Changes in Child Undernutrition and Overweight in India from 2006 to 2019: An Analysis of 22 States

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Research Article

Keywords: National Family Health Survey, Nutrition transition

Posted Date: May 26th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-537129/v1>

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Abstract

Objectives: India has historically displayed high levels of child stunting and low levels of child overweight. Using newly released data, we evaluated changes in priority indicators of child growth from 2006 to 2019 and examined the role of human development measures in these changes.

Methods: We estimated cumulative and annualized changes in state- and district-level child growth indicators using three rounds of National Family Health Surveys (2005-06, 2015-16, 2019-20) in 22 states. Outcomes included stunting, underweight, wasting, and overweight. Human development was measured using a principal components analysis of nine survey-based items. We contrasted expected versus observed changes in district-level growth indicators between 2015 and 2019 based on changes in development measures using two-way Blinder Oaxaca decomposition.

Results: From 2006 to 2019, the prevalence of stunting and underweight decreased by 10.9 percentage points (pp) and 7.1 pp, respectively, while the prevalence of wasting and overweight increased by 2.8 pp and 2.2 pp, respectively. Annualized rates of change for stunting, wasting, and underweight were lower from 2015 to 2020 compared with the 2006 to 2015 period, while rates of change in overweight were higher. Simultaneously, all nine human development indicators improved between 2006 and 2020. A unit increase between 2015 and 2020 in the human development score predicted a -4.7 pp (95% CI: - 5.7, -3.6) change in stunting, yet stunting declined by just -0.3 pp.

Conclusions: Population-level reductions in child undernutrition have stalled and the rise in child overweight has accelerated between 2015 and 2020 relative to the 10 years preceding this period.

Introduction

Since the first cross-national studies of child growth, India has consistently ranked among the countries with highest levels of growth faltering (1–4). India's pernicious child undernutrition problem has been attributed to a complex interaction among structural factors such as inadequate food systems, poor water, sanitation, and hygiene infrastructure (WASH), and household poverty, which ultimately determine individual dietary intake and morbidities that impact child nutrition (5, 6). The period from 2005 onwards witnessed the launch of several ambitious national level development programs targeting many of these structural factors through income, education, sanitation, and direct nutrition campaigns. Whether and how this dynamic development policy landscape has impacted trends in child undernutrition—and child overweight—over the past 15 years is not clear.

We used newly available state- and district-level data drawn from nationally representative surveys of children to evaluate changes in a range of child growth indicators across survey rounds conducted in 2005-06, 2015-16, and 2019-20 in 22 states and union territories. As a secondary objective, we assessed whether reductions in undernutrition and overweight predicted by changes in human development indicators were achieved between 2015-16 and 2019-20.

Methods

We analysed aggregate data from three cross-sectional surveys conducted over 15 years in 22 states and 341 districts in India. We tracked changes in child undernutrition, overweight and household development indicators. Some of the indicators listed are used in monitoring India's progress towards achieving the Sustainable Development Goals (9). The study was determined to be not human subjects research by the Emory University Institutional Review Board.

Data Sources

Nutrition and programming indicators are from state- and district-level data released by the National Family Health Surveys [NFHS] conducted in 2005-06 [Round 3; November, 2005 to August, 2006], 2015-16 [Round 4; 20 January, 2015 to 4 December, 2016] and 2019-20 [Round 5; 19 June, 2019 to 2 February, 2020]. We refer to the NFHS-3, -4, and -5 survey years as 2006, 2015, and 2019, respectively as the years in which the majority of data were collected. NFHS-4 and NFHS-5 employed a multistage sample survey design to generate samples that are representative at the district, state, and national levels for children under 5 years and adults (women 15–49 years, men 15–54 years). NFHS-3 was a multistage sample survey which was representative at the state and national levels. Rural villages or urban census enumeration blocks serve as sampling clusters, from which households were randomly sampled. NFHS-3 surveyed 109,041 households from 29 States and Delhi (10). NFHS-4 surveyed 601,509 households from 36 States and Union Territories (11). Phase-1 of NFHS-5 surveyed 307,554 households from 17 States, 5 Union Territories and 341 districts (12). Additional information on changes in geographic boundaries between rounds is provided in **Supplementary Note 1 and Supplementary Fig. 1**.

