 cm | 0.0008* | −0.9204 | 0.0180 | −19.6950 | −0.0007* | 0.9823 | 0.0158 | −22.7650 |
| **Household characteristics** | | | | | | | | | |
| Household size | | 0.0027* | −2.9523 | −0.0033 | 3.6478 | 0.0008* | −1.0791 | 0.0122 | −17.4960 |
| Piped water | No (Ref.) | | | | | | | | |

(*Continued*)

**Table 6.** (*Continued*)

| | | 2015/16–1998/99 | | | | 2015/16–2005/06 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Endowment | | Coefficient | | Endowment | | Coefficient | |
| Variable | | Coefficient | % | Coefficient | % | Coefficient | % | Coefficient | % |
| | Yes | −0.0004 | 0.3933 | −0.0001 | 0.0788 | −0.0003 | 0.3683 | 0.0006 | −0.8151 |
| Open defecation | No (Ref.) | | | | | | | | |
| | Yes | −0.0152* | 16.6570 | 0.0031 | −3.3852 | −0.0087* | 12.5290 | −0.0016 | 2.3075 |
| Cooking fuel | Unclean (Ref.) | | | | | | | | |
| | Clean | −0.0066* | 7.2706 | 0.0004 | −0.4673 | −0.0045* | 6.4568 | −0.0023 | 3.3574 |
| Household wealth score | | −0.0282* | 30.8150 | −0.0044 | 4.6435 | −0.0198* | 28.4720 | 0.0028 | −4.0838 |
| Region | North (Ref.) | | | | | | | | |
| | Central | 0.0011* | −1.1445 | 0.0057 | −6.245 | −0.0007* | 1.0352 | −0.0317 | 45.5780 |
| | East | −0.0001 | 0.1345 | 0.0416 | −45.431 | −0.0001 | 0.1045 | −0.0600 | 86.2230 |
| | North East | −0.0001* | 0.1394 | −0.0002 | 0.263 | 0.0003* | −0.3902 | −0.0118 | 16.9380 |
| | West | −0.0011* | 1.1756 | 0.0160 | −17.502 | −0.0001* | 0.2079 | −0.0104 | 14.8980 |
| | South | 0.0000 | −0.0218 | −0.0090 | 9.7997 | −0.00001 | 0.0117 | −0.0069 | 9.9231 |
| Total | | −0.089 | | −0.003 | | −0.068 | | −0.001 | |
| Percentage | | 97.094 | | 2.906 | | 92.594 | | 7.406 | |
| *N* | | 153,793 | | | | 153,754 | | | |
| T*otal decline | | −0.091648 | | | | −0.069556 | | | |

*$p<0.05$.

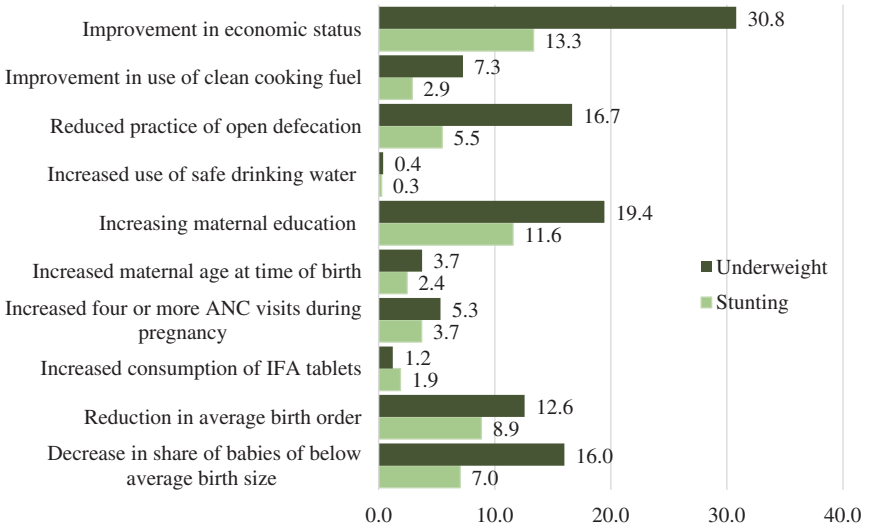


**Figure 2.** Decomposition results show the contribution of determinants to the reduction in childhood stunting and underweight in India between 1998–99 and 2015–16.

