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Double burden of malnutrition among adolescents in India: Evidence from large scale surveys

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Abstract: Irrespective of many government policies and programmes, the nutritional deprivation for adolescents remained high in India. Moreover, due to the unavailability of the data sources, the estimation of nutritional deprivation for this particular age group remained scanty. To fill that gap, this study estimated under-nutrition as well over-nutrition among adolescents in India and examined the factors contributing to this double burden of malnutrition. The study used the anthropometric information for 183,773 adolescents from District Level Household and Facility Survey-4 (2011-2012) and 287,128 adolescents from the Annual Health Survey (2014). Among all the adolescents in India, an estimated 24.8 percent are found to be thin and 7.5 percent are overweight. The level of thinness was higher among the adolescents in Odisha, followed by, Rajasthan, and Bihar while the level of overweight was higher in Goa and Kerala. Adolescents in the early ages of 10 to 14 years were more likely to be thin (RRR:0.63, $p<0.01$) as well as overweight (RRR: 0.50, $p<0.01$) than older adolescents. The gender variation of thinness and overweight put the boys at disadvantages as compared to girls. Adolescents from the lower socio-economic groups were at high risk of being thin, while from the high socioeconomic status had a high risk of being overweight. The higher undernutrition in the age of onset of puberty is a new finding from this study. The double burden of malnutrition among adolescents should be responded by the nutrition programmes focussing on both under and over nutrition.

Keywords: Adolescents, Nutrition, Thin, Overweight, BMI.

Introduction

The current level of nutrition transition across the lower-middle-income countries provides a ground of both optimism as well as a concern (Doak et al., 2005; MoHFW et al., 2019; Ng et al., 2014). The level of undernutrition among the various age group was reduced, while the overweight, as well as obesity across the population has increased over time (Candler et al., 2017; Popkin and Larsen, 2004; Prentice, 2018). But, the pace of rising in the obesity prevalence among the population is much higher compared to the reduction of undernutrition (Candler et al., 2017; Kennedy et al., 2006; Caleyachetty et al., 2018). Available evidence suggests that underweight and obesity are among the top ten leading risk factors for the global burden of disease. This situation is a global public health concern called the double burden of malnutrition (DBM), which can be expressed as the coexistence of both undernutrition as well as over-nutrition in the same population (Bej, 2015; Jaacks et al., 2019; Subramanian et al., 2009).

Adolescence, is a transitional period from childhood to adults, the important developmental period in the life course characterized by a change in physiological, sexual, neurological, and behavioural factors such as rapid physical and mental growth, changes in body composition (Bej, 2015). Adequate nutrition intake is a pillar in growth and development

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for healthy and morbid free life (Georgiadis, 2017; Uzeda et al., 2019). Some global studies estimated that 462 million adolescents across the globe are thin, out of which 90 percent are from lower-middle-income countries. Other reviews also evident the rising burden of obesity and overweight among these groups (Abarca-Gómez et al., 2017; Amugsi et al., 2019; Maehara et al., 2019; Subramanian et al., 2007; Tzioumis and Adair, 2014; Uzeda et al., 2019).

Nutritional deficiencies among adolescents have many illimplications to society as well as nations. These nutritional deficiencies have an impact on educational attainment, cognitive development, future employment, mother's health, and consequently their children's health (Maehara et al., 2019; Subramanian et al., 2007; Uzeda et al., 2019). The rising burden of obesity in adolescents is the main reason behind the rise in many non-communicable diseases including diabetes and hypertension. So providing adequate nutrition is a basic need for better human resources for any country (Dietz, 2017; Popkin et al., 2012).

India as a country with a 1.3 billion population and an emerging middle-income country, grappling with the double burden of malnutrition across all age groups, including adolescents (Swaminathan et al., 2019). The Adolescent's population constitutes one-fifth (20.9 percent) of the total population in India. Adolescents have important role in the development in economy, demographic, social welfare of the nation (Bej, 2015). However, studies evident a higher proportion of adolescents in India suffers from malnutrition (MoHFW et al, 2019; Santhya et al., 2017a, b). A recent report from the National Family Health Survey (NFHS) found a substantial number of adolescents aged 15-19 in India are suffering from undernutrition as well as over nutrition (International Institute of Population Sciences and ICF International, 2017). The survey reported 44.8 percent of boys and 41.9 percent of girls aged 15-19 years in India have Body Mass Index (BMI) below the normal level (BMI <18.5). On the other hand, 4.2 percent of girls and 4.8 percent of boys being overweight/obese in India. However, NFHS data does not include information for the complete age bracket (10-19) of adolescents. Recent survey of Comprehensive National Nutrition Survey (CNNS) estimated 26.4 percent of adolescents are stunted, 4.1 percent of adolescents' overweight and 0.8 percent of them with dual burden (both stunted and overweight) (MoHFW et al., 2019). Another survey conducted by the population council named Understanding the lives of adolescents and young adults (UDAYA) found that a substantial number of adolescents are underweight as well as obese in the two most populated states of India i.e., Uttar Pradesh and Bihar (Santhya et al., 2017a, b).

