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Wealth-based inequality in underweight among Scheduled Tribe women in India: a regional analysis

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Abstract

Background Despite widespread undernutrition among tribal women, there is limited understanding of wealth-based disparities in underweight within this group and how these inequities have changed over time across different regions of India. This study aims to explore trends and patterns of wealth-based inequalities in underweight prevalence among Scheduled Tribe (ST) women across various regions of India.

Methods The study analysed data from the fourth and fifth rounds of the National Family Health Survey, covering 113,549 and 121,326 non-pregnant ST women aged 15–49, respectively. Wealth-based inequality in underweight was assessed using the Erreygers normalized concentration index (ECI), while predicted probabilities of underweight, adjusted for relevant variables, were calculated using binary logistic regression.

Findings Between 2015-16 and 2019-21, underweight prevalence among ST women in India decreased from 31.7 to 25.5%, with all regions showing declines. The northern region witnessed the largest drop (20.1–9.8%), followed by the western region (38.7–30.0%) and eastern-central region. The northeastern region that had consistently low underweight prevalence witnessed minimal change over the study period. Wealth inequality, as measured by the ECI, slightly decreased over the study period, from −0.177 in 2015–16 to -0.134 in 2019–21. However, the reduction in ECI varied significantly across regions. The northern region experienced the most significant reduction in wealth inequality, with a decrease of -0.145 ECI points. In comparison, the western, southern, eastern-central regions exhibited more modest reductions of -0.036, -0.027, and −0.028 ECI points, respectively. The northeastern region, characterized by initially lower levels of inequality, demonstrated no change in its ECI over the study period. The predicted probabilities from the pooled logistic regression analysis indicated a decline in inequality over the study period. This reduction was primarily driven by significant decreases in underweight prevalence among the poorer and poorest wealth quintiles. Notably, the northern, western, eastern-central, and southern regions experienced the most

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pronounced improvements in underweight prevalence among these lower wealth groups. Despite overall progress, wealth-based inequality in underweight persisted, especially in the western, southern, and eastern-central regions, where the 2019-21 ECI remained more than −0.10.

Conclusion Despite progress in reducing underweight among ST women in India, regional disparities and wealth-based inequality in underweight persist. Policies should focus on targeted, region-specific interventions that prioritize economically disadvantaged women, reduce inequality, and improve access to nutrition and healthcare, particularly in the western, southern, and eastern-central regions.

Keywords Underweight, Scheduled Tribe, Tribal women, Erreygers normalised concentration index, Decomposition, NFHS

Introduction

Undernutrition remains a persistent and pressing public health challenge across all age groups in India, with various manifestations such as vitamin deficiencies, underweight, wasting, and stunting [1, 2]. Among these, underweight, characterized by a low body fat percentage resulting from prolonged malnutrition or inadequate diet, stands out as a significant concern due to its profound implications for individual health and development [3, 4]. Notably, underweight individuals face heightened risks of compromised immune function, increasing susceptibility to severe health complications. Among women, underweight not only jeopardizes their own health but also significantly impacts reproductive health, leading to adverse pregnancy outcomes and neonatal complications [5–9].

The Sustainable Development Goals (SDGs) in line with global efforts to combat malnutrition have set ambitious targets including ending all forms of malnutrition by 2030 [10]. Despite concerted global efforts, progress in reducing underweight among reproductive-age women has been slow, with only marginal declines observed since the beginning of the millennium—dropping from 12% in 2000 to 10% in 2022 [9]. In India, where 13% of reproductive-aged women were underweight based on the fifth round of the National Family Health Survey (NFHS) [11], the situation is particularly concerning for women from marginalized communities such as Scheduled Tribes (ST) who bear a disproportionately heavy burden, with a staggering 25.5% women experiencing underweight [11].

The term "Scheduled Tribes" refers to indigenous communities in India who receive special constitutional protections and privileges due to their historically disadvantaged status [12]. These groups have traditionally inhabited isolated regions, often in remote, mountainous, and forested areas, which has led to their exclusion and disadvantage [13, 14]. Despite efforts over the years to uplift them, they remain among the most marginalized social groups in the country. STs continue to confront substantial socioeconomic, demographic, and health-related hurdles, with undernutrition emerging as a particularly daunting challenge. Their sizable population, surpassing a hundred million individuals and comprising around 8.6% of the nation's total populace as per the Indian Census of 2011 [15], highlights the pressing need to address the issue of undernutrition.

The issue of underweight among Indian women has been explored extensively, with studies consistently reporting a higher prevalence of underweight amongST women compared to other social groups [13, 16, 17]. These studies have highlighted significant challenges faced by ST women, including insufficient food intake and limited access to nutritious foods [17–21], which often result in micronutrient deficiencies, particularly iron deficiency, with adverse effects on their health and well-being [22–24]. Previous studies have highlighted household wealth as a significant factor associated with underweight among Indian women, with poorer women being more likely to underweight than their richer counterparts [19, 25–27]. While some studies have examined economic disparities in underweight prevalence, they have predominantly focused on national-level trends. Regional variations in wealth-based inequality, influenced by diverse developmental and socioeconomic contexts, have been largely overlooked. This is particularly concerning forST women, who experience disproportionately high levels of undernutrition compared to other social groups. Despite the significance of this issue, research on wealth-based inequalities in underweight among ST women remains limited. Most existing studies are small-scale and fail to provide comprehensive regional insights, leaving important gaps in the evidence on undernutrition among ST women [19, 28].

Given that STs are not a homogeneous group but consist of tribes with diverse social and economic situations, traditions, cultures, dietary habits, lifestyles, and geographical contexts, it is crucial to study STs separately. This approach helps identify and target the most vulnerable or disadvantaged groups, facilitating more effective government interventions to reduce disparities and promote health equity. While socioeconomic inequalities in health are widely studied, there remains a significant gap in research on how wealth disparities specifically affect the nutritional status of ST women. Understanding these

disparities is essential for developing targeted policies to reduce undernutrition and its health risks. This study, therefore, aims to address this gap by examining wealth-based inequality in underweight prevalence among ST women (aged 15-49) across different regions of India from 2015 to 2021. By focusing on this period, the study aims to shed light on the changing landscape of wealth disparities in underweight and contribute to ongoing efforts to reduce undernutrition and improve the health outcomes of tribal women in India.

Data and methods

Data source

The data for the present study is from two successive NFHS rounds conducted during 2015-16 (NFHS-4) and 2019-21 (NFHS-5). NFHS provides nationally representative information on demographic, health, family welfare, and nutrition data for India, its states and union territories [29]. In addition, it provides district-level estimates for several important indicators. Further details are available in the national reports of NFHS [11, 29]. A total of 699,686 and 724,115 women of reproductive age were interviewed by NFHS 4 and 5. For analysis, we excluded currently pregnant and non-ST women. In addition, we dropped women with missing information or extreme values for both NFHS 4 and 5 data sets. Figure 1 shows in detail the sample selection for the analysis. The final sample for analysis included 113,549 and 121,326 ST non-pregnant women aged 15–49 in NFHS 4 and 5, respectively.

Statistical analysis

Underweight is the primary variable in our analysis. To construct this variable, we utilized height and weight data from the NFHS. Body Mass Index (BMI) was calculated by dividing an individual's weight (in kilograms) by their height (in meters squared), following the standard formula (kg/m^2). This widely accepted method is commonly used to assess body weight relative to height and serves as a key indicator for classifying individuals as underweight, normal weight, overweight, or obese [11]. The NFHS employs a four-category classification for BMI. If an individual's BMI is less than 18.5 kg/m^2, they are categorized as "too thin for their height." BMIs between 18.5 and 24.9 kg/m^2 and 25.0–29.9 kg/m^2 are considered "normal" and "overweight," respectively. A BMI equal to or exceeding 30.0 kg/m^2 is classified as "obese." In this study, the dependent variable, "BMI," has been transformed into a binary format. A woman is classified as "underweight" if her BMI is below 18.5 kg/m^2, and this category is recorded as "1." Conversely, if her BMI falls between 18.5 and 30.0 kg/m^2 or higher, she is categorized as "not underweight," represented as "0." This coding approach aligns with prior research [19, 30–34].

We present state- and region-specific estimates for underweight prevalence to assess the absolute change between the two time points, 2015-16 and 2019-21. Subsequently, we provide underweight estimates by wealth quintiles for each region for both years, highlighting the change in underweight prevalence within each quintile across regions. To quantify wealth-based inequality in underweight among ST women over time, we computed the Erreygers normalized concentration index (ECI) (for a more detailed description of the method, please refer to Appendix 1). We selected theECI for measuring wealth-based inequality in underweight prevalence because the Concentration Index (CI), commonly used for assessing socioeconomic health inequalities, is not appropriate for

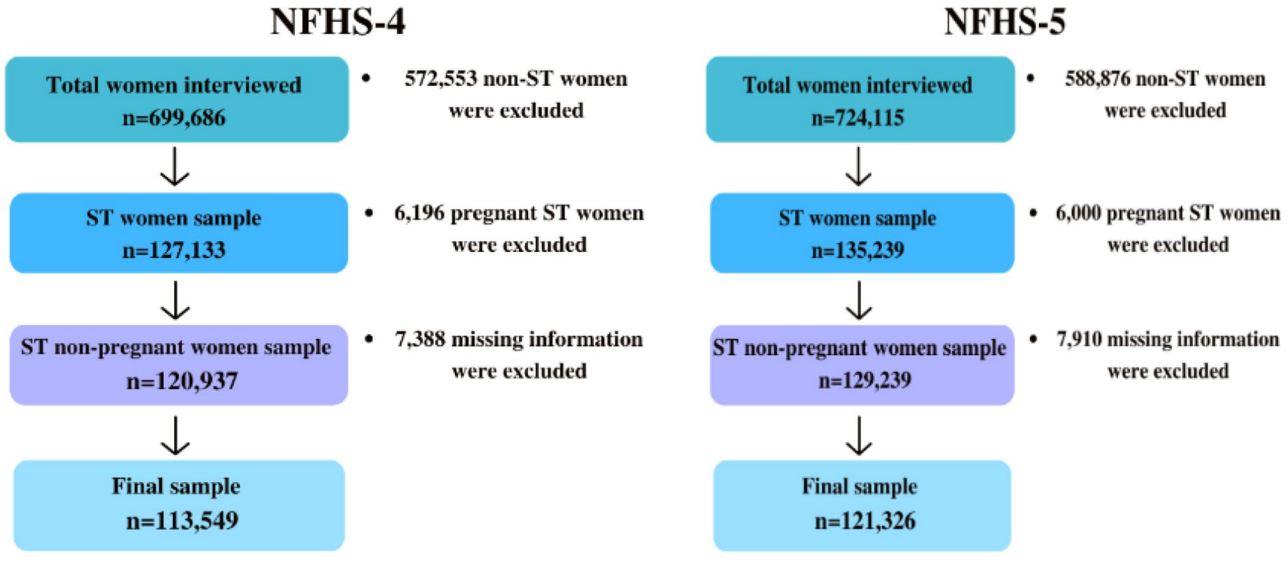

Fig. 1 Sample selection procedure for this study

binary outcomes such as underweight (which has only two categories: yes or no).

As the assessment of wealth-based inequality in underweight prevalence relied on bivariate analysis without adjusting for other variables, we conducted multivariable logistic regression to calculate predicted probabilities of being underweight for wealth quintiles after controlling for a variety of demographic and socioeconomic factors that affect underweight. The choice of the control variables to be used in the regression analysis was based on prior research in this field [17, 20, 21, 31, 35, 36] and the availability of relevant variables in the NFHS dataset. These variables included age, education, household economic status, marital status, religion, place of residence, exposure to mass media, parity, tobacco usage, anaemia or diabetes, dietary habits including types and frequency of food consumption like fruits, vegetables, dairy, legumes, fried food, carbonated beverages, as well as access to adequate toilet facilities [23, 37–41]. These factors are thoroughly detailed in Appendix 2.

We have classified Indian states on the basis of patterns of development, access to resources, and sociodemographic characteristics of tribal population into five regions which are as follows: (a) northern tribal region (Jammu and Kashmir, Himachal Pradesh, and Uttarakhand), (b) northeastern tribal region (Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Meghalaya, Tripura, and Sikkim), (c) eastern-central tribal region (Chhattisgarh, Jharkhand, Madhya Pradesh Odisha, and West Bengal), (d) western tribal region (Rajasthan, Gujarat and Maharashtra), and (e) southern tribal region (Andhra Pradesh, Karnataka, Kerala, Goa, Tamil Nadu, and Telangana). Specifically, Odisha, West Bengal, Jharkhand, Chhattisgarh, and Madhya Pradesh of eastern-central regions were clubbed together because the tribal populations in these states share common characteristics, which set them apart from tribal groups in other parts of India. In contrast, the northeastern, southern, western, and northern regions exhibit distinct tribal demographics, and cultural practices. Similar classification has also been considered by the previous study [42]. The predicted probabilities obtained from the regression analysis were graphed for each wealth quintile, across both time periods and regions, to observe trends and the magnitude of change over the study period. All analyses were performed using Stata 16 statistical software [3].