evidence on the effect of piped water on childhood malnutrition. Rah *et al.* (2015) reported that the use of piped water for drinking did not reduce the risk of stunting among children in rural India. However, a study in Peru found a positive influence of piped water on the risk of childhood stunting (Checkley *et al.*, 2004). It is possible that the real association between piped water and child health indicators may be underestimated because studies cannot consider the biological indicators of used water at the time of consumption (Dearden *et al.*, 2017). A recent report revealed that microbial pollution, which is related to poor sanitation and hygiene practices, is responsible for many waterborne, water-related and water-washed diseases in India (Basu, 2015). The share of water-based diseases in India is also high because a large proportion of the population reside in rural setups (60–70%) and consume groundwater contaminated with microbes. Basu (2015) confirmed that access to safe drinking water had increased in India over recent decades, but water has continued to have an adverse impact on child health. An increase in the use of clean fuel for cooking has also led to some reduction in the burden of stunting (2.9%) and underweight (7.3%) in children between 1998–99 and 2015–16. The present study found evidence to support the Government of India's recent initiative Pradhan Mantri Ujjwala Yojana (PMUY) aimed at improving the health of women and children by providing households with clean cooking fuel (LPG). The scheme aims to provide 80 million LPG connections to families below the poverty line by 2020 (Ministry of Petroleum and Natural Gas, 2016). The association between the use of clean fuels and reduced burden of malnourishment has been confirmed by other studies carried across the world, including India (Kelly *et al.*, 2015; Upadhyay *et al.*, 2020).

The study indicated that a decrease in average birth order makes a considerable contribution to reducing childhood stunting and underweight. The birth rate in India has been falling over the last two decades. Yet many families, especially those in rural settings, continue to have more children than the recommended TFR (more than 2.1 children). India has a large number of malnourished children, so it is important to understand the relationship between birth order and undernutrition. This study found that higher birth order was associated with poor child nutrition. A possible explanation for this could be that mothers with a large number of children are likely to have some unwanted births. They are less likely to take care of themselves during pregnancy and use appropriate post-natal care services. They are also less likely to be able to provide adequate food and other resources to their children, resulting in poorer child health and, in turn, increased child

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mortality (Rahman, 2016). The finding of an association between higher birth order and poor child nutrition is consistent with research conducted elsewhere in the world (Rahman, 2016; Howell *et al.*, 2016). More effort is needed to lower average birth order to ensure a healthier future generation.

Another finding of this study was that mother's age at the birth of child was negatively associated with childhood stunting and underweight. Although the number of babies born to adolescent mothers has been decreasing in India, a significant number of births still occur among very young mothers, especially in rural areas. A lot of research has been done on this, and it has been found that early age at birth is likely to increase the risk of low birth weight, preterm birth, maternal anaemia and other adverse child health outcomes (Gibbs *et al.*, 2012; Fall *et al.*, 2015). However, Yu *et al.* (2016) suggested that the association between young maternal age and child malnourishment is due to the socioeconomic and demographic factors, not just mother's age.

The study results suggest that an increase in the consumption of IFA tablets and an increase in the number of ANC visits have also contributed to the reduction in childhood stunting and underweight among Indian children. Even though the consumption of IFA tablets has increased in India in recent years, there is still scope for improvement. Recent estimates from NFHS-4 (2015–16) suggest that only 30% of women consume the recommended number of IFA tablets (for 100 days or more). The rate of consumption of IFA tablets for 100 or more days varies from 4.4% in Nagaland to 81.7% in Lakshadweep (IIPS & ICF, 2017). Prenatal care visits improve mother and child health by providing mothers with information on vaccination, breastfeeding, post-natal care, birth spacing and family planning (Imdad & Bhutta, 2012). These prevent mothers from catching infections and help treat high-risk pregnancy complications (Kuhnt & Vollmer, 2017).

The study has its limitations. First, due to the cross-sectional nature of data, it could not establish causal relationship between the key socioeconomic, demographic and residence-related characteristics and child malnutrition. Second, the finding should be interpreted carefully due to presence of several intermediate factors that may affect the association between socioeconomic characteristics and childhood stunting and underweight.

In conclusion, this study suggests that the reduction in childhood stunting and underweight in India between 1998–99 and 2015–16 was mostly driven by improvement in household economic status and mother's education. Increased use of clean fuel for cooking and a decrease in the practice of open defecation further contributed to the reduction in childhood stunting and underweight. Maternal and child care programme factors also played an important role. These findings suggest that further reduction in the prevalence of childhood stunting and underweight could be attained through more equitable economic growth, investment in girl's education, greater access to improved toilet facilities, increased use of clean fuel for cooking, a reduction in average birth order and improvement in ANC visit and consumption of IFA tablets by expectant mothers. Policymakers should prioritize these measures to further reduce malnutrition among Indian children.

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**Conflicts of Interest.** The authors have no conflicts of interest to declare.

**Ethical Approval.** This study was based on a secondary dataset with no identifiable information on the survey participants. This dataset was available in the public domain for research use so no approval was required from any institutional review board.

**Author Contributions.** SS conceived the idea. SS and AKU designed the experiment. SS and AKU analysed the data, interpreted the results, drafted the first manuscript and revised the manuscript. All the authors read and approved the final manuscript.

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