There are factors that have an impact on the undernutrition, overweight and double burden of malnutrition in India as well as other countries. Though there are no specific studies on adolescent in India, there are studies that found the correlates of undernutrition as well over nutrition among children and adults (Nguyen et al, 2021; Dutta et al., 2019). These factors ranged from individual, maternal well as the household-level factors. Economic status has considered as one of the pioneer determinants of the double burden of malnutrition. Besides this, dietary intake, pattern, and sufficiency of food, physical activities, have an impact on both overweight as well as underweight (DJ et al., 2011; Maehara et al., 2019; Mondal and Terangpi, 2014; Rao et al., 2006; Caleyachetty et al., 2018; Subramanian et al., 2007; Uzeda et al., 2019; Zarate-Ortiz et al., 2019).

Several golden reviews have attempted to address the levels, patterns, and determinants of undernutrition, particularly among children and women in India. These studies evident a higher proportion of children and women in India suffer from malnutrition (MoHFW et al., 2019; Swaminathan et al., 2019). However, understanding the studies related to the adolescent

in India remained scanty. Though NFHS provides the nutritional information, however, the survey does not include information for the complete age bracket (10-14) of adolescents for the adolescent. The UDAYA survey which provides information on adolescent's health and nutrition is limited to only the states of Bihar and Uttar Pradesh. Some studies also assessed that the nutritional status of the adolescent population is based on primary data collected at small-scale and targeted select groups such as girls only, school-going children, or tribal population (Chaturvedi et al., 1996; Das and Biswas, 2005; Mondal and Terangpi, 2014). It is manifested from the review of literature that so far, very little is known about the nutritional status of adolescents in India due to the lack of national-level data on anthropometric measures consisting of all geography and complete age bracket of adolescents. To unearth the research gaps, the present study utilizes anthropometric data from the two large-scale surveys and provides the prevalence of thinness and overweight among adolescents aged 10-19 years by sex and age group in the states of India. We further examine the role of socio-economic, demographic factors affecting malnutrition using data from selected states of India.

Data and Methodology

There is no single data source available that provides anthropometric information's for the adolescents' age group 10-19 covering all states of India. The present study used two large-scale district-level surveys, namely the fourth wave of District Level Household and Facility Survey (DLHS-4) conducted in 2012-2013 and the Annual Health Survey (AHS) in 2014 conducted by the Government of India. Both surveys used similar survey tools and methodology, with the primary objective to collect district-level data on reproductive, maternal, and child health. Both surveys have information on clinical, anthropometric, and biochemical (CAB) for the population across all ages. Using multistage stratified random sampling design, DLHS-4 provides the data for almost all districts from 18 states and 3 union territories (UTs) while AHS covers all districts of the eight empowered action group (EAG) states including Assam. The present paper used the data for 26 out of 30 states and 3 out of 7 UTs in India. Jammu and Kashmir, Gujarat, Himachal Pradesh, Nagaland, Daman and Diu, Lakshadweep, Dadar and Nagar Haveli, and Delhi were excluded from the analysis due to the unavailability of the data. The sample size reduces to 1,83,673 adolescents in DLHS-4 after removing flag cases in z scores for BMI and 2, 87,128 adolescents in AHS (2014). Using these state-level estimates and population proportion taken from Census of India 2011, an aggregated proportion of thinness and overweight among adolescents is estimated for India. More information about both surveys, sample size, sample weight, and survey design can be found elsewhere (IIPS, 2014; RGI, 2014). Further, to examine the determinants of malnutrition among adolescents, the paper used only DLHS-4 data as socio-economic variables were not given in the CAB file of AHS and merging could not be possible due to missing identifier variables in AHS.

Measurements

Dependent variables: The main dependent variable for the analysis is the nutritional status of the adolescent which is categorized into three such as thin, normal, and overweight. The measure expressed BMI in the form of z-scores standard deviation (SD) from the median of 2007 WHO International Reference Population. The adolescents whose z score for BMI-for-age is less than -2SD below the median are classified as thin. Low BMI-for-age (thinness) indicates recent malnutrition status due to acute starvation and/or severe disease. On the other hand, the adolescents having z score value for BMI-for-age above 1 SD are classified as over-nutrition or overweight category.