Results

Changes in underweight prevalence among ST women between 2015-16 and 2019-21

Table 1 presents tribal region and state wise prevalence of underweight among ST women in India for the years 2015-16 and 2019-21. Over the study period, there was a notable decrease in underweight prevalence from 31.7% (95% CI: 31.0-32.4) in NFHS-4 to 25.5% (25.0-26.1) in NFHS-5. This decline was consistent across India's five tribal regions: Northern, Eastern-Central, Northeastern, Western, and Southern. The greatest change was observed in northern tribal region where quantum of decline over the study period was 10.3% points (pp), with underweight reducing from 20.1% in 2015-16 to 9.8% during 2019-21. The western tribal region experienced 8.7 pp of decline, with underweight reducing from 38.7% in 2015-16 to 30.0% in 2019-21. Similarly, the eastern-central tribal region registered a decline from 34.7% in 2015-16 to 27.9% in 2019-21, marking a significant 6.8 pp decrease. Conversely, the northeastern tribal region reported not only lowest prevalence but also smallest change over the study period. While in the northeastern tribal region experienced a decline of 1.5 pp, from 11.7% during 2015-16 to 10.2% during 2019-21, the southern tribal region witnessed a decline of 4.1 pp from from 25 to 20.9%.

Among the states of India, the prevalence of underweight in 2015-16 varied significantly across states among tribal women. In 2015-16, the undernutrition prevalence surpassed 30% in eight states with significant tribal populations: Gujarat (40.4%), Maharashtra (38.4%), Rajasthan (37.4%), Odisha (36.6%), Jharkhand (35%), Madhya Pradesh (34.4%), Chhattisgarh (34%), and West Bengal (32.9%). In contrast, underweight prevalence was less than 10% in the northeastern states of Sikkim, Arunachal Pradesh, Mizoram, and Manipur. During the 2019-21, the prevalence of underweight was highest in Gujarat (35.2%), followed by Odisha (30.6%), Maharashtra (30.3%), Bihar (29.7%), and Chhattisgarh (29.3%). Over the study period (2015–2021), there was a noticeable decline (>10 pp) in underweight prevalence across many states. Jammu & Kashmir experienced the most significant decline in underweight prevalence at 14.4 pp, followed by Rajasthan (12.8 pp), and West Bengal (10.8 pp). States exhibiting changes of 5 to 10 pp included Gujarat (5.5 pp), Odisha (6.0 p p), Madhya Pradesh (6.9 pp), Jharkhand (7.0 pp), Uttar Pradesh (7.2 pp), Telangana (8.0 pp), and Maharashtra (8.1 pp). Southern states like Kerala, Tamil Nadu, and Karnataka, along with several northeastern states, and Himachal Pradesh and Bihar, showed little to no significant changes over the period.

Wealth-based inequality in underweight

Table 2 presents underweight prevalence categorized by household wealth quintiles across tribal regions of India. The data clearly shows that as household wealth increases, underweight prevalence decreases. Notably, in 2015-16, 39% women in the poorest quintile were underweight, compared to just 15.3% in the richest quintile—an underweight prevalence that is about two and a half times higher in the poorest group. In the subsequent

Table 1 Underweight prevalence among ST women in selected states of India, 2015–2021

States	NFHS 4 (2015-16)		NFHS 5 (2019-21)		Change during 2015- 21 (in PP)
	n	% Underweight [95% CI]	n	% Underweight [95% CI]	
Northern tribal region	**5179**	**20.1[17.8, 22.5]**	**4588**	**9.8 [8.1, 11.8]**	**10.3**
Jammu & Kashmir	3361	20.8 [17.6, 24.3]	2897	6.3 [04.7, 08.6]	14.4*
Himachal Pradesh	1214	14.8 [11.2, 19.1]	1393	13.7 [09.9,18.5]	1.1
Uttarakhand	604	21.6 [17.6, 26.1]	298	15.0 [11.3, 19.7]	6.6
Bihar and Uttar Pradesh	**2198**	**29.6[27.5, 31.8]**	**2533**	**26.4[24.4, 28.5]**	**3.2**
Bihar	1180	29.7 [26.8, 32.8]	1260	29.7 [26.8, 32.8]	0.0
Uttar Pradesh	1018	29.4 [26.5, 32.5]	1273	22.2 [19.6, 25.1]	7.2*
Northeastern tribal region	**47,183**	**11.7 [11.1, 12.3]**	**50,448**	**10.2 [9.5, 10.8]**	**1.5**
Arunachal Pradesh	9347	6.3 [05.6, 07.1]	13,688	4.2 [03.7, 04.8]	2.1*
Assam	4763	14.3 [13.0, 15.7]	5702	11.7 [10.4, 13.2]	2.6
Manipur	3922	7.2 [06.3, 08.2]	3474	6.2 [05.2, 07.3]	1.0
Meghalaya	7384	10.7 [09.7, 11.8]	10,481	11.1 [10.1, 12.1]	-0.3
Mizoram	10,691	8.4 [07.5, 09.4]	6206	5.5 [04.6, 06.5]	2.9*
Nagaland	7369	11.6 [10.6, 12.7]	7601	11.0 [09.9, 12.2]	0.6
Sikkim	2303	4.0 [03.1, 05.1]	1395	4.3 [02.7, 06.7]	-0.3
Tripura	1404	14.4 [12.2, 17.0]	1901	12.6 [10.9, 14.5]	1.8
Eastern-Central tribal region	**38,070**	**34.7 [33.9, 35.5]**	**36,912**	**27.9 [27.2, 28.7]**	**6.8**
Chhattisgarh	8836	34.0 [32.2, 35.9]	10,514	29.3 [28.0, 30.6]	4.7*
Madhya Pradesh	12,524	34.4 [33.2, 35.6]	10,225	27.5 [26.2, 28.8]	6.9*
Jharkhand	7704	35.0 [33.5, 36.5]	7718	27.9 [26.4, 29.5]	7.1*
Odisha	7748	36.6 [35.1, 38.1]	7100	30.6 [29.0, 32.1]	6.0*
West Bengal	1258	32.9 [29.3, 36.7]	1355	22.1 [19.3, 25.1]	10.8*
Western tribal region	**13,924**	**38.7 [36.9, 40.4]**	**17,530**	**30.0 [28.8, 31.3]**	**8.7**
Gujarat	4717	40.4 [38.0, 42.9]	6909	35.2 [33.2, 37.2]	5.2*
Maharashtra	3720	38.4 [35.0, 41.9]	4522	30.3 [28.1, 32.6]	8.1*
Rajasthan	5487	37.4 [35.4, 39.5]	6099	24.6 [22.9, 26.4]	12.8*
Southern tribal region	**4471**	**25.0 [23.0, 27.1]**	**6794**	**20.9[19.3, 22.7]**	**4.1**
Andhra Pradesh	545	28.1 [22.8, 34.1]	438	20.8 [16.0,26.5]	7.3
Karnataka	2363	23.6 [21.1,26.3]	3095	21.2 [18.7,23.8]	2.4
Kerala	264	20.5 [15.5,26.6]	275	18.8 [14.1,24.5]	1.7
Tamil Nadu	496	17.6 [13.3,22.7]	435	19.8 [15.6, 24.9]	-2.3
Telangana	640	29.8 [25.5,34.4]	2349	21.8 [18.7, 25.1]	8.0*
Goa	163	26.4 [18.0,37.0]	202	16.9 [12.2, 23.1]	9.5
India	**1,13,549**	**31.7 [31.0, 32.4]**	**1,21,326**	**25.5 [24.9, 26.1]**	**6.2**

