

## Other Review

# Is obesity becoming a public health problem in India? Examine the shift from under- to overnutrition problems over time

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## Summary

This study aimed to examine the prevalence and trends of overweight, obesity and undernutrition in recent decades in India. Based on a systematic literature search on PubMed and other data sources, most published studies were regional or local surveys in urban areas, while good representative data from the India National Family Health Surveys (NFHS, 1992–1993, 1998–1999 and 2005–2006) allowed for examining the trends at the national level. Overall, the available data showed that in India, prevalence of overweight was low while that of undernutrition remained high. Overweight was more prevalent among female, urban and high-socioeconomic-status (SES) groups. NFHS data showed that the prevalence of overweight in women and pre-school children did not increase much in the last decade: 10.6% and 1.6% in 1998–1999 to 12.6% and 1.5% in 2005–2006 respectively. As for underweight, NFHS 2005–2006 showed high prevalence among ever-married women (about 35%) and pre-school children (about 42%). The prevalence of overweight and obesity had increased slightly over the past decade in India, but in some urban and high-SES groups it reached a relatively high level. Factors associated with undernutrition need closer examination, and prevention of obesity should be targeted at the high-risk groups simultaneously.

**Keywords:** Body mass index, obesity, India, underweight.

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## Introduction

The recent constitution of the Developmental Origins of Health and Disease (DOHaD) (1–3) society has drawn great interest to study the public health challenges faced by countries under rapid economic and nutrition transitions, particularly in those developing countries that have experienced economic development and improvement in people's living standard, and as a result, a shift from under- to overnutrition problems. Obesity increases the risk of many other chronic diseases (4). The prevalence of obesity has been increasing globally, and its impact on public health is marked in both developed and developing countries (4–7). One of our recent studies shows that 30% of Chinese adults are overweight or obese. In major cities, the preva-

lence has reached approximately 50%, a level similar to that in industrialized countries. Meanwhile, the prevalence of obesity-related chronic diseases, such as hypertension, cardiovascular disease and type 2 diabetes, has increased rapidly over the past decade (5,6). Obesity in adults has also become a serious public health problem in many other developing countries in Latin America and in the Commonwealth of Independent States (8).

In India, the second most populous country in the world and where undernutrition has been the major public health concern over the past several decades, little attention has been paid to obesity until recently. The emerging evidences suggest an increase in obesity in children and adults (9,10). Several recent studies reported an increase in overweight in adults in urban areas over the past two decades (11–17).

However, most of these studies are based on local samples, which were not representative. No systematic investigation has been conducted to examine the obesity problem in India. The present study aimed to examine the prevalence and trends in overweight, obesity and undernutrition in India and their disparities among various sociodemographic groups. Regarding underweight, we focused on nationwide surveys in children and adults, to help examine the shift from under- to overnutrition problems over the past two decades.

## Materials and methods

### Literature search

We conducted a systematic search of PubMed for related studies published in English between 1 January 1980 and 31 December 2007. Keywords for literature search were obesity, overweight, central obesity, body mass index and India. The 'related articles' function on PubMed and manual cross references from retrieved articles were applied in order to expand the coverage. The abstracts of identified papers were examined on screen first. Those being found relevant, the full papers were then further examined to determine if they met our inclusion criteria described below. Additional studies that were identified in the course of reading or were brought to our attention by colleagues and experts in related field consulted were included.

### Study inclusion criteria

Only those studies that were published in English, provided prevalence of overweight, obesity or undernutrition (e.g. underweight and stunting) among children or adults, and with a sample size larger than 500 were included. Our research resulted in a total of 41 articles that met our inclusion criteria for this review. These investigations include (i) nationally representative surveys, (ii) nationwide multiple-site surveys and (iii) local surveys. Two series of nationally representative surveys provide most important related data: (i) the three rounds of the National Family Health Surveys (NFHS) – NFHS-1 1992–1993, NFHS-2 1998–1999 and NFHS-3 2005–2006 (18–20), which covered nationwide samples with a focus on young children and child-bearing-age women, but men were only recruited in the third round; and (ii) the Diet and Nutritional Status Survey of rural population, conducted by the National Nutrition Monitoring Bureau (NNMB) in 2001–2002 and again in 2005–2006, which covered the rural areas in 9 out of the 29 states across India (21,22).

### Data extraction

The main information we extracted included description of study samples and settings (e.g. sample size, geographic,

demographic and socioeconomic characteristics), definition and prevalence of the study outcomes (overweight, obesity, central obesity, underweight and stunting), and the survey year. When the original studies did not report the survey year, the publication year was listed.

### Classification of obesity, overweight and undernutrition

For adults, most of the studies defined these outcome using body mass index (BMI,  $\text{kg m}^{-2}$ ) cut-points based on the World Health Organization (WHO) recommendation (4): overweight,  $30 > \text{BMI} \geq 25$ ; obesity,  $\text{BMI} \geq 30$ ; and underweight,  $\text{BMI} < 18.5$ . But some studies used other different definitions (e.g. use  $\text{BMI} \geq 23$  to classify overweight, and  $\text{BMI} > 25$  for obesity). Note that some studies used these adult BMI cut-points for adolescents, e.g. for women aged 15–18 years in the NFHS, which underestimated the prevalence. Different measures and cut-points were used in studies that examined central obesity. Waist–hip ratio was more often used than waist circumference.

Among children and adolescents (<18 years), several different references have been used to define overweight and obesity. Studies in pre-school children used the weight-for-height Z score >1 and >2 to define overweight and obesity, respectively, based on growth reference derived using the data collected in the USA as recommended by a 1995 WHO Expert Committee (23,24). Some studies used age-sex-specific BMI cut-points corresponding to the BMI cut-points of 25 and 30 for adult overweight and obesity, respectively, which were recommended by the International Obesity Task Force (IOTF), i.e. the IOTF reference (25). Some other studies used the US BMI 85th and 95th percentiles (26), which have been widely used, and previously these BMI 85th percentiles had been recommended by the WHO for international use in adolescents (23).

### Nutritional status classification in pre-school children according to the new 2006 WHO Growth Standards

Several recent large nationwide surveys used these standards: overweight (BMI-for-age Z score  $\geq 1$ ), obesity (BMI-for-age Z score  $\geq 2$ ), 'underweight' (weight-for-age Z score  $< -2$ ), 'wasting' (weight-for-height Z score  $< -2$ ), and stunting (height-for-age Z score  $< -2$ ) (27).

### Statistical analysis

To examine the shifts from under- to overnutrition problems and to facilitate comparisons across studies, regions, population groups and over time, we calculated overweight-to-underweight ratio using the combined prevalence of overweight and obesity against the prevalence of underweight reported in individual studies. Some studies only reported characteristics-stratified prevalence

(e.g. sex, age, states) of overweight and obesity. In these cases, we calculated the overall prevalence based on the published results.