Child Growth Outcomes

State- and district-level prevalence of child growth indicators were treated as the outcomes. All outcomes are expressed as the percentage of children under the age of 5 years exhibiting the indicator. Stunting was defined as height-for-age z-score [HAZ] < -2 standard deviations [SD] from the median based on World Health Organization (WHO) growth standards (13). Underweight was defined as weight-for-age [WAZ] < -2SD (13). Wasting was defined as weight-for-height [WHZ] < -2 SD (13). Overweight or obesity in children was defined as weight-for-height > 2 SD (13). Additional information on measurement protocol and quality control is provided in **Supplementary Note 2**.

Human Development Indicators

We focus on two domains of human development: human capital and standard of living. Human capital was measured by four indicators (% women who are literate; % of women with 10 or more years of schooling, sex ratio at birth, and women aged 20–24 years who were unmarried at age 18), and standard of living was measured by five indicators (households with improved sanitation, improved drinking water, electricity, clean cooking fuel, or covered by a health insurance scheme).

Statistical Analysis

We conducted an ecological analysis of child malnutrition and development indicators for 22 states and 297 districts (2015 boundaries) using published estimates at the state and district levels, respectively. The mean prevalence and standard deviation of child malnutrition was weighted by under-five population, and the mean prevalence and standard deviation of development indicators was weighted by the total population. Both sets of weights were normalized to the number of units (i.e., the sum of state weights was 22 and the sum of district weights was 297). We estimated annualized state-level change between surveys as average absolute change in percentage points per year (pp/y). We tested for difference in state-level annualized change between 2006 to 2015 and 2015 to 2019 using a paired Wilcoxon signed-rank test. We also estimated district-level changes in growth indicators between 2015 and 2019.

We benchmarked changes in growth indicators according to targets set by POSHAN Abhiyaan (National Nutrition Mission), India's nationally coordinated flagship nutrition campaign launched in March 2018 (14, 15). POSHAN Abhiyaan announced targets to reduce stunting and underweight by 2 pp/y from 2019–2022 (16, 17).

In addition, we examined expected changes in child growth indicators from 2015 to 2019 based on changes in the set of human development indicators by estimating a two-way Blinder-Oaxaca decomposition (unweighted, bivariate). In the bivariate decomposition, the expected change reflects the change in the child growth indicator that is predicted ("explained") by the human development indicator. The difference between the expected and observed changes reflect the change in the nutrition outcome that was not predicted ("unexplained") by the human development indicator. Our primary measure of human development was a weighted composite score of nine indicators of district-level human development that was derived using principal component analysis of these indicators. In addition, we report the decomposition findings for each of the human development indicators individually.

We conducted a sensitivity analysis to examine the impact of sampling uncertainty on annualized changes of growth and development indicators across time. To do so, we computed the standard errors of state-level estimates of nutrition and development indicators from an individual-level analysis of NFHS-3 and NFHS-4; individual-level data were not available for NFHS-5 at the time of analysis. Because the sampling frame, survey design, and sample size were similar in NFHS-4 and NFHS-5, we applied the NFHS-4 standard errors to NFHS-5 point prevalence to generate estimates of confidence intervals for the annualized change from 2015 to 2019 (**Supplementary Tables S1 and S2**).

All analysis was conducted using R 3.6.1 and Stata 13.0 statistical software.

Results

Child growth outcomes

From 2006 to 2020, the population-weighted prevalence of stunting declined from 46.9–36.0% (10.9 pp reduction) and that of underweight declined from 41.4–34.3% (7.1 pp reduction) (Table 1). In the same

period, the prevalence of wasting rose from 18.9–21.7% (2.8 pp increase) and that of overweight rose from 1.6–3.8% (2.2 pp increase). The annualized rates of change in stunting (-0.3 pp/y versus - 1.1 pp/y; $p < 0.01$) and underweight (-0.2 pp/y versus - 0.7 pp/y; $p < 0.01$) were lower in 2015 to 2019 compared to those from 2006 to 2015, respectively (**Supplementary Fig. 2**). The annualized rate of change in overweight was higher from 2015 to 2019 compared with 2006 to 2015 (0.03 pp/y versus + 0.5 pp/y, respectively). There was no statistically significant difference in the annual rate of change in wasting across the two reference periods. Consistent with the national pattern, we observed slowing reductions in stunting and underweight and faster increases in overweight in rural settings. In urban settings, we observed positive rates of change for stunting, underweight and overweight between 2015 and 2019. Relative changes are presented in **Supplementary Table S3**.