Independent variables: The paper considers several individual-level social and demographic variables like age, sex, education, occupation, and household information such as religion, and caste and wealth index of households, number of members in the households, access to safe drinking water, and sanitation facility. The wealth score variable is created using household amenities data by applying principal component analysis. Further, the wealth score was categorized into three equal quantiles.

Statistical analysis: Descriptive analysis and multinomial logistics regression analyses was used for the analytical purpose. First, the prevalence of thinness and overweight is calculated for each state for age groups 10-14 and 15-19 for both males and females using the descriptive analysis. To validate the estimated prevalence of thinness and overweight, we compared state level estimates with the rates given in the NFHS report (for 15-19 age) using scatter plot with regression line.

To examine the determinants of undernutrition and over-nutrition, the paper employs a multinomial logistic regression analysis. The results are shown in terms of the relative risk ratio for both thinness and overweight for different socio-economic and demographic factors by keeping normal BMI as a reference category in the dependent variable. The whole analysis is done using STATA (version 13) using appropriate sampling weights.

Results

Table 1 presents the prevalence of malnutrition (thinness and overweight) among adolescents in India and the states. A quarter of adolescents in India are thin (low BMI-for-age) at the national level with wide variation across the state. The extent of thinness was higher for the boys (27.9%) than that of among girls (21.8 %). Besides, early-age adolescents are more prone to be thin as compared to late-age adolescents. On the other side, a substantial proportion (7.5%) of adolescents in India are overweight. Surprisingly this proportion was also higher for the boys and early age adolescents. We found the extent of overweight is 8.2 percent among boys, 6.8 percent among girls and 9.0 percent among teenagers (10-14 years), and 5.3 percent among 15-19 years.

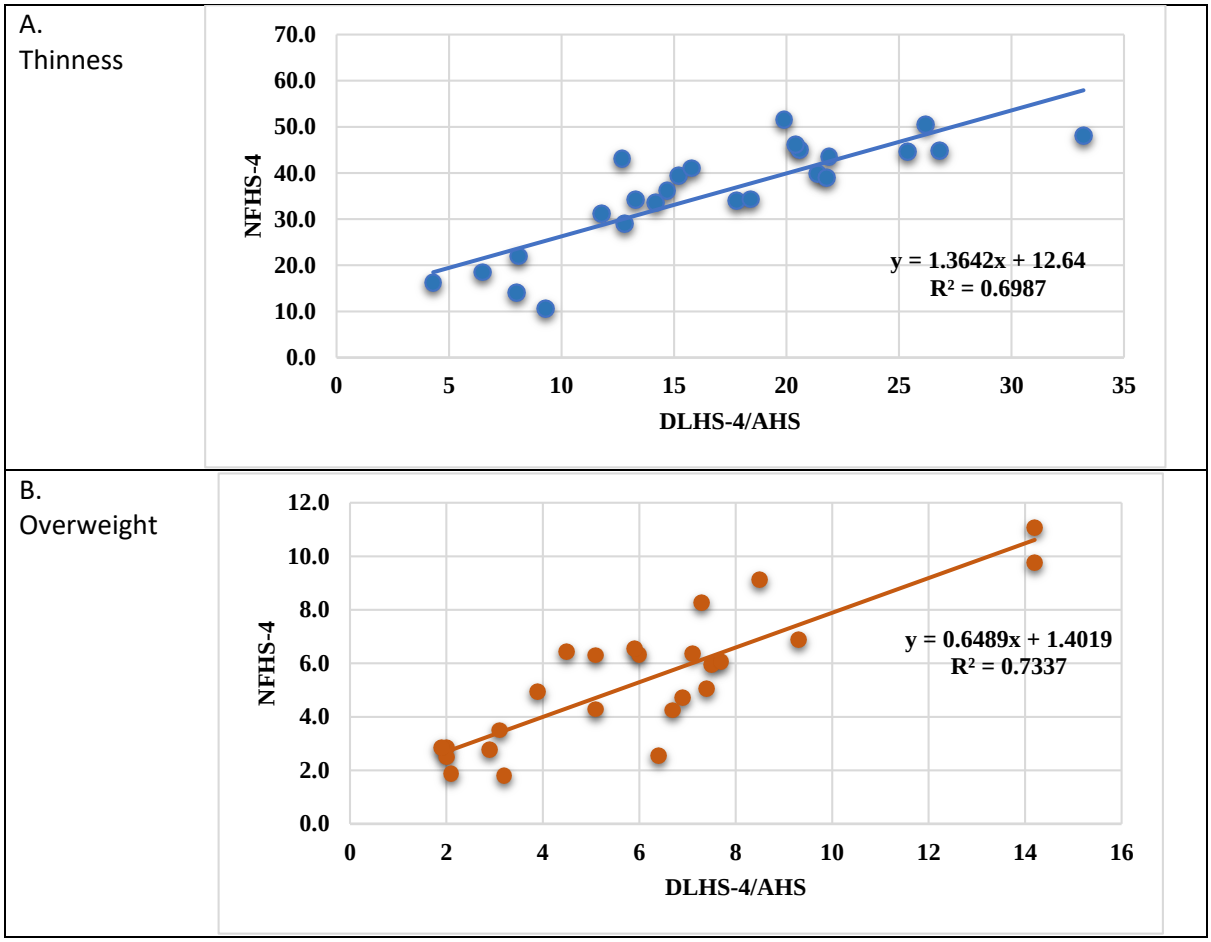
The state-level pattern of thinness put Odisha (32.4%) states at the top followed by Rajasthan (32.3%) and Bihar (29.9%) while the states Arunachal Pradesh (8.1%) followed by Chandigarh (10.9%) in the bottom position. Out of 28 states, 8 states have a higher level of undernutrition than the national level. These states are mainly high focussed empowered action group states including Odisha, Rajasthan, Uttar Pradesh, Bihar, and Madhya Pradesh, Jharkhand, and southern states like Tamil Nadu and Karnataka. Odisha tops in the thinness level among the male adolescent white it is Bihar for the female. The developed states like Kerala and Goa top in the overweight status among adolescents in India and puts Uttar Pradesh and Chhattisgarh at the bottom. The extent of overweight was also higher for goa for male, female, early age and late age adolescents. Most of the states and UTs show a larger proportion of boys than that of girls suffering from overweight, and this gender difference is more visible in Haryana. However, this pattern reverse in the states like Chhattisgarh and the Northeast region of India. Further, younger adolescents from all the states and UTs show a higher rate of overweight. We compare the state-level prevalence of thinness and overweight with those given in the recent state reports of NFHS-4 for 25 states. The pattern observed in this study matches with the NFHS-4 data; however, NFHS estimates are higher than our estimates (see Figure-1). It is to note that NFHS-4 defines thin adolescents aged 15-19 who had a BMI below 18.5 and overweight who had a BMI above 25. Interestingly, z-scores-for BMI estimated for