## Results

### Obesity and overweight in adults

Available nationwide survey data were limited to specific age and gender groups, and few studies provided data on the time trend in the prevalence of overweight. Much fewer surveys had been conducted in rural areas than in urban areas. Thus, findings from those multi-site and local surveys could help provide useful supplementary information. The NFHS data provided the most representative related data in India about women aged 15–49 years (Table 1) and young children, but the prevalence for overweight children was not provided in all three rounds. Overall, the available data indicated that the prevalence of overweight and obesity remained stable over the past two decades in women, although some local surveys showed a drastic increase, while others suggested a decrease. In general, prevalence of overweight and obesity were higher in urban areas and in higher-socioeconomic populations. The NFHS-3 2005–2006 data showed that combined prevalence (BMI  $\geq 25$ ) was 9.3% and 12.6% among men and women aged 15–49 years respectively (18). On the other hand, the NNMB 2005–2006 data show that in the rural areas of nine states across the country, the combined prevalence was 7.8% and 10.9% among adult men and women aged 18–60 years respectively (22). These two nationwide surveys showed that the overweight–obesity–combined prevalence in urban areas was higher than in rural areas, which was consistent with findings of other smaller, local surveys (Table 2). The regional variations have also been documented to reveal large heterogeneity in the trends between the later two NFHS (Fig. 1). The time trend could not be assessed in men because of lack of earlier NFHS data.

#### *By age*

The NFHS-3 2005–2006 showed that the combined prevalence in women increased from 2.4%, 8.2% to 17.4% among 15- to 19, 20- to 29- and 30- to 39-year-old age groups respectively. Note that the rate among those aged 15–19 years would be higher if age-specific lower BMI cut-points for adolescents were used. Other data, e.g. in two multiple-site surveys in urban areas, indicated that the combined prevalence (BMI  $\geq 25$ ) fell after middle age. The inverse U-shaped relationship became more dramatic in the 2000s than in the 1990s (Fig. 2) (28,29).

#### *By sex*

The NFHS-3 showed that combined prevalence (BMI  $\geq 25$ ) was 9.3% and 12.6% among men and women

aged 15–49 years respectively (18). The NNMB 2005–2006 data showed that in rural India, the combined prevalence was 7.8% and 10.9% among adult men and women aged 18–60 years respectively (22). A higher prevalence in women was consistently observed in most studies of different study settings (Table 1), but the gender difference seems to be smaller in rural than in urban areas.

#### *By urban–rural residence*

The combined prevalence was higher in urban areas than in rural areas, which was supported by a large number of local and nationwide surveys, including NFHS and NNMB. A large multiple-site survey conducted in 10 industries in urban areas reported a high combined prevalence (BMI  $\geq 25$ ) of 30.9% (29). Another survey conducted in six major cities (Chennai, Bangalore, Hyderabad, Calcutta, Mumbai and New Delhi) showed that the combined prevalence of overweight and obesity was 30.8% and that of central obesity (waist–hip ratio  $\geq 0.90$  in men and  $\geq 0.85$  in women) was 50.3% (15). The much lower prevalence of overweight, obesity and central obesity in rural Indian population was also shown in other studies (30,31).

#### *By socioeconomic status*

The majority of available studies indicated a higher prevalence in higher-socio-economic-status (SES) groups. The NFHS-2 showed that the combined prevalence was 2.6%, 8.6% and 27.2% in women with low, medium vs. high family SES background, which was defined based on the material and resources in daily life. Women with higher education also had a higher prevalence. NFHS-2 and NFHS-3 showed that the prevalence was approximately 5–7% among illiterate women while it was above 20% among those who had high school or higher education. The patterns were supported by other studies of other gender and age groups from different regions. For example, a regional study (14) demonstrated that the prevalence of obesity–overweight and central obesity was more salient in higher-SES groups (35.5% and 47.5% respectively) than in low-SES groups (18.8% and 23.9% respectively). Other studies have also shown a positive association between SES and obesity and obesity-related disorders (32–34).

#### *By region*

There were large regional differences in the prevalence and in the time trends in the prevalence. A 1994–1996 nationwide study (28) showed that the prevalence of central obesity among women was 55%, with the highest rate in the east India (62.2% in Calcutta), and the lowest in the west India (47.7% in Bombay). NFHS data showed that from 1998–1999 to 2005–2006, the combined prevalence had dropped in Delhi from 33.8% to 26.4%, while in the state of Kerala, it increased from 20.6% to 28.1%. While most states experienced an increase in obesity, the

**Table 1** Nutritional status of women in India: BMI and the prevalence of underweight, overweight and obesity based on the 1998–1999 and 2005–2006 NFHS\*

	N	BMI (kg m <sup>-2</sup> )	Underweight (%, BMI < 18.5)	Overweight and obesity (%, BMI ≥ 25)	Obesity (%, BMI ≥ 30)	Overweight-to-underweight ratio	Overweight-to-obesity ratio
Ever-married women aged 15–49 years (NFHS-2, 1998–1999)							
Total	77 119	20.3	35.8	10.6	2.2	0.30	4.82
Age (years) <sup>†</sup>							
15–19	6 707	19.3	38.8	1.7	0.1	0.04	17.00
20–29	27 958	19.6	40.3	5.6	0.8	0.14	6.73
30–49	42 455	20.9	32.3	15.2	3.4	0.47	4.43
Marital status							
Currently married	72 093	20.3	35.6	10.6	2.2	0.30	4.82
Not currently married	5 026	20.1	39.3	10.3	2.1	0.26	4.90
Residence							
Urban	20 563	22.1	22.6	23.5	5.8	1.04	4.05
Rural	56 556	19.6	40.6	5.9	0.9	0.15	6.56
Education							
Illiterate	44 251	19.5	42.6	5.1	0.9	0.12	5.67
<Middle school complete	15 234	20.6	32.6	12.9	2.7	0.40	4.78
Middle school complete	6 447	21.1	28.0	15.7	3.2	0.56	4.91
≥High school	11 178	22.5	17.8	26.0	6.4	1.46	4.06
Religion							
Hindu	63 394	20.1	36.9	9.6	2.0	0.26	4.80
Muslim	9 207	20.5	34.1	12.4	2.8	0.36	4.43
Christian	1 981	21.4	24.6	17.6	3.4	0.72	5.18
Sikh	1 280	23.0	16.4	30.1	8.0	1.84	3.76
Jain	286	23.4	15.8	33.7	9.8	2.13	3.44
Buddhist/Neo-Buddhist	607	20.4	33.3	10.5	2.8	0.32	3.75
Other	261	19.2	49.4	7.0	0.4	0.14	17.50
No religion	37	20.6	34.5	13.8	3.4	0.40	4.06
Caste/tribe							
Scheduled caste	14 040	19.5	42.1	5.8	0.9	0.14	6.44
Scheduled tribe	6 590	19.1	46.3	9.4	0.5	0.00	0.00
Other backward class	25 474	20.2	35.8	9.4	1.7	0.26	5.53
Other	30 345	21.0	30.5	15.4	3.7	0.50	4.16
Standard of living index							
Low	24 589	18.9	48.1	2.6	0.3	0.05	8.67
Medium	35 732	20.1	35.6	8.6	1.5	0.24	5.73
High	15 938	22.7	17.3	27.2	6.8	1.57	4.00
All women aged 15–49 years (NFHS-3, 2005–2006)							
Total	111 781	20.5	35.6	12.6	2.8	0.35	4.50
Age (years)							
15–19	22 147	19.0	46.8	2.4	0.2	0.05	12.00
20–29	36 413	20.0	38.1	8.2	1.4	0.22	5.86
30–49	53 221	21.4	29.1	20.0	4.9	0.69	4.06