Table 1
Prevalence and change in state-level growth indicators from 2006 to 2020 among children under 5 years of age (n = 22 states)

	2005	2015	2019	Annualized change 2006– 2015*	Annualized change 2015– 2019*	Test for difference in annualized change^ (n = 19)	Poshan Abhiyaan Target for 2022^
All India							
Stunting	46.9	37.0	36.0	-1.1	-0.3	178, p < 0.01	23.0
Wasting	18.9	21.3	21.7	0.3	0.1	126, p = 0.23	7.3
Underweight	41.4	35.1	34.3	-0.7	-0.2	182, p < 0.01	21.1
Overweight	1.6	1.9	3.8	0.03	0.5	179, p < 0.01	n/a
Rural							
Stunting	49.7	40.1	38.0	-1.1	-0.5	169, p < 0.01	26.1
Wasting	20.1	21.5	22.0	0.2	0.1	135, p = 0.11	7.5
Underweight	44.8	37.7	36.2	-0.8	-0.4	182, p < 0.01	23.7
Overweight	1.1	1.7	3.4	0.1	0.4	182, p < 0.01	n/a
Urban							
Stunting	38.8	29.2	32.0	-1.1	0.7	175, p < 0.01	15.2
Wasting	15.2	20.6	20.6	0.6	0.0	106, p = 0.68	6.6
Underweight	31.4	28.5	30.1	-0.3	0.4	150, p = 0.03	14.5
Overweight	2.9	2.4	4.8	-0.1	0.6	165, p < 0.01	n/a
<p>Data for 2006, 2015, and 2019 come from NFHS-3, NFHS-4, and NFHS-5 Phase 1, respectively. All data are restricted to states included in NFHS-5 Phase 1 for comparability. Child stunting was defined as height-for-age < -2SD, child wasting was defined as weight-for-height < -2SD, child underweight was defined as weight-for-age < -2SD, and child overweight was defined as weight-for-height > 2SD. * Annualized change is mean annual absolute change in prevalence for 22 states reported by NFHS surveys in percentage. (%) per annum; ^ Paired Wilcoxon Signed-Rank test for 19 states which were available in NFHS-3. Additional details on geographical boundaries are presented in Supplementary Note 1; # POSHAN Abhiyaan target is estimated as prevalence in 2015 minus targeted annual reduction of 2% for stunting and underweight in children. We additionally used a target of 2 pp/y for wasting.</p>							

The prevalence of stunting, wasting and underweight would be expected to exceed the POSHAN Abhiyaan targets for 2022 by 13 pp, 15 pp, and 13 pp, respectively, if rates of change in child undernutrition observed between 2015 to 2019 continue (Table 1).

Figure 1 displays district-level changes in growth indicators from 2015 to 2019. Of 297 districts analysed, 154, 126, and 137 districts experienced some reductions in stunting, wasting, and underweight, respectively. Far fewer – 49, 32, and 28 – experienced reductions of 7 pp or more (the rate needed needed to achieve targets) in stunting, wasting, and underweight. Nearly all districts (n = 223, 75%) experienced an increase in overweight. We provide the uncertainty estimates for state and district prevalence of child malnutrition and development indicators in **Supplementary Files 2 and 3**. Analyses accounting for sampling uncertainty of estimates of child malnutrition for each survey round into the estimates of annualized change (**Supplementary Table S1**) were consistent with state-level paired differences in annualized change reported in Table 1 except for wasting among urban children.