Note *Statistically significant with $p < 0.05$, n: unweighted number of observations, %: Weighted percentage of underweight, and PP: Percentage point (absolute difference between two percentages); 95% CI: 95% Confidence Interval; NFHS: National Family Health Survey

period of 2019-21, the figures improved a bit to 30.5% for the poorest quintile and 11.6% for the richest.

While all wealth quintiles experienced reduction in underweight prevalence over time, the most significant absolute gains were observed among women from the poorest quintile. In the poorest quintile, underweight prevalence dropped by 8.5 pp as compared with 3.7 pp in the richest quintile. This shift has contributed to a decreasing gap between the quintiles, leading to slight reduction in the magnitude of inequality (represented by ECI), from −0.177 in 2015-16 to -0.134 in 2019-21. Notably, the negative ECI values consistently showed that economically disadvantaged (poorer) women continued to experience a higher prevalence of underweight during both time periods.

The prevalence of underweight in each wealth quintile varied significantly across tribal regions (see Fig. 2). For example, during 2019–21, in the northern tribal region, the prevalence of underweight among the poorest, poorer, middle, richer, and richest quintiles was 5.8%, 10.6%, 10.4%, 13.0%, and 8.7%, respectively. Similarly, in northeastern tribal region the prevalence of underweight across wealth quintiles did not vary substantially. While the prevalence in the poorest quintile was 12.8%, the prevalence in the richest quintile was 5%. In contrast, in the western tribal region, the prevalence of underweight was considerably higher, with rates of 35.8%, 33.7%, 26.3%, 20.1%, and 14.3% among the poorest, poorer, middle, richer, and richest quintile, respectively. This inequality in underweight prevalence across wealth quintiles also

Table 2 Underweight prevalence by wealth quintiles and Erreygers Concentration Index (ECI) for different tribal regions of India

Tribal region	Underweight prevalence	Underweight prevalence by wealth quintiles					ECI	Number of observations
		Poorest	Poorer	Middle	Richer	Richest		
Eastern-Central (2015-16)	34.7	38.4	33.4	26.8	20.2	17.0	-0.128***	38,070
Eastern-Central (2019-21)	27.9	30.7	26.6	22.2	15.0	13.6	-0.100***	36,912
Change between 2015 and 2021	***6.8***	***7.7***	***6.8***	***4.7***	***5.2***	***3.3***	***-0.028***	
North Eastern (2015-16)	11.7	15.6	13.0	10.2	9.9	7.3	-0.057***	47,183
North Eastern (2019-21)	10.2	12.8	11.0	8.4	6.6	5.0	-0.057***	50,448
Change between 2015 and 2021	***1.5***	***2.8***	***2.0***	***1.9***	***3.3***	***2.3***	***0.000***	
Western (2015-16)	38.7	46.4	42.9	35.0	28.0	17.7	-0.187***	13,924
Western (2019-21)	30.0	35.8	33.7	26.3	20.1	14.3	-0.151***	17,530
Change between 2015 and 2021	***8.7***	***10.7***	***9.2***	***8.7***	***7.9***	***3.4***	***-0.036***	
Southern (2015-16)	25.0	41.3	30.4	21.9	15.1	16.5	-0.192***	4471
Southern (2019-21)	20.9	31.5	26.0	20.4	13.5	9.1	-0.165***	6794
Change between 2015 and 2021	***4.1***	***9.8***	***4.5***	***1.5***	***1.6***	***7.5***	***-0.027***	
Northern (2015-16)	20.1	28.4	23.1	19.5	14.2	15.0	-0.108***	5179
Northern (2019-21)	9.8	5.8	10.6	10.4	13.0	8.7	0.037***	4588
Change between 2015 and 2021	***10.3***	***22.6***	***12.5***	***9.1***	***1.2***	***6.3***	***-0.145***	
Uttar Pradesh and Bihar (2015-16)	***29.6***	***33.3***	***27.6***	***24.4***	***20.1***	***12.1***	***-0.105******	2198
Uttar Pradesh and Bihar (2019-21)	***26.4***	***31.4***	***21.8***	***23.2***	***19.0***	***16.2***	***-0.116******	2533
Change between 2015 and 2021	***3.2***	***1.8***	***5.9***	***1.2***	***1.1***	***-4.1***	***0.011***	
India (2015-16)	31.7	39.0	32.9	25.5	19.9	15.3	-0.177***	113,549
India (2019-21)	25.5	30.5	26.5	21.3	15.6	11.6	-0.134***	121,326
Change between 2015 and 2021	***6.2***	***8.5***	***6.4***	***4.2***	***4.3***	***3.7***	***-0.043***	

Note Change between 2015 and 2021 represents the absolute difference in prevalence between the two years. ECI: Erreygers Concentration Index; *** $p < 0.001$

gets reflected in the ECIs of different regions. The 2019-21 ECI was relatively higher in the western (-0.15) and southern (-0.17) tribal regions than in the northern (0.04) and northeastern (-0.06) tribal regions.