Table 1 Continued

	N	BMI (kg m <sup>-2</sup> )	Underweight (%, BMI < 18.5)	Overweight and obesity (%, BMI ≥ 25)	Obesity (%, BMI ≥ 30)	Overweight-to-underweight ratio	Overweight-to-obesity ratio
<b>Marital status</b>							
Currently married	82 145	20.8	33	14.9	3.4	0.45	4.38
Widowed	3 865	20.8	33.5	14.4	3.2	0.43	4.50
Divorced/separated/deserted	1 718	20.7	33.9	14.4	3.7	0.42	3.89
Never married	24 053	19.3	44.9	4.5	0.7	0.10	6.43
<b>Residence</b>							
Urban	36 366	22.0	25.0	23.5	6.1	0.94	3.85
Rural	75 416	19.8	40.6	7.4	1.3	0.18	5.69
<b>Education (years)</b>							
No education	44 926	19.7	41.7	7.3	1.4	0.18	5.21
<5	9 120	20.2	37.2	10.7	2.1	0.29	5.10
5–7	17 032	20.7	34.1	14.2	3.5	0.42	4.06
8–9	15 781	20.6	35	14	3.1	0.40	4.52
10–11	11 718	21.3	29.4	18.1	4.8	0.62	3.77
≥12	13 198	22.1	21.8	23.8	5.4	1.09	4.41
<b>Religion</b>							
Hindu	90 593	20.4	36.4	11.8	2.6	0.32	4.54
Muslim	14 510	20.6	35.1	14.1	3.5	0.40	4.03
Christian	2 788	21.6	23.2	18.2	3.6	0.78	5.06
Sikh	2 080	23.2	17.8	31.6	10.1	1.78	3.13
Jain	348	22.2	21.8	26.6	6.2	1.22	4.29
Buddhist/neo-Buddhist	939	20.0	40.4	10.1	1.5	0.25	6.73
Other	421	19.5	41.1	3.9	0.9	0.09	4.33
<b>Caste/tribe</b>							
Scheduled caste	20 728	19.9	41.1	8.9	1.6	0.22	5.56
Scheduled tribe	9 067	19.1	46.6	3.5	0.5	0.08	7.00
Other backward class	43 916	20.4	35.7	11.6	2.5	0.32	4.64
Other	37 131	21.3	29.4	18.3	4.5	0.62	4.07
Don't know	583	20.1	39.1	9.7	2.0	0.25	4.85
<b>Wealth index</b>							
Lowest	18 995	18.7	51.5	1.8	0.2	0.03	9.00
Second	21 106	19.2	46.3	3.9	0.5	0.08	7.80
Middle	22 867	19.9	38.3	7.4	0.9	0.19	8.22
Fourth	23 756	21	28.9	15.4	2.9	0.53	5.31
Highest	25 058	22.9	18.2	30.5	8.4	1.68	3.63
Total	111 781	20.5	35.6	12.6	2.8	0.35	4.50

\*NFHS-2 recruited ever-married women only (24), while NFHS-3 included all women (23).

†Some of the age groups were combined in NFHS-2 by researchers to assist comparison with those of NFHS-3. BMI, body mass index; NFHS, National Family Health Survey; NFHS-2, NFHS 1998–1999; NFHS-3, NFHS 2005–2006.

**Table 2** The prevalence of overweight, obesity and central obesity among adults in India

Author/published year (reference)	Study year (data collection)	National/regional	SES	Age group (years)	Sample size	Overweight (%)	Classification of overweight	Obesity (%)	Classification of obesity	Central obesity (%)	Classification of central obesity
Nationwide Singh <i>et al.</i> 2007 (47)	1993–1996	U, 5 metro cities	NA	≥25	T = 6 940 M = 3 507 F = 3 433	T = 40.3 M = 38.3 F = 42.4	BMI ≥ 25	T = 6.8 M = 6.2 F = 7.3	BMI ≥ 30	NA	NA
Singh <i>et al.</i> 1998 (28)	1994–1996	Nationwide, U (5 cities)	All	25–64	F = 3 212	NA	NA	NA	NA	F = 55.0	WHR > 0.85
IPS and Macro International 2000 (19)	1998–1999	NFHS-2, national, U R		15–49	F = 77 119	10.6	BMI ≥ 25	2.2	BMI ≥ 30		
Ramachandran <i>et al.</i> 2001 (15)	2000	Nationwide (6 cities)	All	≥20	T = 11 216 M = 5 288 F = 5 928	T = 30.8	BMI ≥ 25	NA	NA	T = 50.3	WHR ≥ 0.90/M WHR ≥ 0.85/F
NNMB 2002 (21)	2000–2001	Nationwide, 9 states, R	All	18–60	M = 11 074 F = 17 318	M = 5.7 F = 8.2	BMI ≥ 25	M = 0.4 F = 1.2	BMI ≥ 30	NA	NA
Reddy <i>et al.</i> 2006 (29)	2002–2003	Nationwide, 10 industries, U	All	20–69	T = 19 973 M = 11 898 F = 8 075	T = 51.3 M = 50.9 F = 51.9	BMI ≥ 23	NA	NA	M = 30.9 F = 32.8 M = 18.2 F = 23.3	WC > 90 cm/M WC > 85 cm/F WC > 94 cm/M WC > 88 cm/F
IPS and Macro International, 2007 (18)	2005–2006	NFHS-3, national, U R	All	15–49	M = 65 742 F = 111 781	M = 9.3 F = 12.6	BMI ≥ 25	M = 1.3 F = 2.8	BMI ≥ 30		
NNMB 2007 (22)	2005–2006	Nationwide, 9 states, R	All	18–60	M = 14 039 F = 18 603	M = 7.8 F = 10.9	BMI ≥ 25	M = 0.8% F = 1.8%	BMI ≥ 30	NA	NA
Regional Gopinath <i>et al.</i> 1994 (11)	1985–1987	N, U	All	25–64	T = 13 414 M = 6 143 F = 7 171	T = 27.6 M = 21.3 F = 33.4	BMI > 25	NA	NA	NA	NA
Ramachandran <i>et al.</i> 1997 (16)	1988–1989	S, U	All	≥20	T = 900	T = 22.0 M = 10.0 F = 33.0	BMI ≥ 27/M BMI ≥ 25/F	NA	NA	NA	NA
Dhurandhar and Kulkarni 1992 (58)	1989–1990	W, U	All	15–76	T = 1 784 M = 791 F = 993	T = 40.9† M = 36.9 F = 44.1	BMI ≥ 25	NA	NA	NA	NA
Ramachandran <i>et al.</i> 2000 (17)	1990, 1995	S, U	All	≥20	T = 2 463 M = 1 196 F = 1 267	T = 24.6† M = 19.6 F = 29.4	BMI ≥ 25	NA	NA	T = 33.9 M = 40.6 F = 27.6	WHR > 0.90/M WHR > 0.85/F

Table 2 Continued

Author/published year (reference)	Study year (data collection)	National/regional	SES	Age group (years)	Sample size	Overweight (%)	Classification of overweight	Obesity (%)	Classification of obesity	Central obesity (%)	Classification of central obesity
Gupta <i>et al.</i> 2003 (59)	1991	W, U	All	≥20	T = 1 800 M = 960 F = 840	T = 27.2 <sup>†</sup> M = 24.5 F = 30.2	BMI ≥ 25	NA	NA	T = 32.1 <sup>†</sup> M = 21.8 F = 44.0	WC > 102 cm/M WC > 88 cm/F NA
Shukla <i>et al.</i> 2002 (48)	1991–1994	W, U	All	≥35	T = 99 598 M = 40 071 F = 59 527	T = 25.5 <sup>†</sup> M = 19.2 F = 29.7	BMI ≥ 25	T = 5.0 <sup>†</sup> M = 2.2 F = 7.0	BMI ≥ 30	NA	NA
Reddy <i>et al.</i> 2003 (60)	1991–1995	N, U R	All	35–64	M: U = 1 456 R = 1 070 F: U = 1 594 R = 1 417	M: U = 35.1 R = 7.7 F: U = 47.6 R = 11.3	BMI ≥ 25	M: U = 7.1 R = 0.7 F: U = 16.4 R = 2.2	BMI ≥ 30	M: U = 71.8 R = 44.9 F: U = 39.5 R = 35.7	WHR ≥ 0.95/M WHR ≥ 0.85/F
Gupta <i>et al.</i> 1997 (30)	1992–1993	W, R	L	≥20	T = 3 148 M = 1 982 F = 1 166	NA	NA	T = 5.7 M = 5.2 F = 6.3	BMI ≥ 27	T = 4.4 (22/503) M = 4.3 (17/399) F = 4.8 (5/104)	WHR ≥ 0.95 (data available only in part of participants) NA
Khongsdier 2005 (61)	1993–1994	E, R	L	18–59	M = 575	M = 11.65	BMI ≥ 23	NA	NA	NA	NA
Singh <i>et al.</i> 1998 (31)	1993–1995	N, U	All	25–64	T = 1 806 M = 904 F = 902	T = 39.0 <sup>†</sup> M = 31.7 <sup>†</sup> F = 46.2 <sup>†</sup>	BMI > 25	T = 11.9 <sup>†</sup> M = 10.5 <sup>†</sup> F = 13.3 <sup>†</sup>	BMI > 27	T = 47.9 <sup>†</sup> M = 40.9 <sup>†</sup> F = 55.9 <sup>†</sup>	WHR > 0.88/M WHR > 0.85/F
Ramachandran <i>et al.</i> 1997 (16)	1994–1995	S, U	All	≥20	T = 2 183 M = 1 081 F = 1 102	T = 16.2 <sup>†</sup> M = 15.7 <sup>†</sup> F = 16.7 <sup>†</sup>	BMI > 25	T = 5.1 <sup>†</sup> M = 5.0 <sup>†</sup> F = 5.3 <sup>†</sup>	BMI > 27	T = 19.1 <sup>†</sup> M = 23.7 <sup>†</sup> F = 14.3 <sup>†</sup>	WHR > 0.88/M WHR > 0.85/F NA
Gupta <i>et al.</i> 2003 (12)	1995	W, U	L	≥20	T = 2 212 M = 1 415 F = 797	T = 20.4 <sup>†</sup> M = 20.7 F = 19.9	BMI ≥ 25	NA	NA	T = 60.3 <sup>†</sup> M = 54.7 F = 70.1	WHR > 0.90/M WHR > 0.80/F
Prabhakaran <i>et al.</i> 2005 (62)	1995–1998	N, industry	NA	20–59	M = 2 122	35 58.5	BMI ≥ 25 BMI ≥ 23	3.3	BMI ≥ 30	7.2 43.7	WC > 102 cm WC > 90 cm
Beegom <i>et al.</i> 1995 (63)	(1995)	S, U	All	25–64	T = 1 497 M = 737 F = 760	NA	NA	NA	NA	T = 56.0 M = 54.5 F = 57.4	WHR > 0.88

Table 2 Continued

Author/published year (reference)	Study year (data collection)	National/regional	SES	Age group (years)	Sample size	Overweight (%)	Classification of overweight	Obesity (%)	Classification of obesity	Central obesity (%)	Classification of central obesity
Mohan <i>et al.</i> 2001 (14)	1996	S, U	All	≥20	T = 1 262	M = 38.0 <sup>H</sup> M = 13.4 <sup>L</sup> F = 33.1 <sup>H</sup> F = 24.2 <sup>L</sup>	BMI > 25	NA	NA	M = 53.4 <sup>H</sup> F = 41.6 <sup>H</sup> M = 30.8 <sup>L</sup> F = 16.9 <sup>L</sup>	WHR > 0.90/M WHR > 0.85/F
Misra <i>et al.</i> 2001 (13)	1998	N, U	All	>18	T = 532 M = 170 F = 362	T = 13.9 M = 13.3 F = 15.6	BMI > 25	T = 30.7 M = 10.6 F = 40.2	%BF > 25/M %BF > 30/F	T = 37.8 M = 9.4 F = 51.1	WHR > 0.95/M WHR > 0.80/F
Reddy 1998 (33)	(1998)	S, U R	All	18–75	T = 1 119 M = 456 F = 663	T = 8.6 <sup>†</sup> M = 6.6 F = 10.0	BMI ≥ 25	NA	NA	NA	NA
Sidhu and Tatla 2002 (64)	1998–1999	N, U	UM	≥20	F = 1 000	F = 45.3	BMI ≥ 25	F = 25.3	BMI ≥ 30	NA	NA
Griffiths and Bentley 2001 (54)	1998–1999	S, U R	All	15–49	F = 4 032	T = 12.2 U = 37.0 R = 8.0	BMI ≥ 25	T = 2.2%	BMI ≥ 30	NA	NA
Gupta <i>et al.</i> 2003 (12)	2002	W, U	L	≥20	T = 1 123 M = 550 F = 573	T = 36.3 <sup>†</sup> M = 33.0 F = 39.4	BMI ≥ 25	NA	NA	T = 62.0 <sup>†D</sup> M = 54.4 <sup>D</sup> F = 69.2 <sup>D</sup>	WHR > 0.90/M WHR > 0.80/F
Anand <i>et al.</i> 2007 (49)	2003–2004	N, U	L	15–64	T = 2 561	M = 15.9 F = 21.6	BMI ≥ 25	M = 2.1 F = 5.6	BMI ≥ 30	NA	NA
Hazarika <i>et al.</i> 2004 (65)	(2004)	E, R, Assam	L	≥30	T = 3 180 M = 1 441 F = 1 739	T = 6.9	BMI ≥ 25	T = 0.9	BMI > 30	T = 60.8	WHR < 0.9
Deshmukh <i>et al.</i> 2006 (66)	2004	W, R	NA	≥18	T = 2 700 M = 1 059 F = 1 641	T = 11.0 M = 11.6 F = 10.6	BMI ≥ 23	T = 5.1 M = 5.1 F = 5.2	BMI ≥ 25	Definition 1: M = 7.6 F = 8.7 Definition 2: M = 21.5 F = 30.5	Definition 1: WC > 90 cm/M WC > 80 cm/F Definition 2: WHR > 0.9/M WHR > 0.8/F

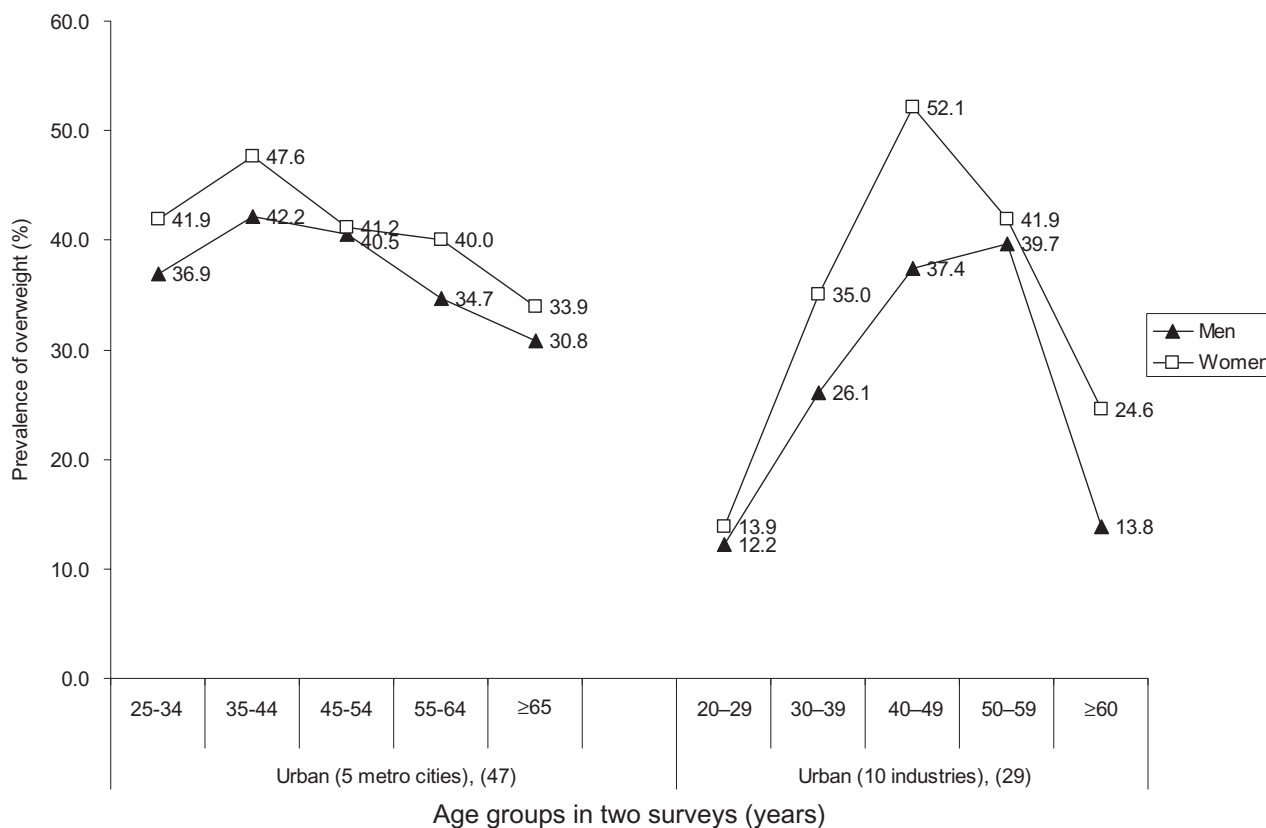
When the original studies did not report the survey year, the publication year was listed in {}.

<sup>†</sup>Calculated by researcher based on reported data.

A, prevalence of obesity for 1988–1989; B, prevalence of obesity for 1994–1995; BF, body fat; BMI, body mass index (kg m<sup>-2</sup>); E, east region; F, female; H, high- and medium-income group; L, low-income group; M, male; N, north region; NA, not available; NFHS, National Family Health Survey; NFHS-2, NFHS 1998–1999; NFHS-3, NFHS 2005–2006; R, rural area; S, south region; SES, socioeconomic status; T, total; U, urban area; UML, upper middle-income group; W, west region; WC, waist circumference; WHR, waist-to-hip ratio.







**Figure 2** Prevalence of overweight and obesity (body mass index  $\geq 25$ ) by age among urban Indian adults between two time periods. Worth noting: the two surveys might not be comparable because of the differences in samples.

prevalence of overweight was seen mostly in the north-eastern and south India. (Fig. 1) (18,19). The mean BMI for men and women did not differ much across the states. However, underweight in women was more pronounced in some states, such as Bihar (45%), Chattisgarh (43%) and Jharkhand (43%), while men in Tripura, Madhya Pradesh and Rajasthan were thinner compared with men in other states. Overweight/obesity was more prevalent in the states of Punjab, Delhi, Kerala and some of the north-eastern states (18).

#### Time trends

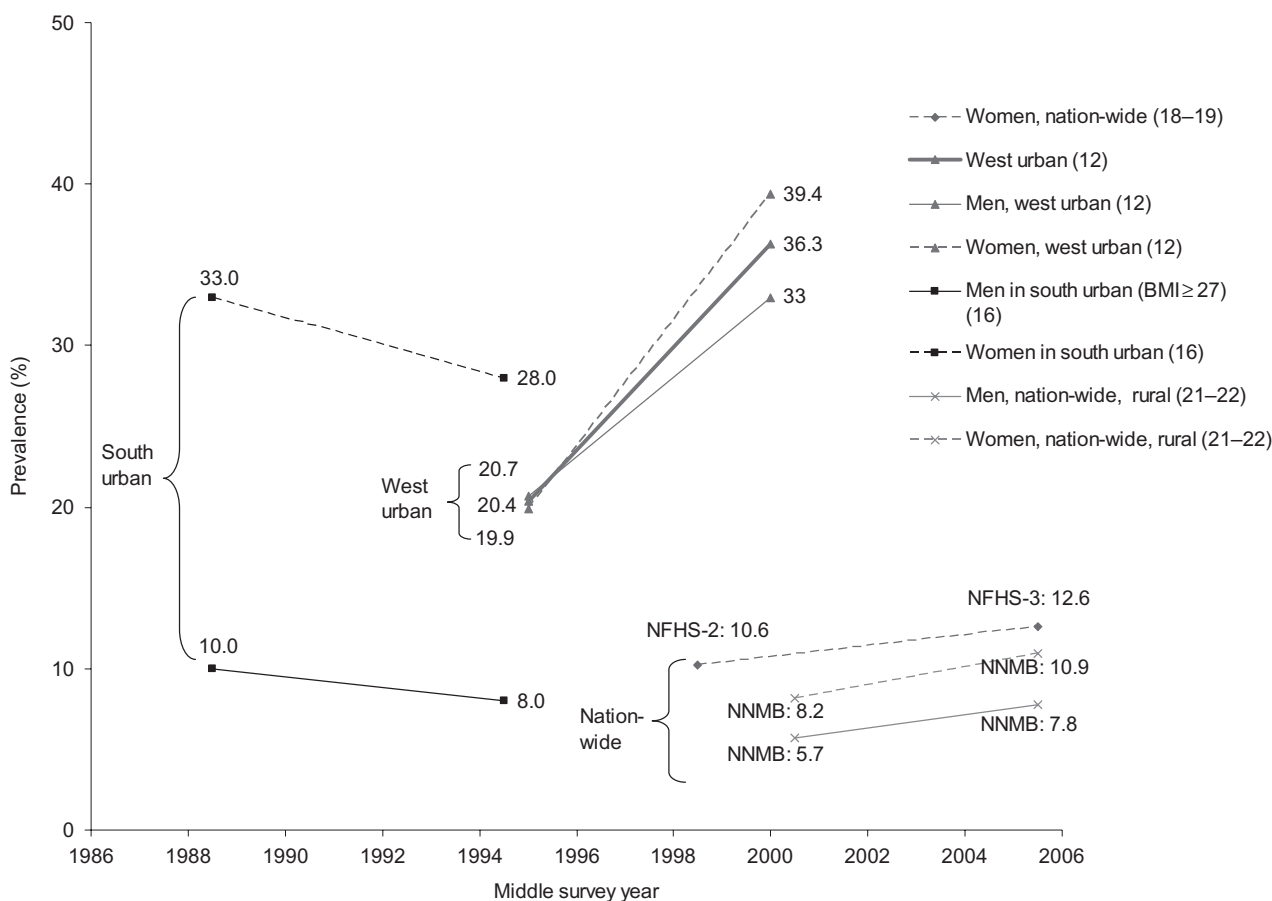
The combined prevalence increased slightly during the past decade as indicated by several large nationwide surveys. Figure 3 presented findings from several selected studies based on more representative data regarding the time trend in overweight. For assuring the comparability of criteria and study settings over time, we only included those studies that reported combined prevalence in the same or similar settings using the same definition (BMI  $\geq 25$ , shown as Fig. 3 with an exception as noted). Figure 1 shows the regional variation in the trends among women based on the 1998–1999 and 2005–2006 NFHS (18,19). The prevalence in NFHS increased slightly over the past decade, although

some local surveys showed an increase trend, while others suggested a decrease. The time trends varied across different regions and study settings (Table 1, Figs. 1 and 3). The 2005–2006 NFHS data showed that the combined prevalence was 12.6% in women and 9.3% in men (18), and this has not increased materially in women from previous (10.6%) NFHS in 1998–1999 (19), with a 0.3% per year increment. The NNMB data for adults showed a moderate increase in the combined prevalence between 2000–2001 and 2005–2006 among men (5.7% to 7.8%, increased by 0.4% a year) and women (8.2% to 10.9%, increased by 0.5% a year) in the rural population in nine states (21,22). One study of an urban lower-SES group in west India showed a drastic increase in prevalence, from 20% to 36%, while the prevalence of central obesity increased less over the past decade, 60% in 1995 and 62% in 2002 (12).

#### Overweight and obesity among children and adolescents

##### The prevalence

Several nationwide surveys provided related data for pre-school children (<5 years old), but there were fewer data on older children and the published studies were predominately



**Figure 3** Time trends in the prevalence of overweight and obesity in India between the 1980s and 2000s: based on nationwide or regional surveys. Overweight and obesity, BMI  $\geq 25$ , unless noted for other definition. Middle survey year, the mid-point of the survey period. Solid lines denote for men and dashed lines for women, while thick solid lines denote for overall prevalence. The NFHS-3 found that the prevalence in men was 9.3. BMI, body mass index; NFHS, National Family Health Survey; NFHS-2, NFHS 1998–1999; NFHS-3, NFHS 2005–2006; NNMB, National Nutrition Monitoring Bureau.

conducted in urban areas. The combined prevalence of overweight and obesity varied considerably across studies and population groups (Table 3). Gender difference in combined prevalence was inconsistent among studies (35–39). Overall, the prevalence was lower in pre-school children than in older children (7), and was higher in urban than in rural adolescents (40). Most of the studies demonstrated that the prevalence was low in pre-school children (e.g. 3.5%) compared with that in other countries (7). The prevalence in pre-school children did not change during 1998–2003 based on two national surveys (Table 3) (41–43). Nevertheless, some studies showed that the prevalence of overweight in urban school-age children was comparable to that in industrialized countries. A recent study in northern India among 21 485 urban children aged 5–18 years showed that based on the IOTF reference, the prevalence of overweight was 15.3% in boys and 14.8% in girls (38). Another 1998–1999 survey on 9- to 15-year-old urban school children from different family SES backgrounds showed that the

prevalence of overweight was 25.3% (35), while it was 32.1% in a study of 870 school children aged 10–16 years from affluent families (36).

#### Time trends

The prevalence in pre-school children was relatively stable in recent decades. Nationwide surveys showed that the prevalence of obesity (weight-for-height Z score  $>2$ ) was 1.1% in 1992–1993 and 1.6% in 1998–1999. The trends in adolescents were mixed based on available data, although they did not allow for an assessment at the national level. For example, one study showed that in adolescent girls living in Chennai with higher-SES background, the prevalence of overweight (BMI  $> 85$ th percentile) was stable over the past two decades, 15.5% in 1981 and 15.9% in 1998 (44). Two other independent studies conducted in southern urban areas showed that the prevalence of overweight was 20% in 2000 and less than 10% in 2003 (37,39).

**Table 3** The prevalence of overweight and obesity among children and adolescents in India

Author/published year (reference)	Study year	National/regional	SES	Age (years)	Sample size	Overweight (%)	Classification of overweight	Obesity (%)	Classification of obesity	Comments
Nationwide (all are among pre-school children)										
de Onis <i>et al.</i> 2001 (43)	1992–1993	National, NFHS-1	All	<4	T = 25 584	NA	NA	T = 1.6	WHZ > 2SD	1995 WHO reference
Martorell <i>et al.</i> 2000 (67)	1992–1993	National	All	1–5	T = 9 849	T = 3.5	WHZ > 1SD	T = 1.1	WHZ > 2SD	1995 WHO reference
de Onis <i>et al.</i> 2003 (42)	1998–1999	National	All	1–5	NA	NA	NA	T = 1.6	WHZ > 2SD	1995 WHO reference
IIPS and Macro International, 2007(18)	2005–2006	National, NFHS-3	All	<5	T = 46 655 M = 24 346 F = 22 306	NA	NA	T = 1.5 M = 1.7 F = 1.4	WHZ > 2SD	2006 WHO Growth Standards
Regional (included pre-school and older children)										
Subramanyam <i>et al.</i> 2003 (44)	1981	S, U	H	10–15	F = 707	15.5	BMI > 85th (US)	5.9	BMI > 95th	US BMI percentile
Gupta <i>et al.</i> 1990 (9)	1985–1986	N, U	All	1–15	T = 3 861	NA	NA	T = 7.6	Wt(g)/Ht(cm) <sup>2</sup> ≥ 2.26	
Subramanyam <i>et al.</i> 2003 (44)	1998	S, U	H	10–15	F = 610	15.9	BMI > 85th (US)	6.2	BMI > 95th	US BMI percentile
Chhatwal <i>et al.</i> 2004 (35)	1998–1999	N, U	All	9–15	T = 2 008	T = 25.3 M = 28.1 F = 22.8	BMI ≥ 85th (US)	T = 11.1 M = 12.4 F = 9.9	BMI ≥ 85th & TSTF ≥ 90th	1995 WHO reference
Ramachandran <i>et al.</i> 2002 (39)	2000–2001	S, U	All	13–18	T = 4 700 M = 2 382 F = 2 318	T = 20.0* M = 21.4 F = 18.5	IOTF <sup>†</sup>	T = 3.1* M = 3.6 F = 2.7	IOTF	IOTF
Monga MS 2004 (10)	2001–2002 (2002)	N, U	All	1–9	T = 1 238	T = 14.46	BMI > 85th (US)	T = 6.2	BMI > 95th	US BMI percentile
Kapil <i>et al.</i> 2002 (36)	(2002)	N, U	H	10–16	T = 870 M = 561 F = 309	T = 32.1 M = 31.4 F = 33.2	IOTF	T = 7.4 M = 8.3 F = 5.5	IOTF	IOTF
Laxmaiah <i>et al.</i> 2007 (37)	2003	S, U	All	12–17	T = 1 208	M = 6.1% F = 8.2%	IOTF	M = 1.6% F = 1.0%	IOTF	IOTF
Mohan <i>et al.</i> 2004 (40)	(2004)	N, U & R	All	11–17	U = 2 467 R = 859	U = 14.0 R = 8.3	BMI ≥ 25	U = 2.4 R = 3.6	BMI ≥ 30	
Marwaha <i>et al.</i> 2006 (38)	(2006)	N, U	All	5–18	T = 21 485 M = 9 763 F = 11 722	T = 15.0* M = 15.3* F = 14.8*	IOTF	T = 3.5* M = 3.7* F = 3.2*	IOTF	IOTF

When the original studies did not report the survey year, the publication year was listed in (').

\*Calculated by researcher based on reported data.

<sup>†</sup>IOTF, International Obesity Task Force; overweight and obesity were defined using BMI cut-points corresponding to 25 and 30 at age 18 years respectively.

BMI, body mass index (kg m<sup>-2</sup>); E, east region; F, female; H, high- and middle-income group; L, low-income group; M, male; N, north region; NA, not available; NFHS, National Family Health Survey; NFHS-2, NFHS 1998–1999; NFHS-3, NFHS 2005–2006; R, rural area; S, south region; SES, socioeconomic status; T, total; TSTF, triceps skinfold thickness; U, urban area; WHZ, weight-for-height Z score.

### Is there a shift from underweight to overnutrition problems in India?

Data from children and adults showed that the prevalence of underweight remains very high, although increasingly studies are calling attention on obesity and its related comorbidity problems in India. Overall, national data show moderate improvement in undernutrition over the past decades compared with some other countries in spite of India's economic development during this period (45,46).

#### Adults

Table 4 shows the undernutrition status among Indian adults. There were remarkable differences between rural-urban areas, SES and regions. The three NFHS surveys revealed that the prevalence of underweight among women aged 15–49 years was constant in the recent decade (35.8% in 1998–1999 and 35.6% in 2005–2006) (18,19). The prevalence of underweight in NNMB surveys decreased from 2000–2001 to 2005–2006, both among men (37.4–33.2%) and women (39.4–36.0%) in the rural areas (21,22). Other regional studies showed that the prevalence was more than 20% in rural areas, but was generally less than 10% in urban areas.

From a relative perspective, overweight was a more serious issue in urban areas, while it was underweight in rural areas. Approximately, our calculated overweight-to-underweight prevalence ratios were <4 in urban areas, but were <0.3 in rural areas (Table 4). At the national scale, the ratio was only 0.35 in women and 0.27 in men based on the NFHS 2005–2006. In contrast, a five-city survey showed a ratio of 6.8 in men and 8.0 in women, suggesting that overweight had replaced malnutrition as the major nutrition problem since the mid-1990s in these cities (47). Other smaller regional surveys showed a similar wide range of ratios across studies with different settings. Also of interest is that both the NFHS and NNMB surveys indicated a small increase in the ratio in recent years.

Two independent studies in Mumbai during the early 1990s suggested a dramatic social disparity: prevalence of underweight was about 3% in a random sampling study (47), and was about 19% in the other study that did not enrol residents in apartments with high security (48). Another study on a slum area in a northern city showed that about 29% of men and 21% of women were underweight (49). These imply disparity among districts in urban cities, and there were serious double burden of overnutrition and undernutrition associated with SES.

#### Children

The prevalence of underweight, stunting and wasting in children all increased with age in all three rounds of

surveys, which implies growth faltering in India. Nevertheless, this situation appears to be bettered in the recent decades. Even though the prevalence of stunting and underweight in newborn increased from NFHS-1 to NFHS-3, the prevalence decreased in children older than 6 months of age. As for wasting, the prevalence increased from 9.5% in 1998–1999 to 30.3% in 2005–2006 in infants, at a rate of >1% per year. The prevalence of wasting was generally higher in NFHS-3 than in NFHS-1, except for the 12- to 23-month-old children, although for most of these age groups the prevalence of stunting decreased during this period (Table 5) (18–20). The overweight-to-underweight ratio (weight-for-height >2SD vs. weight-for-age <2SD) was 0.03 (1.6% over 47.0%) in 1998–1999 among children under 3 years old (42), and was 0.04 (1.5% over 42.5%) in 2005–2006 among children under 5 years of age (18). The two NNMB surveys showed that from the early to the mid-2000s, the prevalence of underweight in rural children decreased from 60% to 55%, and that of wasting decreased from 23% to 15%, while that of stunting increased (49% vs. 52%) (21,22). These nationwide data imply that undernutrition is still prevalent in Indian pre-school children. The urban–rural difference in the prevalence of overweight and underweight and their ratios should also be noted: 2.5% vs. 16.9% (ratio = 0.15) in urban and 1.2% vs. 20.7%, (ratio = 0.05) in rural areas (18).

### Discussion

Previously, it was widely speculated that India has been experiencing an increase in the prevalence of overweight and obesity among both adults and children because of its economic development, and such an increase has been observed in most other developing countries during recent years (50,51). In this first comprehensive investigation of such in India, we examined the situation of over- as well as undernutrition, regarding both adults and children, from several perspectives, such as time trends, regional and sociodemographic differences in recent decades. To our surprise, available data indicate that at the national level, the overall prevalence of overweight and obesity did not increase much or even decreased in some study settings. The nationally representative NFHS surveys showed that the prevalence of overweight among women aged 15–49 years was 10.6% in 1998–1999 and 12.6% in 2005–2006, a smaller increase than that observed in other countries, such as China (4,7). Previously, the UN Standing Committee on Nutrition Report presented a static picture for overweight and obesity in Indian men and women (0.006% and 0.002% annual increase respectively) between 1974 and 1998 (52). However, a closer look at other studies published during the same period does not conform to this uniformity among both sexes. The overall scenario suggests

**Table 4** Shifts from under- to overnutrition problems among adults in India – the ratio of prevalence of overweight to underweight

Author/published year (reference)	Study year	Area/region	Population, sample size	Age group (years)	Prevalence of underweight (BMI < 18.5)	Prevalence of Ow and Ob	Ow-to-underweight ratio	Criteria for underweight, Ow, Ob
Nationwide Singh <i>et al.</i> 2007 (47)	1993–1996	National (5 cities), U	6940	≥25	T = 5.5	Overall	T = 7.33	BMI < 18.5
					M = 5.6	Ow = 40.3	BMI ≥ 25	
					F = 5.3	Ob = 6.7	BMI ≥ 30	
IPS and Macro International, 2000 (19)	1998–1999	National, U R	NFHS-2, 77 220 ever-married women	15–49	M = 37.4	Male	M = 0.15	BMI < 18.5
					F = 39.4	Ow = 5.7	BMI ≥ 25	
						Ob = 0.4	BMI ≥ 30	
IPS and Macro International, 2007 (18)	2005–2006	National, U R	NFHS-3, F = 111 781 M = 65 742	15–49	M = 34.2	Overweight	M = 0.27	BMI < 18.5
					F = 35.6	M = 9.3	BMI ≥ 25	
						F = 12.6	BMI ≥ 30	
Nationwide Singh <i>et al.</i> 2007 (47)	1993–1996	National (5 cities), U	6940	≥25	M = 33.2	Obesity	M = 0.23	BMI < 18.5
					F = 36.0	M = 1.3	BMI ≥ 25	
						F = 2.8	BMI ≥ 30	
Regional Shukla <i>et al.</i> 2002 (48)	1991–1994	Mumbai, W U	Tobacco survey 99 598	≥35	M = 19.5	Male	M = 0.98	BMI < 18.5
					F = 19.1	Ow = 19.2	BMI ≥ 25	
						Ob = 2.2	BMI ≥ 30	

Table 4 Continued

Author/published year (reference)	Study year	Area/region	Population, sample size	Age group (years)	Prevalence of underweight (BMI < 18.5)	Prevalence of Ow and Ob	Ow-to-underweight ratio	Criteria for underweight, Ow, Ob
Reddy <i>et al.</i> 2003 (60)	1991–1995	N; U R	Rural M = 1 070 F = 1 417 Urban M = 1 456 F = 1 594	35–64	Rural M = 38.0 F = 35.5 Urban M = 13.6	Rural Male Ow = 7.7 Ob = 0.7 Female Ow = 11.3 Ob = 2.2 Urban Male Ow = 35.1 Ob = 7.1 Female Ow = 47.6 Ob = 16.4	Rural M = 4.94 F = 3.14 Urban M = 0.39 F = 0.23	BMI < 18.5 BMI ≥ 25 BMI ≥ 30
Sidhu and Tatla 2002 (64)	1998–1999	Punjab, N U	F = 1000	≥20	F = 4.5	Ow = 20 Ob = 25.3	4.44	BMI < 18.5 BMI ≥ 25 BMI ≥ 30
Khongsdier 2005 (61)	2002	Meghalaya NE U	M = 575	18–59	M = 26	Ow = 11.6	0.45	BMI < 18.5 BMI ≥ 23
Anand <i>et al.</i> 2007 (49)	2004	Haryana N U	2 561	15–64	M = 29 F = 21.2	Male Ow = 15.9 Ob = 2.1 Female Ow = 21.6 Ob = 5.6	M = 0.55 F = 1.02	BMI < 18.5 BMI ≥ 25 BMI ≥ 30
Deshmukh <i>et al.</i> 2006 (66)	2004	Wardha, W R	2 700	≥18	51.5	Ow = 11.0 Ob = 5.1	0.21	BMI < 18.5 BMI ≥ 25 BMI ≥ 30
Hazarika <i>et al.</i> 2004 (65)	(2004)	Assam, NE, R	3 188	≥30	37.1	Ow = 6.9 Ob = 0.9	0.19	BMI < 18.5 BMI ≥ 25 BMI ