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A Double Edged Sword? Improvements in Economic Conditions over a Decade in India Led to Declines in Undernutrition as Well as Increases in Overweight among Adolescents and Women

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ABSTRACT

Background: India is facing a dual burden of undernutrition and overweight/obesity, and there are gaps in our understanding of the driving factors over time.

Objective: This study examined the national and state trends for BMI and identified the determinants of underweight and overweight/obesity among adolescent girls and women.

Methods: We used India's National Family Health Surveys data collected in 2005–2006 ($n = 110{,}887$) and 2015–2016 ($n = 645{,}193$). We applied multiple regression and decomposition analysis to assess determinants of underweight (BMI *z* score < -1 SD; <18.5 kg/m^2) and overweight/obesity (BMI *z* score >1 SD; ≥ 25 kg/m^2).

Results: Over the past decade, the prevalence of underweight decreased (43% to 38% and 33% to 19%) and the prevalence of overweight/obesity increased (3% to 5% and 15% to 24%), among adolescents and women, respectively, with high heterogeneity across states. Factors associated with a lower prevalence of underweight among women included higher socioeconomic status (SES) (OR: 0.35; 95% CI: 0.31, 0.41), urban residence (OR: 0.49; 95% CI: 0.45, 0.54), improved diet diversity (OR: 0.75; 95% CI: 0.69, 0.82), and latrine use (OR: 0.76; 95% CI: 0.70, 0.82). Higher education levels, decision-making, and ownership of money were also associated with a lower prevalence of underweight. Factors positively associated with overweight/obesity among women included SES (OR: 3.24; 95% CI: 2.81, 3.73), urban residence (OR: 2.23; 95% CI: 2.05, 2.42), diet diversity (OR: 1.21; 95% CI: 1.10, 1.32), latrine use (OR: 1.31; 95% CI: 1.21, 1.43), and education (OR: 1.39; 95% CI: 1.24, 1.55). Adolescents shared similar determinants to women. Overall, SES was a key driver of changes in women's BMI, explaining 29% of the reduction in undernutrition and 46% of the increase in overweight/obesity.

Conclusions: Despite overall declines, regional and age disparities remain in the overall burden of underweight and the increases in overweight/obesity are concerning. The identified divergent risk factors (SES, residence, diet, education) highlight that simply improving economic status will not ensure healthy BMI status for women and girls. Balanced multidisciplinary approaches are needed to address both undernutrition and overweight. *J Nutr* 2019;00:1–9.

Keywords: BMI, underweight, overweight, obesity, India, women, adolescents

Introduction

Globally, 9.7% of women and 8.4% of girls are underweight, while 14.9% and 5.6% are obese (1, 2). Despite recent trends of increasing BMI, underweight remains a significant and persistent public health issue in South Asia where it affects nearly 1 in 4 women (2). In the 2016–2017 *Lancet* articles examining trends in BMI in 200 countries, India was ranked as the country with the highest underweight burden with over 100 million women being underweight, contributing to 41.6% of the global burden (2). Likewise among girls (5–19 y), the highest prevalence of undernutrition is in India where over 1 in 5 girls are moderately to severely underweight (1, 3). While India's underweight burden is a pressing concern, the emerging overweight/obesity prevalence likewise cannot be ignored. India was also recently ranked as the third highest country for obesity

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in women; with 20 million women affected, contributing to 5.3% of the global obesity burden (2).

Maternal undernutrition has been referred to as a "silent emergency" in India (4). Being underweight is associated with increased risk of premature death from infectious disases such as tuberculois and respiratory dieases, as well as reduced life expetancy (5, 6). Women who are underweight before or during pregnancy are at increased risk of adverse birth outcomes, including maternal and neonatal mortality, preterm birth, low birth weight, and impaired fetal growth (4, 7, 8). In Eastern Maharashtra, women who were underweight during pregnancy were at increased risk of neonatal dealth and delivering a low birth weight baby; if women were both underweight and anemic, then the risk of poor birth outcomes was further elevated (4). Likewise maternal overweight and obesity are associated with increased maternal morbidity, preterm birth, and infant mortality (7). In Kolkata, women who were obese during pregnancy were at increased risk of gestational diabetes, hypertension, and pre-eclampsia, and their infants were more likely to be born preterm and via cesarean delivery (9).

Despite the importance of both maternal undernutrition and overweight/obesity, key gaps remain in our understanding of the drivers of change over time for different target groups in India. The 2019 *Lancet* Global Syndemic commission report advocates for breaking down silos and collaborating on common systemic drives and double-or-triple duty actions (10). Most prior work has looked at undernutrition or overnutrition in isolation (11–13), and not examined factors that could simultaneously influence these 2 outcomes. While several studies have examined the determinants in a single cross-sectional survey, a more comprehensive analysis of change over time and dual burden focus is required to inform policy decisions. Previous work also often grouped all women of reproductive age 15–49 y together (14, 15), although separate examination among adolescent girls and women is essential because adolescent girls are a particularly vulnerable group and may require targeted and specialized programs and interventions.

The release of the new India National Family Health Survey (NFHS-4) data (3) for 2015–2016 provides an opportunity to address these key gaps in the literature. We aim to understand the regional and state trends for maternal BMI in India as well as examine the key determinants for both underweight and overweight/obesity among adolescents and adults over the past decade. We hypothesize that socioeconomic status (SES), urban residence, education, dietary diversity, and decision-making power will be associated with the changes in both underweight and overweight/obesity over time. Among adolescents, we hypothesize that SES, urban residence, and dietary diversity will also be divergent risk factors associated with both decreases in undernutrition and increases in overweight/obesity.