Over the study period, the most significant shift in the prevalence of underweight occurred in the bottom quintile (poorest). However, the reduction in underweight prevalence varied considerably across regions. For instance, the prevalence of underweight in the northern region dropped by 22.6 pp (from 28.4% to 9.8%) as compared to only 2.8 pp (15.6–12.8%) in the northeastern tribal region and 1.8 pp (33.3–31.4%) in Bihar and Uttar Pradesh combined. Conversely, the change in underweight prevalence within the top quintile (richest) was less pronounced, ranging from 2 to 4 pp in the eastern-central, northeastern and western tribal regions and 6–8 pp in the northern and southern tribal region.

The greatest change in the inequality in underweight prevalence was recorded for the northern region where the ECI decreased from − 0.108 in 2015-16 to 0.037 in 2019-21. The ECI decreased only slightly in rest of the regions over the study period. For example, the ECIs for the western and southern tribal region were − 0.187 and − 0.192 during 2015-16, which reduced slightly over the study period, dropping to -0.151 and − 0.165 during 2019-21. The inequality in underweight was lowest in the northeastern tribal region (ECI = -0.057) during 2015-16 and it did not change over the study period.

Predicted probability of being underweight among ST women

The results of regression analysis are presented in terms of predicted probability of being underweight by household wealth quintiles (see Fig. 3a and f). This analysis controls for a number of factors that affect the likelihood of being underweight. The progressive decline in predicted probability of being underweight as one moves from poorest quintile to the richest quintile confirms our previous observation regarding the wealth-based inequality in underweight among the tribal women in India and its regions. In 2015-16, the probability of being underweight was 0.24 for ST women in the poorest quintile, and it decreased progressively to 0.13 for those in the richest quintile. Similarly, in 2019-21, the probability of being underweight for ST women in the poorest quintile was 0.19, decreasing to 0.10 for those in the richest quintile.

Furthermore, across the regions, we observed a downward trend in the predicted probability (pp) from 2015-16 to 2019-21 (see Fig. 3a and f). The most significant decrease in predicted probability occurred in the western tribal region, where among the predicted probability in the poorest wealth quintile decreased from 0.44 to 0.34, while among the richest, it dropped from 0.22 to 0.15. This was followed by the northern tribal region, where predicted probability decreased from 0.16 to 0.08 among the poorest and from 0.11 to 0.05 among the richest. Subsequently, in the eastern-central tribal region, the

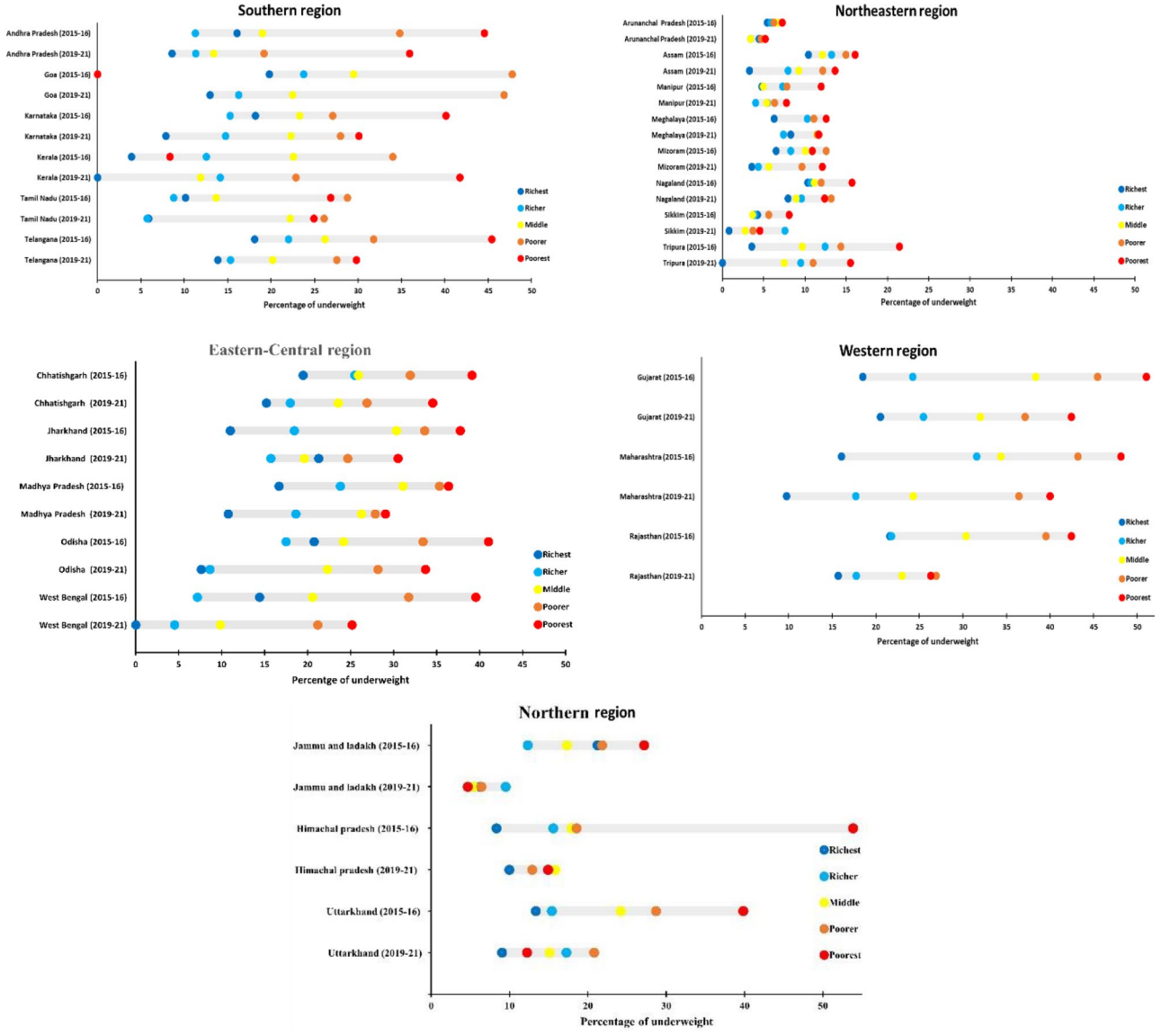

Fig. 2 Proportion of underweight women by wealth quintiles in different tribal regions and states of India, 2015-16 and 2019-21

predicted probability decreased from 0.36 to 0.31 among the poorest and from 0.20 to 0.17 among the richest. The northeastern tribal region exhibited the least change in predicted probability, with a shift from 0.12 to 0.09 among the poorest and from 0.06 to 0.05 among the richest between 2015- 16 and 2019-21. Lastly, in the southern tribal region, the predicted probability changed from 0.33 to 0.30 among the poorest and from 0.12 to 0.11 among the richest. Despite an overall decrease seen over the study period, the wealth-based inequality in underweight among ST women in India persisted, notably evident in the western, southern, eastern-central tribal regions. The gradient depicted in the line graphs vividly illustrates this gap, although it was less prominent in the northeastern and northern tribal regions.

Discussion

The findings of our study provide valuable insights into the trends in underweight prevalence and the associated wealth-based inequality among reproductive-age ST women in India between 2015-16 and 2019-21. Our analysis shows a reduction in underweight prevalence across the country during the study period, which is a positive outcome. However, the persistence of underweight among one in every four tribal women remains concerning. The observed decline in underweight prevalence varied considerably across India's tribal regions, with the northern tribal region experiencing the most substantial decrease, followed by the western and eastern-central tribal regions. In contrast, the northeastern tribal region consistently exhibited the lowest prevalence of underweight during the study period, but with minimal change.

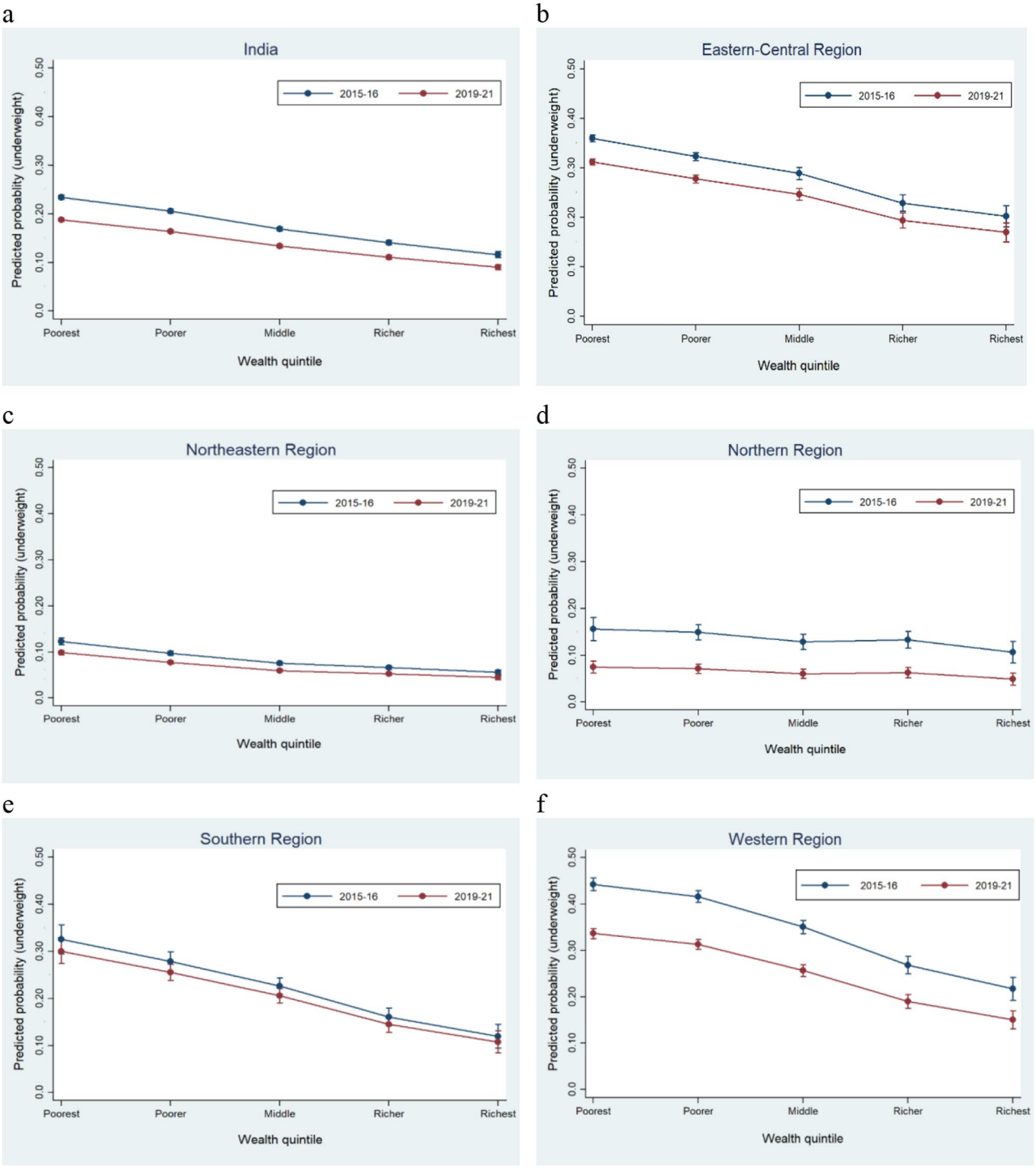

Fig. 3 Predicted probability of underweight among ST women in India and its tribal regions, 2015–2021. Note: The predicted probabilities shown in the graphs are based on regression models that have been adjusted for respondent age, education, marital status, religion, place of residence, mass media exposure, parity, tobacco use, anaemia, diabetes, type of diet, fried food, aerated drinks, and toilet facility. The vertical bars in the graphs show 95% confidence interval for the probability estimate

Despite the overall reductions in underweight prevalence, the prevalence remains high in some regions, with one in three women being underweight in the eastern-central, and western tribal regions, and one in five in the southern tribal region.

The higher prevalence of underweight among economically disadvantaged ST women in our study is consistent with previous research, which has consistently highlighted the persistent wealth-based disparities in underweight prevalence among tribal populations [17, 31, 33, 43–48]. This inequality is largely driven by challenges such as food insecurity, limited dietary diversity, and the inability to afford nutritious foods [40, 44, 47]. Women from wealthier quintiles tend to have diets with a higher percentage of energy from fats, which contribute to lower prevalence of underweight [31, 48]. In contrast, economically disadvantaged women are often engaged in physically demanding, labour-intensive work, such as agriculture, which increases energy expenditure and contributes to higher underweight rates [31, 49]. Poor living conditions, limited access to healthcare, and inadequate nutrition further exacerbate the situation, leaving women in lower wealth quintiles more vulnerable to infections and undernutrition. Additionally, limited income often results in underutilization of healthcare services, further compounding the problem [44].

A key finding from our study is the reduction in wealth-based inequality in underweight prevalence over the study period. However, this reduction in wealth-based inequality was not uniform across regions, and the extent of improvement varied significantly. The greatest change in the inequality in underweight prevalence was recorded for the northern region. The western, southern, and eastern-central tribal regions exhibited higher initial levels of inequality, which were reduced over time but only slightly, though the levels of underweight remained high. Conversely, the northeastern tribal region, which initially had lower inequality in underweight prevalence, showed minimal change over the study period. This indicates that while wealth-based inequality in underweight prevalence decreased most notably in tribal regions such as the northern, western, and southern areas, the northeastern tribal region maintained its relatively low levels of inequality throughout the study.

It was observed that women from the poorest wealth quintile experienced the most significant reduction in underweight prevalence, in contrast to the more modest decreases seen in the richer quintiles. However, the extent of this reduction varied considerably across regions, with the greatest improvements occurring in the northern tribal region. This suggests that targeted efforts to reduce undernutrition among the most economically disadvantaged tribal women are producing positive outcomes. Notably, the reduction in wealth-based inequality is a promising development, pointing to a potential narrowing of the nutritional disparity between the wealthiest and the poorest ST women.

These findings suggest that while national-level trends in underweight prevalence are positive, significant regional differences exist, underscoring the need for context-specific interventions. The reduction in wealth-based inequality in underweight in the northern tribal region, where underweight prevalence declined most substantially, can be attributed to targeted government interventions in food security, healthcare, and sanitation. On the other hand, the persistent high prevalence of underweight in the western, southern, and eastern-central tribal regions highlight the need for more focused efforts in these areas to address the underlying causes of undernutrition, such as food insecurity, lack of access to healthcare, and inadequate sanitation. In contrast, the northeastern tribal region, where inequality was low and the prevalence of underweight remained stable, presents a unique case. The region's relatively low levels of inequality suggest that existing policies might be more effective in reaching the most vulnerable populations, but there may be a need to revisit and refine these interventions to address stagnation in progress. It is possible that factors unique to the region, such as differences in socio-economic conditions, healthcare infrastructure, or cultural practices, may be contributing to the lack of significant change.

Despite several initiatives aimed at addressing food insecurity and undernutrition, the prevalence of underweight among economically disadvantaged ST women remains a significant challenge in India, particularly in tribal regions of the western, eastern-central, and southern states. Government programs such as the Public Distribution System (PDS), Integrated Child Development Scheme (ICDS), and *Antyodaya Anna Yojana* (AAY) provide subsidized food grains to vulnerable populations [50, 51]. The National Food Security Act of 2013 reinforces this commitment, extending access to subsidized food grains to vulnerable groups. Additionally, the POSHAN Abhiyaan, launched in 2018, addresses malnutrition through programs like the Mid-day Meal Scheme and Weekly Iron Folic Acid Supplementation [52]. Moreover, state-level initiatives, like Maharashtra's *Amruta Ahar Yojana* [53], Gujarat's *Poshan Sudha Yojana* and Odisha's *Mukhyamantri Sampoorna Pushti Yojana* [54], target nutritional deficiencies among vulnerable populations, particularly pregnant and lactating women and adolescents but effectiveness varies, requiring ongoing refinement in these schemes. Odisha's *Mo Upakari Bagicha*, Jharkhand's *Didi Badi Yojana*, and Chhattisgarh's *Chiraag Badi Yojana* aim to promote kitchen gardens in rural households, enhancing dietary diversity and fulfilling nutritional needs [55, 56]. However, as

these initiatives are relatively recent, their success and efficiency in decreasing the burden of undernutrition in these states are yet to be evaluated. In tribal regions, initiatives such as the *Ashram* School scheme and MGNREGA aim to empower communities through education and employment opportunities, while the Smart Village initiative in Rajasthan focuses on women and family empowerment [57–59]. However, the impact of these interventions has been inconsistent, and tribal women in some regions continue to face high rates of underweight, despite some progress in reducing wealth-based inequalities in nutrition.

A key barrier to improving the nutritional status of ST women is the intersection of poverty, food insecurity, and limited access to healthcare [60]. Many tribal communities struggle with encroachment on their traditional land, water, and forest resources, which directly impacts their food sovereignty [61]. Furthermore, these communities often have poor access to basic healthcare services, resulting in inadequate treatment for malnutrition and related health issues. While government initiatives have made strides in addressing these challenges, the persistence of high underweight prevalence in some regions indicates the need for more tailored and region-specific solutions. To better target the most vulnerable ST women, programs must focus on food assistance, micronutrient supplementation, and community-based health education, particularly for the poorest women in these regions. Additionally, culturally appropriate solutions, including locally accepted dietary changes and awareness campaigns, should be integrated into these interventions. More comprehensive efforts are needed to address the underlying causes of malnutrition, such as securing land and forest rights, improving healthcare access, and promoting sustainable employment opportunities. Ultimately, prioritizing these initiatives is essential to ensuring lasting improvements in the health and well-being of tribal women across India.

This study has several limitations that should be considered when interpreting its findings. Firstly, key variables such as physical fitness, physical activity, hygiene practices, and waste management were not included in the analysis due to their unavailability in the NFHS dataset. Additionally, as a cross-sectional study, it does not allow for the establishment of causality between the variables. We also recognize that the reliance on self-reported data for several variables may have introduced potential biases. Despite these limitations, this study offers valuable insights into the changing patterns of wealth-based inequalities in underweight among tribal women. However, further research is needed to explore the factors contributing to regional disparities in the magnitude of inequality reduction.

Conclusion

Our study underscores both progress and persisting challenges in addressing underweight among ST women in India. While there has been a commendable decrease in both the prevalence of underweight and the wealth-based disparities in underweight among these women, the progress has been uneven across regions and wealth quintiles suggesting that it is imperative that interventions continue to be tailored to regional nuances and socioeconomic disparities to foster equitable progress nationwide. Our findings underscore the urgency for policymakers to prioritize marginalized and economically disadvantaged ST women. This calls for bolstering existing central and state-level initiatives, emphasizing education on nutrition and healthy lifestyles, enhancing access to affordable, fortified food options, and ensuring adequate healthcare services.

Appendix 1: Erreygers concertation index

The concentration index is a tool for determining if inequalities in the health variable exist and whether they are more concentrated in any population group. The concentration index is mathematically defined as twice the area between the line of equality (the 45-degree line) and the concentration curve; the equation is expressed as:

$$C = \frac{2}{\mu} cov\,(h, r)$$

Where C is the concentration index, h is the health variable, μ is the mean of the health variable, and r is the cumulative percentage. The index value lies between −1 to +1 for an unbounded variable, but for a bounded variable, it ranges from μ-1 to 1- μ. Whereas, when the health variable is binary, the mean of the range of concentration index values: as the mean increases, the range of possible concentration index values shrinks. To solve this issue, Wagstaff recommended a normalisation formula in which he proposed dividing the health concentration index by its upper bound. Still, the revised index for the binary health variable given by Wagstaff does not satisfy the cardinal invariance property. To create a rank-dependent socioeconomic inequality index which satisfies all four properties (Transfer property, Mirror property, The level of independence property, and the cardinal invariance), Erreygers defined the corrected concentration index as [62, 63].

$$E(h) = \frac{8}{n^{2(b_h - a_h)}} \sum_{i=1}^{n} z_i h_i$$

Where the n is the sample size, a_h is the minimum value of the health variable, b_h is the maximum value of the health variable, h_i is a binary health variable that is equal to 1 when the woman is underweight and takes a value of 0 otherwise, and $z_i = \frac{n+1}{2} - \lambda_i$.

Source: Erreygers G. Correcting the Concentration Index. J Health Econ. 2009;28 [2]:504–15.

Appendix 2: description of variables used in this study

Variables	Description
Respondent's age	Respondents were asked about their current age and the variable was formed binary based on response of respondent. If the respondent was 15–24 years, they were labelled as 'young' (1) and if 25–49 years, were labelled as 'not-young' (0)
Education level	Education level indicates the highest education level attained by the respondent. It is divided into 'Not educated' (1) and 'Educated' (0) by combining primary, secondary and higher education
Household wealth	The wealth index is a composite index of household amenities and assets. Wealth quintiles are compiled by assigning the household score to each usual (de jure) household member, ranking each person in the household population by their score, and then dividing the distribution into five equal categories, - 'poorest'; 'poorer'; 'middle'; 'richer'; 'richest', each with 20% of the population. Further, we categorised the household wealth into two categories: poor (included poorest and poorer) (1) and non-poor (included middle, richer and richest) (0)
Marital status	Respondents who were married, widowed, divorced, no longer living together/separated were labelled as 'Married' (0), and respondents who were never in union and married but *gauna* not performed were labelled as 'Not married' (1)
Religion	There is two classification of the religion- 'Hindu' (1) and 'non-Hindu' (0) (including Muslim, Christian, Sikh, Buddhist/Neo-Buddhist, Jain, Jewish, Parsi/Zoroastrian, no religion, and other)
Place of residence	Respondents were asked about their place of residence. We have formed binary category- 'Rural' (1) and 'Urban' (0)
Mass media exposure	Respondents were asked about the frequency of (a) listening to the radio, (b) watching TV, and (c) reading newspapers/magazines. Those who responded- never in any of the questions are labelled as 'not exposed' (1), and yes in any one is labelled as 'exposed' (0)
Parity	Respondents were asked about the number of children, if they replied zero were labelled as 'No child' (0), and if one or more they were labelled as 'One or more' (1)
Tobacco use	Respondents replying yes in any of these questions (a) smokes a cigarette, (b) smoke a pipe filled with tobacco, and (c) chew tobacco were labelled as 'Yes' (1) and were labelled as 'No' (0) if otherwise.
Anaemia	Respondents were asked whether they had anaemia if they responded having severe, moderate, and mild anaemia they were labelled as 'Yes' (coded as 1) and were labelled as 'No' (coded as 0) if otherwise
Diabetes	Respondent who reported currently having diabetes were labelled as 'Yes' (1) and if otherwise were labelled as 'No' (0)
Type of diet	Respondent who reported consuming egg, fish, and meat were labelled as 'non-vegetarian' (1) and if not consuming any of these were labelled as 'Vegetarian' (0)
Frequency of consumption of fried food	Respondents were asked about the frequency of consumption of fried food, if they respondent never or occasionally, they were labelled as 'Never or occasionally' (0) and if respondent daily or weekly, they were labelled as 'Daily or weekly' (1)
Frequency of consumption of aerated drinks	Respondents were asked about the frequency of consumption of aerated drinks, if they respondent never or occasionally, they were labelled as 'Never or occasionally' (0) and if respondent daily or weekly, they were labelled as 'Daily or weekly' (1)
Toilet facility	Respondents were asked about the type of toilet facility if they replied using- pit latrine without slope/open pit, no facility, no facility/bush/field, bucket toilet, hanging toilet/latrine, and others then they were labelled as 'Unimproved' (1) and all the other options were labelled as 'Improved' (0)

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Author contributions
ANS: data curation, data analysis, visualization, interpretation of data, writing– original draft, writing– review and editing. ADS: conceptualization, study design, data analysis, interpretation of data, supervision, writing– original draft, writing– review and editing. MC: data analysis, interpretation of data, writing– original draft, writing– review and editing. SS: writing– original draft, writing– review, and editing. PT: writing– original draft, writing– review, and editing.

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Data availability
The dataset analyzed during the current study is available in the Demographic and Health Surveys (DHS) repository, https://dhsprogram.com/data/available-datasets.cfm, and can be obtained for free by sending an online request. Codes used in the analysis can be made available from the corresponding author on request.

Declarations

Ethics approval and consent to participate
The present study used secondary data, which is available in the public domain. The dataset has no identifiable information about the survey participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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