Reflecting improvements in state human development indicators from 2005 to 2019 (Table 2), there were positive absolute annualized rates of change in each of the indicators examined over both time periods with one exception (percentage of population living in a household with an improved drinking water source between 2005–2015). After accounting for sampling uncertainty, national-level estimates of annualized change between 2006–2015 and 2015-19 were different for 5 out of 9 development indicators (**Supplementary Table S2**). However, paired tests of annualized changes at state-level were different only among 3 out of these 5 indicators (Table 2), and for 5 out of 9 indicators overall suggesting that there was heterogeneity across state-level annualized changes between the two periods. The largest absolute annualized changes from 2015-19 were observed in the percentage of households with improved sanitation facilities (4.3 pp/y) and households using clean fuel for cooking (4.8 pp/y).

Table 2
Change in development indicators from 2006 to 2020 (n = 22 states)

	2006	2015	2019	Annualized change 2006– 2015 ¹	Annualized change 2015– 2019 ¹	Test for difference in annualized change [^] (n = 19)
Women who are literate (%)	55.1	70.5	75.0	1.2	1.1	79, p = 0.54
Women with 10 or more years of schooling	15.7	36.0	41.4	1.4	1.3	23, p < 0.01
Women age 20–24 years unmarried before age 18 years (%) ²	56.0	70.2	72.1	1.6	0.3	33, p = 0.01
Sex ratio at birth for children born in the last five years (females per 1,000 males)	912.0	931.6	937.1	1.1	3.9	115, p = 0.44
Population living in households that use an improved sanitation facility	34.8	52.7	69.8	2.0	4.3	162, p < 0.01
Population living in households with an improved drinking-water source (%)	89.5	88.7	94.4	0.6	-0.1	55, p = 0.11
Population living in households with electricity	70.9	89.0	97.7	2.0	2.2	37, p = 0.02
Households using clean fuel for cooking (%)	26.9	44.5	62.7	1.8	4.8	185, p < 0.01

1 Annualized change is mean annual absolute change in prevalence; ^ Paired Wilcoxon Signed-Rank test; Additional details on geographical boundaries are available in **Supplementary Note 1**; 2 Reverse coded relative to the survey indicator for the analysis; 3 Ayushman Bharat - PMJAY and Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA) were not fully rolled out at time of NFHS-5.

Data for 2006, 2015, and 2019 come from NFHS-3, NFHS-4, and NFHS-5 Phase 1, respectively. All data are restricted to states included in NFHS-5 Phase 1 for comparability.

	2006	2015	2019	Annualized change 2006– 2015 ¹	Annualized change 2015– 2019 ¹	Test for difference in annualized change [^] (n = 19)
Households with any usual member covered under a health insurance or financing scheme (%) ³	5.8	28.6	33.3	2.6	0.9	84, p = 0.68
1 Annualized change is mean annual absolute change in prevalence; ^ Paired Wilcoxon Signed-Rank test; Additional details on geographical boundaries are available in Supplementary Note 1 ; 2 Reverse coded relative to the survey indicator for the analysis; 3 Ayushman Bharat - PMJAY and Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA) were not fully rolled out at time of NFHS-5.						
Data for 2006, 2015, and 2019 come from NFHS-3, NFHS-4, and NFHS-5 Phase 1, respectively. All data are restricted to states included in NFHS-5 Phase 1 for comparability.						

The differences between the observed and expected district-level changes in child growth indicators associated with changes in human development between 2015 and 2020 are shown in Table 3. The development score accounted for 46% of the variance in the nine human development indicators and predicted statistically significant reductions in all three measures of undernutrition, yet the observed reductions fell short of the predictions in all cases. As an example, given the change in the development score from 2015 to 2020 we would predict a -4.7 pp (95% CI: -5.7, -3.6) change in stunting. Instead, stunting declined by just 0.3 pp, so that observed levels of stunting were 4.4 pp higher than what we would expect based on changes in human development. In contrast, the human development score predicted a modest increase in overweight (0.6 pp; 95% CI: 0.4, 0.8); in fact observed changes in overweight exceeded this prediction by 1.6 pp (95% CI: 1.1, 2.0).