India (combined DLHS-4 and AHS) as shown in figure-2 decreases after 12 years, that is, around at the onset of puberty and again increases after age 15 among both boys and girls.

Tables 1: Prevalence of thinness and overweight among adolescents aged 10-19 in states and India

State	Thinness					Overweight					Sample size
	Total	Male	Female	10-14	15-19	Total	Male	Female	10-14	15-19	
Andaman and Nicobar	17.7	18.5	17.0	21.8	13.7	13.3	13.3	13.3	13.8	12.8	729
Andhra Pradesh	19.0	23.1	15.1	22.5	15.2	10.3	10.9	9.8	12.1	8.5	8093
Arunachal Pradesh	8.1	8.7	7.5	11.9	4.3	10.0	10.3	9.8	13.1	7.1	9540
Assam	22.5	24.8	20.3	25.8	15.1	5.2	5.9	4.5	6	3.4	19789
Bihar	29.9	31.2	28.6	28.4	33.6	6.3	7.6	5.0	8.3	2.2	47006
Chandigarh	10.9	11.2	10.6	14.2	7.3	9.7	10.4	8.8	11.3	8.0	785
Chhattisgarh	20.1	22.9	17.1	23.7	12.8	3.3	3.1	4.6	3.9	2.0	13887
Goa	15.3	17.5	12.9	16.2	14.2	21.8	24.1	19.4	28.4	14.2	720
Haryana	21.1	22.1	19.9	24.1	17.8	10.2	12.2	7.8	13.4	6.7	20164
Jharkhand	27.8	32.4	23.1	30.7	21.1	3.7	4.1	3.2	3.9	3.1	17156
Karnataka	26.1	30.4	22.1	29.9	21.9	8.0	8.1	7.8	9.7	6.0	26630
Kerala	14.7	16.0	13.4	16.6	12.8	18.9	21.4	16.4	23.7	14.2	4683
Madhya Pradesh	26.1	27.6	24.5	26.1	26.3	3.7	4.3	3.1	4.4	2.0	40162
Maharashtra	24.4	26.7	22.2	27.8	20.4	10.0	11.4	8.7	12.3	7.4	26764
Manipur	13.2	15.4	11.2	17.2	8.1	9.0	8.6	9.3	11.3	5.9	4538
Meghalaya	11.3	14.2	8.8	14.8	6.5	7.6	6.0	9.0	8.5	6.4	4186
Mizoram	12.0	14.2	9.8	14.6	8.0	6.4	5.8	7.0	7.2	5.1	6525
Odisha	32.4	38.1	26.9	37.7	21.7	4.3	4.9	3.7	4.4	3.9	25697
Puducherry	19.9	22.9	17.0	22.6	16.6	14.6	14.8	14.5	16.4	12.5	2562
Punjab	16.8	18.2	15.0	20.1	13.3	8.5	9.6	7.0	9.4	7.5	22523
Rajasthan	32.3	36.4	28.1	34.9	26.8	4.2	5.1	3.2	4.9	2.9	31319
Sikkim	11.2	15.8	7.1	12.8	9.3	9.0	7.5	10.3	10.3	7.3	2223
Tamil Nadu	25.6	31.2	20.0	28.7	21.8	10.7	10.0	11.4	11.9	9.3	22488
Telangana	23.6	23.7	23.6	27.4	19.9	10.3	11.7	8.9	12.9	7.7	6347
Tripura	16.3	19.8	12.9	20.0	11.8	6.2	6.4	6.1	7.6	4.5	2492
Uttar Pradesh	28.2	32.2	24.2	29.6	25.4	3.2	3.7	2.7	3.7	1.9	81627
Uttarakhand	23.7	26.9	20.4	26.7	18.1	6.9	7.6	6.2	7.9	5.1	10485
West Bengal	20.3	24.3	16.9	24.3	15.8	9.6	10.1	9.2	12.0	6.9	11781
India	**24.8**	**27.9**	**21.8**	**27.1**	**21.7**	**7.5**	**8.2**	**6.8**	**9.0**	**5.3**	**470901**

Figure-1: Prevalence of thinness and overweight among adolescents age 15-19 in states from DLHS-4/AHS and NFHS-4



The sample distribution of adolescents aged 10-19 who were assessed for their weight and height in the DLHS-4 by their background variables is shown in table-2. There are more boys than girls in the overall sample. Adolescents from Other Backward Castes (OBCs) and Hindu religion predominates among rest groups. The sample constitutes only 9.0 percent illiterates and around 17.4 percent of adolescents with higher education. Further, it constitutes 63.0 percent of adolescents residing from rural and 37.0 percent from an urban area. This sample distribution does not represent India's population. However, it represents a population with better socio-economic status as DLHS-4 was conducted in advanced states.

Table 2: Sample distribution of selected states (DLHS-4) by background characteristics

Background variables		Sample Size	Percentage
Sex	Male	92,008	50.04
	Female	91,765	49.96
Age Group	10-14	97,512	53.03
	15-19	86, 261	46.97
Caste	Others	43,687	23.71
	Schedule Caste	46,604	25.7
	Schedule Tribe	33,447	18.14
	Other Backward Class	60,035	32.46
Religion	Hindu	1,22,675	66.77
	Muslim	18,460	10.09
	Others	42,638	23.14
Education	Illiterate	16,579	9.01
	Below primary	46,490	25.37
	Middle	60,994	33.19
	Secondary/Matric	33,553	18.27
	Higher	26,157	14.16
Wealth Index	Poor	62,131	33.59
	Middle	63,453	34.63
	Rich	58,189	31.78
Place of Residence	Rural	1,12,980	63.15
	Urban	70,793	36.85
Fuel Use	Others	1,04,944	57.6
	Improved fuel	78,829	42.4
Drinking Water	Unsafe	1,11,657	61.1
	Safe	72,116	38.9
Sanitation facility	Yes	1,20,945	65.25
	Open defecation	62,828	34.75

Figure 2: Z-score for BMI for age, India

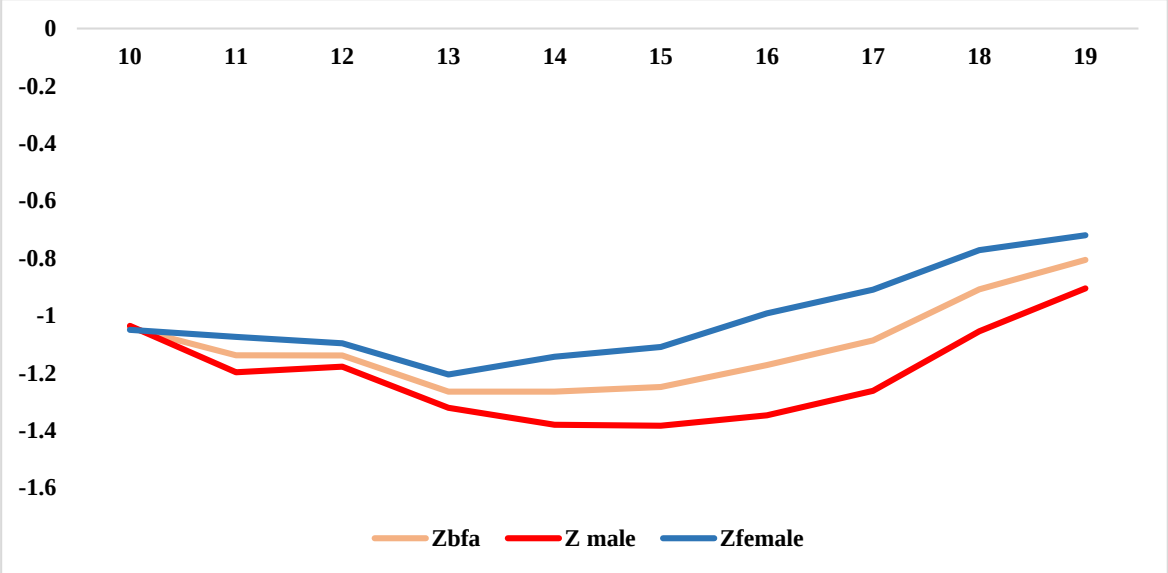


Table-3 presents the pattern of nutritional status among the adolescents in the selected sample (DLHS-4 states) by background characteristics. It shows that the double burden of malnutrition (DBM) is more among boys than that in girls and more among early adolescence than in late adolescence. About 8.5 percent and 14.0 percent of adolescents from Schedule Caste (SCs) and OBCs are severely thin and thin, respectively. On the other side, 8.7 percent and 3.4 percent of adolescents belonging to the general caste are overweight and obese, respectively. Undernutrition is more prevalent among Hindus, while over nutrition is more common among Muslims. Undernutrition decreases with the level of education; however, over-nutrition is more predominant among adolescents with some level of education, and afterward, it decreases. Furthermore, undernutrition is more among adolescents from poor households; those do not use improved fuel, have no access to safe drinking water, who openly defecate and reside in the rural area.

Table 3: Nutritional status among adolescents in selected states (DLHS-4) by their background characteristics

Background variables		Nutritional status				
		Normal	**Severely Thin**	**Thin**	**Overweight**	**Obese**
Sex	Boy	66.6	8.9	14.2	7.4	3.0
	Girl	73.2	6.0	11.7	6.9	2.2
Age Group	10-14	64.6	9.4	14.3	8.3	3.4
	15-19	75.9	5.2	11.4	5.8	1.7
Caste	Others	69.4	6.2	12.3	8.7	3.4
	Schedule Caste	68.9	8.5	14.4	6.2	2.1
	Schedule Tribe	76.5	5.3	9.9	6.5	1.8
	Other Backward Class	67.2	8.5	14.1	7.3	2.9
Religion	Hindu	67.7	8.5	14.0	7.1	2.7
	Muslim	68.1	7.7	12.8	8.2	3.3
	Others	77.0	4.3	9.9	6.8	2.0
Education	Illiterate	68.2	9.1	14.5	5.7	2.48
	below primary	66.2	9.1	13.9	7.6	3.25
	Middle	68.9	7.8	13.2	7.5	2.63
	Secondary/Matric	74.2	5.6	11.4	6.8	2.01
	Higher	74.5	4.9	11.7	6.6	2.26
Wealth Index	Poor	70.0	8.5	13.9	5.8	1.9
	Middle	69.6	7.8	13.3	6.7	2.5
	Rich	70.1	5.8	11.6	9.0	3.5
Place of Residence	Rural	70.5	7.9	13.6	6.0	2.0
	Urban	68.8	6.6	11.9	9.0	3.7
Fuel for cooking	Others	70.4	8.3	13.9	5.6	1.8
	Improved fuel	69.2	6.3	11.6	9.2	3.7
Drinking Water	Unsafe	69.6	7.9	13.7	6.5	2.3
	Safe	70.4	6.7	11.7	8.1	3.1
Sanitation	Yes	70.8	6.2	11.9	8.1	3.0
	Open defecation	68.3	9.7	15.0	5.2	1.8
Sample	N=183,773	128,348	13,620	23,729	17,257	819

The results from the multinomial logistic regression analysis are presented in Table-4. The results are presented in terms of the relative risk ratio (RRR) of adolescents of being thin and overweight by their socio-economic characteristics. The adolescents who had BMI in the normal range are taken as the reference category of the dependent variable. Findings suggest that adolescent girls have a significantly (0.69, $p<0.01$) lesser risk of being thin and more risk

of being overweight (RRR 0.80, p<0.01) as compared to that of boys. It is also found that the adolescents at later ages have a lower risk (RRR 0.63, p<0.01) of both under and overweight than the adolescents in early ages.

Table 4: Determinants of nutritional status among adolescents: Relative risk ratio (with 95%CI) from multinomial logistic regression

Particulars	Variables	Thinness			Overweight		
		RRR	[95% CI]		RRR	[95% CI]	
Sex	Boy ®						
	Girl	0.69***	0.67	0.71	0.80***	0.78	0.83
Age Group	10-14®						
	15-19	0.63***	0.61	0.65	0.50***	0.48	0.52
Caste	Others®						
	Schedule Caste	1.14***	1.10	1.19	0.86***	0.82	0.90
	Schedule Tribe	0.78***	0.75	0.82	0.84***	0.79	0.89
	Other Backward Class	1.14***	1.10	1.18	0.89***	0.86	0.93
Religion	Hindu®						
	Muslim	0.91***	0.87	0.95	1.11***	1.05	1.17
	Others	0.62***	0.60	0.64	0.80***	0.76	0.83
Education	Illiterate®						
	Below primary	0.93***	0.89	0.98	1.15***	1.08	1.23
	Middle	0.89***	0.85	0.93	1.14***	1.07	1.22
	Secondary/Matric	0.85***	0.80	0.89	1.25***	1.16	1.36
	Hr. Secondary/pre University	0.85***	0.81	0.90	1.30***	1.20	1.42
Wealth Index	Poor®						
	Middle	0.97*	0.94	0.99	1.10***	1.05	1.15
	Rich	0.88***	0.84	0.91	1.31***	1.24	1.38
Place of Residence	Rural®						
	Urban	0.92***	0.89	0.95	1.35***	1.29	1.41
Fuel use	Others®						
	Improved fuel	0.93***	0.90	0.96	1.25***	1.19	1.31
Safe Drinking water	No®						
	Yes	0.99	0.96	1.01	1.12***	1.08	1.15
Sanitation facility	Open defecation	1.20***	1.16	1.23	0.88***	0.85	0.92
constant	N=183,773	0.53***	0.50	0.56	0.14***	0.13	0.16

® represents reference category, normal weight is reference category in the dependent variable, implies
*p<0.05, ** implies p<0.01,

Adolescents belonging to Scheduled Tribes (STs) have (RRR 0.78, p<0.01) lower risk, while OBCs and SCs have a higher risk of being thin than that of general category. However, adolescents from OBCs, SCs, and STs have a lower risk of being overweight than the general caste. Education is significantly negatively associated with thinness among adolescents. The relative risk of thinness is more among adolescents from poor households who do not use improved fuel and who openly defecate (RRR 1.20, p<0.01), and from a rural area. On the other hand, the relative risk of being overweight is higher among adolescents from richer households who do not have access to safe drinking water and sanitation facility and belong to an urban area (RRR 1.35, p<0,01).

Discussion

India, which is home to 243 million adolescents, the assessment of nutritional levels from both sides, that is, undernutrition and over-nutrition would provide a better understanding of the nutrition programmes. While a recent report found that around a four-fifth of the adolescents in India suffered from any forms of malnutrition or micronutrient deficiencies (MoHFW et al., 2019). For which, India's commitment towards achieving overwhelming global targets of reductions of malnutrition remained questionable. Irrespective of many government policies to decline poverty and hunger it remained a challenge in India particularly to many poorer states. At the same time, there is no reliable and comprehensive data, which provides the estimates for nutritional and health information for the adolescents in India, though it is major group and has socio-economic importance. So, this paper targets to estimates the pattern of nutrition among adolescents in India, its variation across the population subgroup, and socio-economic determinates from the available sources. The paper adopts the WHO reference population and uses z scores for BMI that has made our state-level estimates comparable within India, and also globally. The use of BMI for assessing the under and overnutrition in childhood, adolescents to adult age is justifiable from previous studies (Cole et al., 2007).

We found that a quarter of adolescents in India are thin while 7.5 percent of adolescents are overweight. The estimates of thinness were low as compared to the estimates of the latest estimates of NFHS. Although levels of thinness and overweight are not matching with the given estimates for states of India in NFHS-4, the pattern is considerably like that report. The reason behind the dissimilarity due to the choice of cut-off and age-group as NFHS provides the estimates for adolescents aged 15 or more. The percentage of thin adolescents is highest in Odisha followed by, Rajasthan, Bihar, and Uttar Pradesh, and these all are from EAG states, the lower performing states in health and economic indicators. On the other hand, the lowest prevalence of thinness is in northeast India, including Arunachal Pradesh and Sikkim and northern UT of Chandigarh. A higher rate of over-nutrition is observed in Goa, Kerala, and Puducherry. This state-level pattern suggests a need for strengthening nutrition programme for adolescents in both lower-performing states (EAG) on undernutrition and advanced states/UT like Goa, Kerala, and Puducherry on over nutrition. The main reason behind the double burden of malnutrition can be explained by food patterns due to changing nutritional transition, life skill behaviour, and access to various services, and lesser physical activity. A distinctive finding of this paper is that the z-score for BMI starts decreasing at the onset of puberty, and then again increases after age 15. In other words, the level of undernutrition is higher in the age of puberty. Prevalence of thinness and overweight is higher among 10-14 age group than adolescents at a later age. Previous studies, including Indian data and developing countries, also reported similar age patterns of thinness (Ackerson et al., 2008; Chaturvedi et al., 1996; Rao et al., 2006). However, in contrast to our finding, a paper on girls' population in West Bengal in India found a higher prevalence of thinness among girls of age 17 years than 10 years aged (Das and Biswas, 2005). The paper found that males are more likely to be thin and overweight than girls. Similar findings were observed in the previous research that reported a higher level of thinness among boys than that among girls (Chaturvedi et al., 1996; Debnath et al., 2013; Amugsi et al., 2019; Mondal and Terangpi, 2014; Caleyachetty et al., 2018). This finding suggests that nutrition programme should target younger adolescents, not only to fight hunger, poverty, and malnutrition but also to reduce overweight and obesity. Moreover, young boys should not be left from being beneficiaries of nutrition interventions. The overarching approach should be considered to overcome the double burden of malnutrition.

It can be observed from the paper that the adolescents from the households with lower affluent level, who do not use improved fuel, not having access to safe drinking water, or openly defecate, from a rural area and belonging to SCs, STs, and OBCs are more susceptible to be undernourished than their counterparts. On the other hand, the risk of over-nutrition is more among adolescents from wealthy families, general caste, Muslims, and urban areas. Various studies in India also find contextual risk factors, including households, district, and state-level socioeconomic variables affecting childhood malnutrition (Bharti et al., 2019; Borkotoky et al., 2018). This paper supports that socio-economic factors are playing a crucial role in adolescent's malnutrition status, and there is a need to strengthen the current health programme and interventions on nutrition for adolescents (Bej, 2015). India has longstanding nutrition programmes, including the Public distribution system targeting poor households, Integrated Child Development Services for children under age 6 and their mothers. Further in 2014, the Ministry of Health and Family Welfare, Government of India, launched a health programme, Rashtriya Kishor Swasthya Karyakram, for adolescents in the age group of 10-19 years, which also includes nutrition component. However, so far, the performance of such programmes needs to be assessed, as the double burden of malnutrition is substantially high in India.

Although, the paper also suffers from data limitation as determinants are examined using data for selected states (DLHS-4 states) of India that excluded EAG states and Assam. Therefore, the findings on the determinants of nutritional status imply the economically superior states of India. Moreover, due to limited information in data, the study could not consider some critical variables on food insecurity and the dietary behaviour of adolescents. This paper uses two different data sets, which could not be combined at the individual level and having all background variables. The timing of both surveys also differs slightly. However, as nutrition does not change in a short time, a difference of a few years would not affect our results.

Conclusion

A healthy life and nutritional status of adolescents is the essential factor in leveraging the future demographic dividend and future health of the country's population. Therefore, the study findings are crucial and provide useful information on nutritional levels among adolescents from different states of India and its determinants. To our best knowledge, the present study is the first attempt that provides the double burden of malnutrition by considering prevalence of both thinness and overweight based on z score-for-BMI among adolescents aged 10-19 years using district level surveys DLHS-4 and AHS data covering almost all states of India. The study demonstrates that adolescents an early age and boys have a higher risk of the double burden of malnutrition. Prevalence of thinness increases at the onset of puberty in both boys and girls. Further, adolescents from lower socio-economic profile have more risk of being thinness and from the higher socio-economic group has more chance of being overweight. The paper suggests a need to extend the available food security programmes to reach adolescents, including teenage boys and girls, and targeting lower socio-economic groups. On the other hand, programmatic efforts on monitoring of overweight, particularly among wealthier families should get the start at least among school going children. Overall, this paper suggests an overarching approach should be considered to fight with the double burden of malnutrition among adolescents in India.

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