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Methods

Data sources

This paper uses nationally representative data from the Indian 2005–2006 NFHS-3 (16) and the 2015–2016 NFHS-4 (3). NFHS-3 included data from 109,041 households and was representative at the state level. NHFS-4 was the first national nutrition survey to be representative at both state and district levels, with data from 601,509 households. Analysis was restricted to women of reproductive age 15–49 y who were not pregnant and did not give birth in the 2 mo before the survey, and had available data on weight and height (n = 110,887 in NFHS-3 and 645,193 in NFHS-4) (**Supplemental Figure 1**).

Variables

Outcome variables.

Anthropometric measurements for adolescents and women were obtained by trained field staff using standard procedures (17, 18). Weight was measured using a calibrated Seca 874 digital scale and height was assessed using the Seca 213 stadiometer. BMI was calculated and categorized as underweight (<18.5 kg/m^2) or overweight (≥25 kg/m^2). For this analysis we used >25 BMI to define overweight/obese adults as this is the current cutoff supported in India's National Family and Health Report (NFHS-4). However, lower cutoffs (>23) for Asian populations have been recommended because of a differential risk of poor health outcomes and higher BMIs (19–21). For adolescents, we calculated BMI z scores by comparing each girl's weight and height measurements to the WHO standards (22, 23), then categorized as low BMI (< −1 SD), normal (−1 to 1 SD), or overweight (>1 SD). "Thinness" in adolescents has also been defined as BMI z score < −2 SD, which corresponds approximately with a BMI of 17 kg/m^2 (21). We chose to use BMI z score < −1 to define underweight for the purposes of this analysis as it roughly corresponds with BMI of 18.5 kg/m^{2}for comparability with adult analysis.

Determinants.

The selection of potential determinants of underweight and overweight/obesity was guided by a conceptual framework from the *Lancet* nutrition series (7), a review specific for adolescent girls and women in India (24), as well as data availability in the NFHS survey. These frameworks build most heavily from the literature on undernutrition. Underlying causes of undernutition include: social, economic, and political context, and lack of capital. Proximal causes include food insecurity, access to health services and water and sanitation as well as women's status (education, age at marriage, gender equality). Collectively, these factors influence the conditions (inadequate dietary intake, care for women and disease) for women across the lifecycle throughout adolescence and adulthood. This framework is likewise relevant for overweight/obesity as several reviews have identified similar key underlying sociodemographic factors (25–27). We purposefully chose to use the same model for undernutrition and overweight/obesity to gain an understanding of how similar factors may play out as divergent risks/protective factors. We aim to better understand if the same factors are driving both the increase in overweight/obesity and decrease in underweight across India or if there are distinct risk factors.

In this paper, we examine the role of individual and household characteristics. Individual characteristics included age, age at first birth or age at marriage for adolescents (<19 y), education, and diet. Dietary diversity score was calculated by asking women how often they consume various foods (daily-score 3, weekly-score 2, occasionally-score 1, or never 0). The cumulative score of the 7 groups (pulses, dairy, meat, fish, egg, vegetable, and fruit) was categorized into tertiles for low, medium, or high dietary diversity. Women's empowerment included questions on decision-making power, mobility, and exposure to domestic violence, and was only available for a subsample of women (n = 55,011 and 55,556 for 2006 and 2016, respectively). A decision-making composite score was calculated based on reported decisions on health care, large household purchases, ability to spend the husband's earnings, and whether permission is needed to visit family or relatives. Mobility composite score was calculated based on women's reported ability to

TABLE 1 Characteristics of adolescents and women of reproductive age (15–49 y) in India, by survey round NFHS-3 and NFHS-4[1]

	Adolescents (15–19 y)				Adults (20–49 y)			
	2006		2016		2006		2016	
	n	Values	*n*	Values	*n*	Values	*n*	Values
Age, y	21,450	16.91 ± 1.38	117,722	16.93 ± 1.39	89,437	32.59 ± 8.22	527,471	33.19 ± 8.47
Married before 19 y, %	3292	21.8	11,248	10.9	48,434	65.2	236,681	47.8
Age at first birth <19, %	1399	9.1	3882	3.7	29,318	39.8	131,491	27.1
Total living children	21,450	1.02 ± 0.16	117,722	1.00 ± 0.07	89,437	2.55 ± 1.32	527,471	2.24 ± 1.19
Urban residence, %	9280	29.8	31,453	29.9	40,935	32.7	157,756	34.9
SES index								
Lowest	7123	41.0	23,375	20.3	28,516	40.6	92,174	17.6
Low	4871	22.8	25,524	21.8	19,038	21.4	101,611	19.7
Medium	3972	16.5	25,321	21.9	16,284	16.0	106,565	20.7
High	3086	12.1	23,132	19.3	13,754	12.9	110,139	21.0
Highest	2300	7.7	20,370	16.7	11,434	9.2	116,982	21.1
SC/ST/OBC, %	13,927	68.8	90,617	75.3	54,586	66.0	392,681	72.6
Religion is Hinduism, %	14,921	79.0	85,938	78.6	65,482	81.6	391,940	80.8
Improved latrine, %	8482	30.0	54,946	46.2	37,185	32.6	269,454	51.1
Education, %								
No schooling	3074	20.0	7882	6.5	32,175	45.5	175,847	32.6
1–5 y	2904	15.1	8250	6.8	12,994	14.8	72,218	13.6
6–9 y	8578	36.4	47,769	37.4	19,281	19.1	116,062	21.6
≥10 y	6891	28.6	53,821	49.3	24,978	20.5	163,344	32.2
Dietary diversity								
Low	8854	44.9	55,512	44.1	34,772	42.6	227,571	39.1
Medium	7456	34.0	36,754	31.2	31,370	34.3	169,053	32.1
High	5140	21.2	25,456	24.7	23,295	23.1	130,847	28.8
Decision-making score	3360	1.43 ± 1.45	2077	2.24 ± 1.70	73,218	2.53 ± 1.45	76,105	2.96 ± 1.46
Mobility score	21,450	0.71 ± 1.09	20,582	0.96 ± 1.24	89,437	1.57 ± 1.33	92,143	1.67 ± 1.35
Ownership of money, %	7230	35.2	5110	26.3	41,698	47.2	40,541	45.4
Work for pay, %	4706	25.0	2904	14.7	31,108	36.6	25,474	29.0
Any violence, %	662	34.5	306	24.7	21,168	41.4	19,044	34.6

[1]Values are percentages or means ± SDs. Dietary score was calculated based on how often (daily-3, weekly-2, occasionally-1, or never-0) women consume food from 7 groups (pulses, dairy, meat, fish, egg, vegetable, and fruit), score ranges from 0 to 21. Decision-making is a composite score of decisions on health care, large household purchases, ability to spend the husband's earnings, and whether permission is needed to visit family or relatives, score ranges from 0 to 4. Mobility is a composite score of women's ability to go to travel alone to the market, health facility, and places out of village, score ranges from 0 to 3. NFHS, National Family Health Survey; SC/ST/OBC, scheduled caste/scheduled tribe/other backwards caste.

travel alone to the market, health facility, and places out of village. Dichotomous variables were included for work for pay in the last 12 mo (yes/no) and ownership of money (yes/no). Intimate partner violence was created if women ever experienced any types of emotional, physical, or sexual violence. There were insufficient data available to examine factors pertaining to empowerment among adolescents.

Household-level variables included area of residence (rural, urban), religion, scheduled caste/tribe, number of living children, and household SES. The SES index was constructed using the principal component analysis method, using several variables including house and land ownership, housing structure, access to services, and ownership of assets and livestock (28, 29). The SES index was then categorized as quintiles, with the lowest quintile representing the poorest and the highest quintile representing the richest.

Statistical analysis

The analysis was conducted separately for adolescents aged 15–19 y and women aged 20–49 y. Descriptive analysis was conducted to report characteristics of study sample for adolescents and adult women in 2006 and 2016. To examine state-level variability in trends of underweight and overweight/obesity prevalence, we created maps showing the prevalence in each year. Seven union territories (A&N Islands, Chandigarh, D&N Haveli, Daman and Diu, Lakshadweep, Nagaland, and Pondicherry) were not included in the 2006 sample frame, therefore, they are not included in the 2006 maps and in the change analysis. Multivariable logistic regressions were conducted to examine association between individual-level (dietary score, current age, age at marriage/first birth, education) and household-level determinants (number of living children, SES, residence, caste, religion, access to improved latrine), and either underweight or overweight/obesity in adolescents and adults in 2006 and 2016. In the full model for adults, additional variables for women's empowerment and gender-based violence were included in the data subset where available. Finally, we applied a regression decomposition analysis to assess how a change in key determinants can predict changes in underweight and overweight/obesity from 2005–2006 to 2015–2016. All models controlled for the cluster sampling design and sampling weights used in the survey. Given the larger sample size in 2016 compared to 2006, we ran a sensitivity analysis using a smaller, randomly selected 2016 data set (using a fifth of the sample, stratified by state) and replicated the above analysis. Overall, association estimates were similar across data sets and the reduction in sample size did not influence main findings or interpretation of manuscript (data not shown).

Results

Characteristics of the adolescents and women included for NFHS-3 (2005–2006) and NFHS-4 (2015–2016) are summarized in Table 1. Across the 2 surveys, women's age, religion, and urban/rural residence remained constant. Over the past decade, however, the percentage of women with no formal

education decreased by 13%, and the use of an improved latrine increased from 33% in 2006 to 51% in 2016. The percentage of women married before the age of 19 y has decreased from 65% to 48% among adult women and from 22% to 11% among adolescents. Violence against women remains high, with 1 in 3 women reporting ever experiencing emotional, physical, or sexual violence.

Although the distribution of BMI among adolescents did not change over time (**Figure 1**A), there was a right shift in the BMI distribution among women (Figure 1B). Overall, between 2006 and 2016, the prevalence of underweight decreased from 33.0% to 18.8% among adult women and from 42.7% to 38.3% among adolescents. In contrast, the national prevalence of overweight/obesity increased from 15.1% to 24.1% among adult women and from 3.0% to 5.2% among adolescents (Figure 1C and D).

The prevalence of underweight decreased across most states, with high heterogeneity in the state-level change from 2006 to 2016 (**Supplemental Table 1**, **Supplemental Figure 2**). Among adult women, the prevalence of underweight in 2016 was <30% in all states, a dramatic shift from 2006 when nearly half of the states had an underweight burden over 30%. The state-level prevalence of underweight among women in 2016 ranged from 6.2% in Kerala to 28.6% in Jharkhand. In contrast, for adolescents, state-level decreases in the prevalence of underweight were modest. Only 4 states moved from a high prevalence in 2006 to <30% in 2016, and in Delhi the prevalence of underweight actually increased by 10% (29% in 2006 and 39% in 2016). The underweight prevalence in 2016 ranged from 10.6% in Mizoram to nearly 1 in 2 adolescents in Gujarat.

In most states, the burden of overweight/obesity increased but the change was highly variable across states and age groups (**Supplemental Table 2** and **Supplemental Figure 3**). Among adults, state-level overweight/obesity increased from 3 to 14 states with a high burden (>30%). The prevalence of overweight/obesity in 2016 ranged from 47.3% in Chandigarh to 12.2% in Jharkhand. Among adolescents, in 2006, no state had a prevalence of overweight/obesity >10%, whereas in 2016, 6 states had a prevalence >10% (note, for 4 of these 6 states data were only available for 2016). Overweight/obesity prevalence among adolescents ranged from 14.5% in A&N Islands to 2.4% in Jharkhand in 2016.

The multivariate models on the determinants of underweight among adolescents and women in India for 2006 and 2016 are shown in **Table 2**. Using the most recent data from 2016, adolescents with high dietary diversity scores compared to low scores were 9% less likely to be underweight. Parity was positively associated with underweight (OR: 1.35; 95% CI: 1.07, 1.72). Adolescents living in the highest SES households (compared to lowest), urban settings (compared to rural), and who used an improved latrine were 24%, 15%, and 5%, respectively, less likely to be underweight. Similar key determinants were associated with low BMI among adolescents in 2006, with the exception of dietary diversity and urban settings.

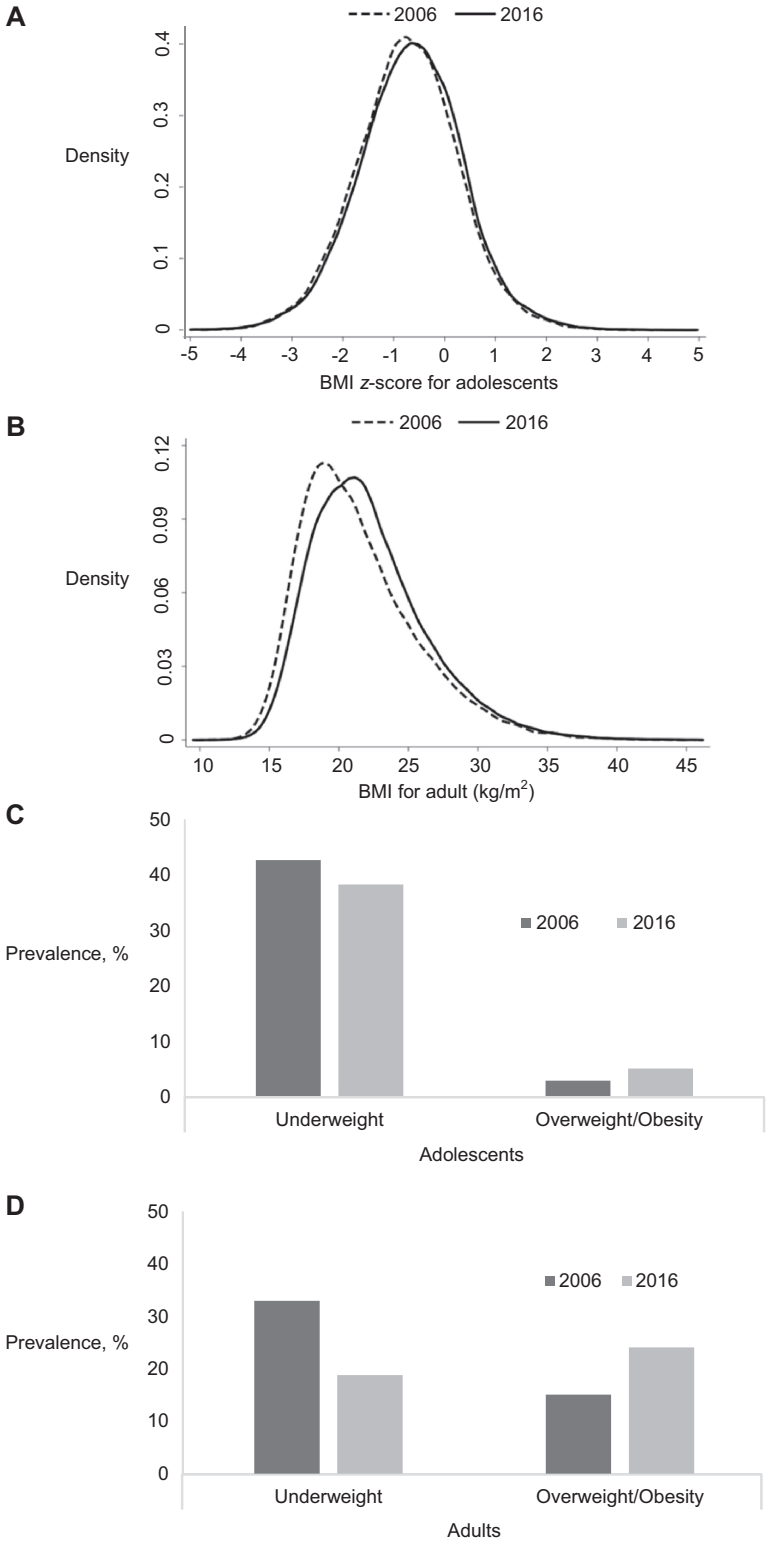
Adult women with higher dietary diversity scores were 25% less likely to be underweight compared to women with low dietary diversity scores. Younger age at first birth was associated with lower risk of being underweight (OR: 0.80; 95% CI: 0.74, 0.86); however, increasing parity was positively associated with underweight (OR: 1.09; 95% CI: 1.06, 1.13). Women with higher education (compared to no schooling) and higher SES (compared to lowest SES) were 32% and 65%, respectively, less likely to be underweight. Use of an improved latrine was also associated with a lower prevalence of underweight (OR: 0.76; 95% CI: 0.70, 0.82). Hindu women were more likely to be underweight (OR: 1.26; 95% CI: 1.15, 1.38) compared to non-Hindu women. Women with higher decision-making and ownership of money tended to be at reduced risk of underweight, while working for pay increased risk of underweight. Gender-based violence was not significantly associated with underweight. Results were similar using the 2006 data set and in the larger data set, with only the individual-level and household-level factors compared to the full model with maternal empowerment variables.

The multivariate models on the determinants for overweight/obesity among adolescents and women in India for 2006 and 2016 are shown in **Table 3**. Key factors positively associated with overweight/obesity among adolescents and women included improved diet diversity (OR: 1.39; 95% CI: 1.25, 1.54 and 1.21: 1.10, 1.32), higher SES (OR: 2.78; 95% CI: 2.35, 3.30 and 3.24: 2.81, 3.73), living in urban area (OR: 2.18; 95% CI: 1.98, 2.41 and 2.23: 2.05, 2.42), use of an improved latrine (OR: 1.34; 95% CI: 1.20, 1.50 and 1.31: 1.21, 1.43), higher education levels (OR: 1.42; 95% CI: 1.15, 1.75 and 1.39: 1.24, 1.55), and early age at first birth (OR: 1.67; 95% CI: 1.44, 1.93 and 1.26: 1.17, 1.37). Hindu adolescents and women were less likely to be overweight/obese (OR: 0.90; 95% CI: 0.81, 1.00 and 0.79: 0.72, 0.86). Higher mobility scores were positively associated with overweight/obesity, whereas work for pay was negatively associated. Key determinants were consistent across the 2 surveys in 2006 and 2016.

Results from the regression models addressed the question of which factors were associated with underweight and overweight/obesity at a given time point. The significant variables from the regression analysis were included in a decomposition analysis to estimate the extent to which changes in these factors contributed to change in underweight and overweight/obesity over time. Because of the small changes in prevalence of underweight and overweight/obesity among adolescents, we report only the results for adults. Overall, the decomposition model explained 42% of the underweight reduction and 65% of the overweight increase from 2006 to 2016 (**Figure 2**). For underweight, the explained share was accounted for by the improvements in SES (28.9%), improved latrine (4.2%), education (3.6%), and age (3.0%). The increase in overweight/obesity was explained by changes in SES (46.0%), improved latrine (6.8%), education (6.7%), and age (7.2%).

Discussion

To our knowledge, our study provides the most comprehensive analysis of the shared determinants of underweight and overweight/obesity among adolescent girls and women in India. Our study identifies common factors associated with a reduced risk of underweight but an increased risk of overweight/obesity, including higher SES, living in urban areas, improved diet diversity, higher education, and using an improved sanitation facility. These associations were consistent for both adult women and adolescents, with the exception of education. Among adults, women with ownership of money and greater decision-making power tended to be at reduced risk, whereas working for pay increased risk of underweight. In addition, the decomposition analysis results suggest household SES to be 1 of the primary drivers of change in BMI, explaining 29%



[1]BMI: body mass index; BMIZ: BMI *z*-score [1]Underweight defined as BMIZ < –1 for adolescents, BMI <18.5 kg/m^2 for adults; overweight defined as BMIZ >1 for adolescents, BMI >25 kg/m^2 for adults

FIGURE 1 BMI distribution shifts, by survey year for (A) adolescents, 15–19 y, and (B) adults, 20–49 y of age in India; and the prevalence of underweight and overweight/obesity, by survey year for (C) adolescents, 15–19 y and (D) adults, 20–49 y of age in India. Underweight defined as BMI *z* score < -1 for adolescents, BMI <18.5 kg/m^2 for adults; overweight defined as BMI *z* score >1 for adolescents, BMI >25 kg/m^2 for adults.

TABLE 2 Determinants of underweight among women 15–49 y of age in India, by survey year[1]

	Adolescents (15–19 y)		Women (20–49 y)			
	Individual and household		Individual and household		Full model	
	2006	2016	2006	2016	2006	2016
	$n = 21,349$	$n = 117,683$	$n = 89,005$	$n = 527,359$	$n = 55,011$	$n = 55,556$
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Respondent's current age	1.05*** (1.02, 1.08)	1.03*** (1.01, 1.04)	0.96*** (0.96, 0.97)	0.95*** (0.95, 0.95)	0.97*** (0.96, 0.97)	0.95*** (0.94, 0.95)
Age at first birth <19[2]	0.79*** (0.71, 0.88)	0.77***(0.73, 0.82)	0.95* (0.91, 1.00)	0.83*** (0.81, 0.85)	0.98 (0.93, 1.04)	0.80*** (0.74, 0.86)
Total living children	1.33* (1.05, 1.70)	1.35* (1.07, 1.72)	1.04*** (1.02, 1.06)	1.03*** (1.02, 1.04)	1.06*** (1.03, 1.09)	1.09*** (1.06, 1.13)
Urban residence, binary	0.94 (0.86, 1.04)	0.85*** (0.81, 0.90)	0.52*** (0.49, 0.56)	0.52*** (0.50, 0.54)	0.49*** (0.46, 0.53)	0.49*** (0.45, 0.54)
SES index (lowest as ref)						
Low	0.97 (0.88, 1.07)	0.96 (0.91, 1.01)	0.76*** (0.71, 0.80)	0.82*** (0.79, 0.84)	0.77*** (0.72, 0.83)	0.82*** (0.75, 0.90)
Medium	0.93 (0.83, 1.04)	0.97 (0.92, 1.03)	0.56*** (0.52, 0.60)	0.68*** (0.66, 0.71)	0.58*** (0.53, 0.63)	0.62*** (0.56, 0.69)
High	0.76*** (0.66, 0.87)	0.88*** (0.83, 0.94)	0.43*** (0.40, 0.47)	0.55*** (0.52, 0.57)	0.41*** (0.37, 0.46)	0.51*** (0.46, 0.57)
Highest	0.66*** (0.56, 0.78)	0.76*** (0.71, 0.81)	0.31*** (0.28, 0.34)	0.40*** (0.38, 0.42)	0.30*** (0.26, 0.34)	0.35*** (0.31, 0.41)
SC/ST/OBC	1.00 (0.92, 1.09)	1.08** (1.03, 1.14)	1.04 (0.98, 1.09)	1.09* (1.06, 1.12)	1.03 (0.96, 1.10)	1.03 (0.95, 1.13)
Religion is Hinduism	1.07 (0.97, 1.18)	1.08** (1.03, 1.13)	1.18*** (1.11, 1.26)	1.19*** (1.15, 1.23)	1.20*** (1.10, 1.30)	1.26*** (1.15, 1.38)
Improved latrine	0.87** (0.79, 0.97)	0.95* (0.91, 0.99)	0.76*** (0.72, 0.81)	0.79*** (0.76, 0.81)	0.74*** (0.69, 0.80)	0.76*** (0.70, 0.82)
Education (no schooling as ref)						
1–5 y	1.01 (0.88, 1.16)	1.01 (0.93, 1.10)	0.82*** (0.77, 0.87)	0.82*** (0.80, 0.85)	0.91*** (0.84, 0.98)	0.84*** (0.76, 0.93)
6–9 y	1.03 (0.92, 1.16)	1.03 (0.96, 1.11)	0.85*** (0.80, 0.91)	0.75*** (0.72, 0.77)	0.85*** (0.79, 0.92)	0.79*** (0.72, 0.86)
≥10 y	0.97 (0.85, 1.11)	0.99 (0.92, 1.07)	0.79*** (0.73, 0.85)	0.70*** (0.68, 0.72)	0.73*** (0.66, 0.81)	0.68*** (0.61, 0.75)
Dietary diversity (low as ref)						
Medium	1.06 (0.98, 1.16)	0.99 (0.95, 1.03)	1.01 (0.96, 1.06)	0.93*** (0.90, 0.95)	1.03 (0.97, 1.10)	0.87*** (0.81, 0.93)
High	1.04 (0.94, 1.14)	0.91*** (0.86, 0.95)	0.84*** (0.79, 0.89)	0.82*** (0.79, 0.84)	0.85*** (0.79, 0.92)	0.75*** (0.69, 0.82)
Decision-making					0.98** (0.96, 0.99)	0.98+ (0.96, 1.00)
Mobility					0.98 (0.96, 1.00)	0.99 (0.97, 1.01)
Ownership of money					0.99 (0.94, 1.04)	0.93* (0.87, 0.99)
Work for pay					1.10** (1.03, 1.16)	1.10* (1.02, 1.19)
Any violence					1.05+ (1.00, 1.11)	1.03 (0.96, 1.10)

[1]Results presented as OR. SC/ST/OBC, scheduled caste/scheduled tribe/other backwards caste; SES, socioeconomic status.
[2]Low BMI defined as BMI z score < -1 for adolescents and BMI <18.5 kg/m^2. For adolescents, use age at first married <19.
$^+P < 0.1$, $^*P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

of the reduction in undernutrition and 46% of the increase in overweight/obesity over the past decade.

Household SES may influence BMI through multiple complex pathways, including purchasing power, differences in food consumption patterns, cultural norms on body size ideals, among other factors; although many questions remain on the specific mechanisms (25, 30, 31). Globally, similar positive associations with SES and BMI have been reported consistently in 36 low- and middle-income countries (32). Our divergent results for increased risk of underweight among low SES families compared with increased risk of overweight/obesity among high SES families are in alignment with prior research in India (12, 15, 33, 34). Using NFHS data from 1998–1999 and 2005–2006, Subramanian et al., report strong positive correlations between women's BMI and SES and conclude that the double burden of undernutrition and overnutrition remains "socially segregated" in India (34). Likewise in a 2013–2014 cross-sectional survey in Tamil Nadu, higher wealth index was associated with an increased risk of having a BMI ≥25 (OR: 1.07) and BMI ≥30 (OR: 1.09), and was associated with a lower risk of having a BMI <18.5 (OR: 0.93) (33). However, Sengupta et al., cautions against generalizations, given the rising risk of overweight/obesity in low SES and rural populations within states with a high overall burden of overweight/obesity (35). In the current analysis, similar to global trends in low- and middle-income countries, residing in urban areas was associated with a lower risk of underweight and a higher risk of overweight/obesity (25, 26). However, as India continues to develop and undergo nutrition transition, we may see a growing obesity burden among low SES and rural populations as has been demonstrated in other contexts (36, 37).

As economic growth increases in India, parallel improvements have been made in education and access to improved sanitation, with contrasting associations with underweight and overweight/obesity. In the current analysis, higher education among women was associated with reduced risk of underweight in a dose-response manner, with higher educational attainment being associated with greater reductions in risk. This was evident in the adult analysis but not in adolescents. This may be because some adolescents are still in school at the time of the survey and we are not able to capture downstream outcomes of education on maternal capacity and income earning potential. Conversely, greater educational attainment was associated with higher prevalence of overweight and obesity among both women and adolescents. Similar trends have been reported in prior research studies in India (12, 33, 38). There are multiple mechanisms through which education may influence BMI, including food choices, media exposure, income, and use of health care services. In addition, education may be considered a marker of socioeconomic position as described by Luhar et al., and thus follows a similar pattern to wealth (12).

Likewise, the use of an improved latrine was negatively associated with underweight and positively associated with overweight/obesity among both adolescents and women. The mechanisms in which sanitation may contribute to underweight

TABLE 3 Determinants of overweight/obesity among women 15–49 y of age in India, by survey year[1]

	Adolescents (15–19 y)		Women (20–49 y)			
	Individual and household		Individual and household		Full model	
	2006	2016	2006	2016	2006	2016
	$n = 21,349$	$n = 117,683$	$n = 89,005$	$n = 527,359$	$n = 55,011$	$n = 55,556$
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Respondent's current age	1.08^{+} (0.99, 1.17)	0.98 (0.95, 1.02)	1.08*** (1.08, 1.09)	1.07*** (1.07, 1.07)	1.08*** (1.07, 1.08)	1.06*** (1.06, 1.07)
Age at first birth <19[2]	1.25 (0.91, 1.71)	1.67*** (1.44, 1.93)	1.21*** (1.14, 1.29)	1.26*** (1.23, 1.30)	1.21*** (1.12, 1.30)	1.26*** (1.17, 1.37)
Total living children	0.39 (0.10, 1.45)	1.01 (0.58, 1.76)	0.93*** (0.90, 0.95)	0.99* (0.98, 1.00)	0.89*** (0.86, 0.92)	0.95** (0.92, 0.98)
Urban residence, binary	2.66*** (2.11, 3.37)	2.18*** (1.98, 2.41)	2.91*** (2.69, 3.13)	2.21*** (2.14, 2.29)	2.88*** (2.64, 3.15)	2.23*** (2.05, 2.42)
SES index (lowest as ref)						
Low	1.62** (1.18, 2.24)	1.40*** (1.18, 1.65)	1.61*** (1.47, 1.76)	1.42*** (1.36, 1.49)	1.61*** (1.46, 1.78)	1.50*** (1.33, 1.70)
Medium	1.52* (1.09, 2.13)	1.72*** (1.46, 2.03)	2.26*** (2.06, 2.49)	1.80*** (1.72, 1.89)	2.21*** (1.97, 2.48)	2.08*** (1.82, 2.38)
High	2.58*** (1.78, 3.75)	2.23*** (1.90, 2.62)	3.31*** (3.00, 3.65)	2.27*** (2.16, 2.38)	3.26*** (2.90, 3.67)	2.58*** (2.26, 2.95)
Highest	2.92*** (2.02, 4.22)	2.78*** (2.35, 3.30)	4.13*** (3.68, 4.64)	2.82*** (2.68, 2.98)	3.96*** (3.44, 4.56)	3.24*** (2.81, 3.73)
SC/ST/OBC	0.77* (0.62, 0.95)	0.81*** (0.73, 0.90)	0.97 (0.91, 1.03)	0.90*** (0.87, 0.92)	1.02 (0.95, 1.10)	0.95 (0.88, 1.03)
Religion is Hinduism	0.86 (0.68, 1.09)	0.90* (0.81, 1.00)	0.68*** (0.64, 0.73)	0.80*** (0.77, 0.83)	0.66*** (0.61, 0.72)	0.79*** (0.72, 0.86)
Improved latrine	1.19 (0.91, 1.56)	1.34*** (1.20, 1.50)	1.38*** (1.29, 1.49)	1.27*** (1.23, 1.31)	1.38*** (1.27, 1.50)	1.31*** (1.21, 1.43)
Education (no schooling as ref)						
1–5 y	1.39 (0.84, 2.28)	1.11 (0.85, 1.45)	1.46*** (1.33, 1.59)	1.37*** (1.33, 1.42)	1.34*** (1.20, 1.51)	1.29*** (1.17, 1.43)
6–9 y	1.48 + (0.95, 2.29)	1.28* (1.03, 1.58)	1.80*** (1.65, 1.96)	1.59*** (1.54, 1.64)	1.67*** (1.50, 1.85)	1.45*** (1.32, 1.59)
≥10 y	1.30 (0.82, 2.07)	1.42** (1.15, 1.75)	1.66*** (1.50, 1.84)	1.50*** (1.45, 1.56)	1.57*** (1.39, 1.77)	1.39*** (1.24, 1.55)
Dietary diversity (low as ref)						
Medium	1.16 (0.92, 1.46)	1.23*** (1.11, 1.35)	1.09** (1.02, 1.16)	1.09*** (1.06, 1.12)	1.08^{+} (0.99, 1.17)	1.18*** (1.09, 1.27)
High	1.52** (1.17, 1.98)	1.39*** (1.25, 1.54)	1.33*** (1.23, 1.44)	1.20*** (1.16, 1.24)	1.30*** (1.19, 1.43)	1.21*** (1.10, 1.32)
Decision-making					1.02^{+} (1.00, 1.050)	1.02 (0.99, 1.04)
Mobility					1.08*** (1.05, 1.11)	1.02^{+} (1.00, 1.05)
Ownership of money					1.02 (0.95, 1.09)	0.99 (0.92, 1.06)
Work for pay					0.78*** (0.72, 0.84	0.88** (0.81, 0.95)
Any violence					0.89** (0.83, 0.96)	0.95 (0.89, 1.02)

[1] Results presented as OR. SC/ST/OBC, scheduled caste/scheduled tribe/other backwards caste; SES, socioeconomic status.
[2] High BMI defined as BMI *z* score >1 for adolescents, and BMI >25 for adults. For adolescents, use age at first married <19.
$^{+}P < 0.1$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

burden could be through increased risk of infection and diarrheal diseases (39, 40). However, there is no clear mechanism by which improved sanitation would be associated with obesity; this could be a result of residual confounding with household and community wealth.

Higher dietary diversity scores in this analysis were negatively associated with underweight while positively associated with overweight and obesity. Drivers of food choice are complex and as outlined in the conceptual framework by Bailey et al., may be influenced by personal cultural perceptions and habits, food safety, health, convenience, family and food roots, cost, and the nutrition transition in India (41). The nutrition transition is categorized by changes in dietary patterns and physical activities (27). Generally during transition, the diet shifts from home-cooked and cereal-based diets to more prepared/processed foods higher in fat, sugar, and salt. Prior research has reported that higher SES groups in India consume diets containing a higher proportion of fat (32% compared with 17%) than lower SES groups (42). Although carbohydrates remain a staple in Indian diets, there have been shifts in the types of carbohydrates being consumed; with low consumption of coarse grains (sorghum, millet, barley, whole-wheat flour) and high consumption of refined grains (white rice, white flour, sugar, jaggery). There have also been decreases in the consumption of pulses, fruits, and vegetables, and increasing intakes of meat and processed foods high in salt (43). Furthermore, in the absence of information on physical activity, diet only partially explains the association with weight status. Hence, the results should be interpreted with caution. The shifts in diet along with declining physical activity could be contributing to growing obesity and noncommunicable diseases in India (43).

The cross-sectional nature of the data set only allows for examination of association and we cannot assign causality to any risk factors identified. We are also limited by the variables available in the NFHS data sets. Information on physical activity and more detailed information on diet, such as 24-h dietary recall or food frequency questionnaire data, would allow for a more in-depth understanding of dietary changes over time and associations with undernutrition and overnutrition. This analysis was restricted to adolescent girls and women, but future work comparing these results to those for men may be valuable as there is a similar national pattern of decreasing underweight (34% to 19%) and increasing overweight/obesity (9% to 19%) for men over the last decade (3). The use of the different cutoffs may influence national-level and state-level classification of the double burden, as reported by Sengupta et al (35).

Our current analysis adds to the literature on the dual burden of underweight and overweight/obesity at both the national level and the state level in India, 1 of the countries with the greatest burden of undernutrition among women and girls across the globe (1, 2). Despite rapid advances in economic growth, there remain substantial heterogeneity and health inequalities across India. Over the past decade, there has been progress in reducing the underweight burden in India. However, improvements were most evident among women and only slight improvements were made among adolescent girls,

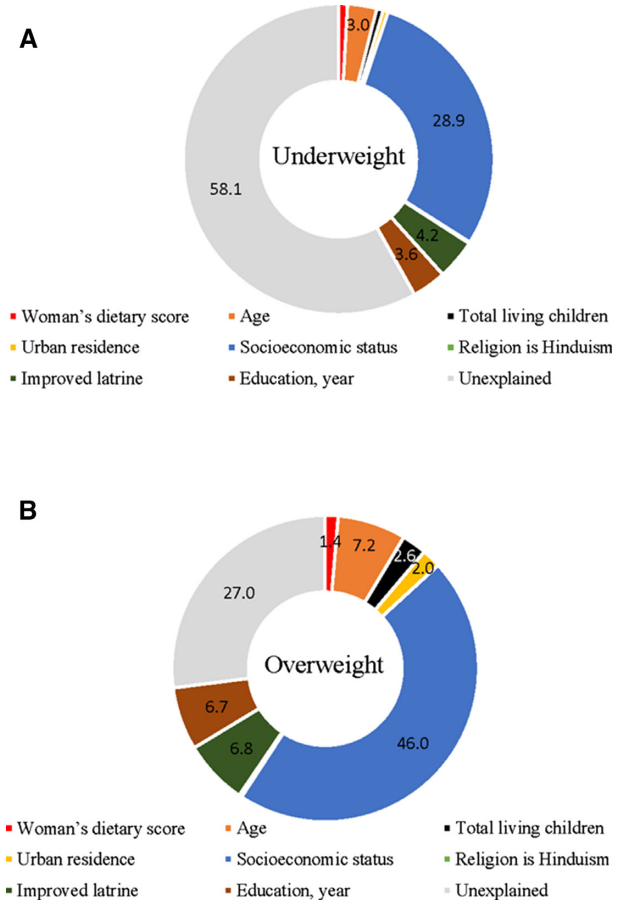


FIGURE 2 Decomposition for underweight and overweight/obesity among adults, 20–49 y of age in India: (A) underweight; (B) overweight. Regression decomposition analysis results for key determinants associated with changes in underweight (A) and overweight/obesity (B) from 2005–2006 to 2015–2016. The explained share (%) for the changes in underweight and overweight/obesity is provided when >1% and is color coded with the key.

with large variation across states. Stratification by women and adolescent girls also highlights the lack of progress in reducing underweight among adolescent girls despite overall trends. Failing to act during this critical time period is a lost opportunity to prevent the vicious cycle of intergenerational malnutrition (44).

Given the dual burdens of overweight and underweight and divergent risk factors, our work cautions against concentrating on one end of the spectrum rather than focusing on obtaining a healthy BMI. Efforts focused on alleviating undernutrition must be implemented with caution, especially among communities where the prevalence of overweight and obesity are on the rise. For example, social-safety net programs such as the public distribution system and supplementary food programs might have to be revisited to assess the quality and quantity of foods provided through these programs. In addition, policies and programs that enforce urban planning and strengthen built environment to facilitate physical activity are much needed. Given the large variation across India and differences in the stage of nutrition transitions, there is a need for state-specific approaches (35). Balanced multidisciplinary approaches are needed that tackle the underlying social and economic constraints as well as direct education, sanitation, and nutrition interventions to successfully address both underweight and overweight adolescent girls and women in India. India has several strong existing nutrition policies aimed at women and girls (45). However, in some areas implementation of these programs is poor, not reaching those in greatest need (46). In particular, insufficient progress is being made to reduce undernutrition among adolescent girls. Historically, nutrition policies have focused on anemia and underweight and there is a need for greater attention to the dual burden of malnutrition. This research calls for intensification of efforts to improve the nutritional status of women and girls in India.

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