Table 3

Expected and observed district-level changes in child growth indicators associated with changes in human development indicators between 2015-16 and 2019-20 (n = 297 districts)

	Stunting		Wasting		Underweight		Overweight	
	-0.30		1.19		0.83		2.19	
	Expected change	$\Delta_{\text{obs}} - \text{exp}$	Expected change	$\Delta_{\text{obs}} - \text{exp}$	Expected change	$\Delta_{\text{obs}} - \text{exp}$	Expected change	$\Delta_{\text{obs}} - \text{exp}$
Human Development composite score	-4.7 (-5.7, -3.6)	4.4 (3.3, 5.4)	-1.4 (-1.9, -1.0)	2.6 (1.4, 3.9)	-5.2 (-6.4, -4.0)	6.1 (4.8, 7.3)	0.6 (0.4, 0.8)	1.6 (1.1, 2.0)
Women who are literate (%)	-2.1 (-3.0, -1.2)	1.8 (0.6, 3)	-0.8 (-1.2, -0.3)	1.9 (0.8, 3.1)	-2.6 (-3.7, -1.5)	3.4 (2, 4.8)	0.3 (0.1, 0.4)	1.9 (1.5, 2.3)
Women with 10 or more years of schooling	-2.2 (-3.2, -1.3)	1.9 (0.8, 3.1)	-0.5 (-0.8, -0.2)	1.7 (0.6, 2.8)	-2.2 (-3.1, -1.3)	3.1 (1.3, 4.8)	0.2 (0.1, 0.3)	2.0 (1.5, 2.4)
Women age 20–24 years unmarried before age 18 years (%)	-0.8 (-1.7, 0.1)	0.5 (-0.6, 1.7)	-0.3 (-0.7, 0)	1.5 (0.4, 2.6)	-1.1 (-2.3, 0.1)	1.9 (0.5, 3.3)	0.2 (0.0, 0.3)	2.0 (1.6, 2.5)
Sex ratio at birth for children born in the last five years (females per 1,000 males)	0.0 (-0.2, 0.1)	-0.3 (-1.8, 1.3)	0 (-0.1, 0.1)	1.2 (-0.1, 2.5)	-0.1 (-0.2, 0.1)	0.9 (-0.9, 2.7)	0.0 (0.0, 0.1)	2.2 (1.7, 2.7)
Population living in households that use an improved sanitation facility	-5.2 (-6.3, -4)	4.9 (3.5, 6.3)	-2.4 (-3.1, -1.7)	3.6 (2.4, 4.8)	-6.7 (-8.1, -5.4)	7.6 (6, 9.2)	0.7 (0.4, 1)	1.5 (1, 2)
Population living in households with an improved drinking-water source (%)	0.1 (0.0, 0.3)	-0.4 (-1.9, 1.0)	0.2 (0.0, 0.4)	1.0 (-0.3, 2.3)	0.5 (0, 0.9)	0.4 (-1.3, 2.1)	-0.1 (-0.2, 0)	2.3 (1.8, 2.7)

Child stunting was defined as height-for-age < -2SD, child wasting was defined as weight-for-height < -2SD, child underweight was defined as weight-for-age < -2SD, and child overweight was defined as weight-for-height > 2SD. All values are coefficient $\pm$ bootstrapped standard error. $\Delta_{\text{obs}} - \text{exp}$: Difference between observed and expected change between 2015 (NFHS-4) and 2020 (NFHS-5). Contributions are modelled through two-way Blinder-Oaxaca decomposition with each indicator entered separately. Equal weights ($w = 0.5$) were applied for both survey rounds. The decomposition model gives each of the 297 districts analysed equal weight, and district grand mean will not sum to the state population-weighted mean.

	Stunting		Wasting		Underweight		Overweight	
Population living in households with electricity	-5.2 (-7.2, -3.2)	4.9 (2.9, 6.9)	-1.6 (-3, -0.2)	2.8 (0.6, 4.9)	-5.2 (-7.7, -2.7)	6.0 (3.3, 8.7)	0.7 (0.1, 1.4)	1.4 (0.7, 2.2)
Households using clean fuel for cooking (%)	-4.0 (-4.9, -3.1)	3.7 (2.3, 5.2)	-0.6 (-1.1, -0.1)	1.8 (0.5, 3.1)	-3.4 (-4.3, -2.5)	4.2 (2.4, 6)	0.3 (0.1, 0.5)	1.9 (1.3, 2.4)
Households with any usual member covered under a health insurance or financing scheme (%) ²	-0.5 (-0.9, -0.1)	0.2 (-1.3, 1.7)	-0.1 (-0.4, 0.1)	1.3 (0.2, 2.5)	-0.3 (-0.7, 0.1)	1.1 (-0.5, 2.8)	-0.1 (-0.2, 0)	2.3 (1.9, 2.8)
<p>Child stunting was defined as height-for-age < -2SD, child wasting was defined as weight-for-height < -2SD, child underweight was defined as weight-for-age < -2SD, and child overweight was defined as weight-for-height > 2SD. All values are coefficient $\pm$ bootstrapped standard error. $\Delta_{\text{obs} - \text{exp}}$: Difference between observed and expected change between 2015 (NFHS-4) and 2020 (NFHS-5). Contributions are modelled through two-way Blinder-Oaxaca decomposition with each indicator entered separately. Equal weights ($w = 0.5$) were applied for both survey rounds. The decomposition model gives each of the 297 districts analysed equal weight, and district grand mean will not sum to the state population-weighted mean.</p>								

With respect to individual development indicators, 7 of 9 predicted statistically significant reductions in one or more child undernutrition indicators and 6 of 9 predicted significant increases in overweight. In most cases, reductions in undernutrition were smaller than expected while the rise in overweight was larger than expected.

Discussion

As compared to the period between 2006 to 2015, the pace of reductions in child stunting and underweight across Indian states have slowed whereas the rise of child overweight has accelerated between 2015 and 2020. These changes disrupt favourable trends that included large reductions in undernutrition and stability of overweight observed in the preceding time period between 2006 to 2015. Our findings also indicate that India is likely to fail in achieving the national targets set by the National Nutrition Mission (POSHAN Abhiyaan) for stunting, wasting, and underweight of $\sim 23\%$, $\sim 7\%$, and $\sim 21\%$, respectively, by year 2022 (15, 18). While there is no national target for the prevalence of child overweight in 2022, and the projected prevalence in 2022 (5.2%) is estimated to be close to the LMIC average in 2017 (6.0%), the rise in the proportion of overweight children is expected to offset any reductions in undernutrition (19–21). The total prevalence of unhealthy weight among children in India will likely remain a concern (22, 23). We also found that both undernutrition and overweight increased in urban areas. If current trends continue, the gap between child stunting in urban and rural areas will reduce by nearly 4 pp by 2022.

The stalled progress in undernutrition occurred against the backdrop of improvements in 7 of 9 development indicators from 2015 to 2020. Our findings highlight a potentially worrisome disconnect between the apparent expansion of human development and improvements in child nutrition outcomes (24). Specifically, the bivariate decomposition analysis predicted moderate to large declines in population-level undernutrition based on the rise in favourable development indicators such as women's literacy and households with electricity. Our analyses showed that these predicted reductions in undernutrition did not occur. Moreover, overweight is rising at a rate that is greater than what would be expected by improvements in human development observed in the past 5 years. The higher than expected prevalence in all four measures of unhealthy weight in children may imply that overall improvements in standard of living and human capital did not materialize in gains for child nutrition.

The observed stagnation in reductions in child undernutrition are consistent with data suggesting a reversal in the decline in annual infant mortality rates (25). Our results are also consistent with studies conducted in other contexts that have shown limited reductions in the prevalence of stunting despite implementation of successful nutrition-sensitive and nutrition-specific interventions (26).

Child wasting, measured as weight-for-height, reflects current deficits in tissue and fat mass. Wasting has also demonstrated a small but statistically significant lagged association with linear growth status, measured as length-for-age especially for children aged 1 year or less, which is a marker of long-term undernutrition (27, 28). Therefore, the apparent rise in wasting may be a predictor of future stunting at the population level. Prior literature suggests that the prevalence of stunting in India is not susceptible to seasonal variability while the prevalence of wasting tends to be 5–10% higher between June to December compared to January to May, due to seasonal variation in food availability and infectious disease (29). Given that phase 1 of NFHS-5 (which is all that is currently available) was conducted in most states from June to December 2019, it is possible that the observed prevalence of wasting is an overestimate. Nevertheless, the unchanged national prevalence of stunting between rounds with one-fourth of districts experiencing a rise in prevalence of more than 5 percentage points is concerning.

Our analysis has several strengths. We used the latest available data to evaluate and benchmark ongoing efforts to reduce child malnutrition in India, and priority setting for global reductions in child undernutrition. The application of decomposition analysis permitted us to explore the hypothetical reductions that should have been achieved based on improvements in human development indicators in the population. However, our analyses must be interpreted in light of data limitations. In order to produce timely results that can inform relevant decisions including equitable allocation of funds to programs and states, we analysed aggregated data released at the state and district levels with varying precision of estimates as seen for NFHS-3 and NFHS-4 (**Supplementary File 2, Supplementary File 3**). This precluded more sophisticated hypothesis testing regarding the secular trends in child nutrition indicators. Such testing may be done once individual-level data become available in the future. Data on indicators from states with a high burden of undernutrition, such as Uttar Pradesh, Madhya Pradesh, Rajasthan, Chhattisgarh, Jharkhand and Uttarakhand, were not collected in Phase 1 of NFHS-5 and were excluded from the current analysis (30). This may skew predicted national level prevalence for 2022 as these high-

burden states would be expected to demonstrate the most gains from a comprehensive intervention package as proposed by POSHAN Abhiyaan. We could not explore the association of changes in micronutrient supplementation and of provision of supplementary nutrition with changes in malnutrition outcomes due to data unavailability (31). Finally, our decomposition analysis described associations between human development indicators and child nutrition measured over the same time period. In doing so, we were not able to evaluate a lag between human development and improvements in child undernutrition.

A recent analysis of five LMICs that achieved substantive reductions in child stunting suggest a combination of direct (nutrition-specific) and indirect (nutrition-sensitive) health and nutrition interventions (32, 33). Our findings underscore the importance of targeted monitoring of nutrition outcomes, and support of nutrition sensitive and specific interventions, to address the high and persistent burden of child undernutrition (34, 35). Attention to child nutrition will be even more important in the coming years in light of the unprecedented economic and psychosocial strain of the ongoing COVID-19 pandemic (36). Projections show that in the absence of additional social safety net programs to tackle mounting food insecurity and financial distress incurred through the COVID-19 related economic shut down, there may be a doubling of the number of wasted and stunted children in South Asia alone by 2022 (37). Given that parts of India which experience the highest burden of child undernutrition also tend to be the most vulnerable to loss of life from COVID-19, it is important to focus on inter-ministerial efforts to curb the pandemic while at the same time avoiding reversal of gains made in alleviation of undernutrition (38).

In summary, the observed slowing progress in measures of child undernutrition warrants further exploration when considered against apparent indicators of progress. Further investigation is prudent to determine whether inequitable human development across segments of the population, or broader social and economic shocks (such as demonetization) are driving the stalling rates of reductions in undernutrition. Furthermore, investigation of outcomes beyond anthropometric growth, such as cognition, would provide a more comprehensive picture of the impact of changes in socioeconomic conditions on child social and developmental outcomes.

Abbreviations

CNNS- Comprehensive National Nutrition Survey; DHS – Demographic and Health Survey; HAZ – Height-for-age z-score; ICDS – Integrated Child Development Services; LMIC – Low- and Middle-Income Country; NFHS- National Family Health Survey; PCA – Principal Components Analysis; pp – percentage points; WAZ – Weight-for-age z-score; WHZ – Weight-for-Height z-score

Declarations

Ethics approval and consent to participate:

This study used publicly available aggregate data

Consent for publication:

Not applicable

Availability of data and materials:

Data described in the manuscript, code book, and analytic code will be made publicly and freely available without restriction at <https://github.com/jvargh7/nfhs-child-malnutrition>

Competing interests:

None declared

Funding:

Not applicable

Authors' contributions:

JSV and ADS conceptualized the study; JSV conducted the analysis and wrote the initial draft; JSV, JAM, SAC, MRZ and ADS contributed in writing and editing the manuscript.

Acknowledgements:

We thank the participants, staff and donors of National Family Health Surveys (2005-2020).

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Figures

Figure 1

District-level changes in child growth indicators from 2015 to 2019 pp: percentage points; A: Stunting; B: Wasting; C: Underweight; D: Overweight Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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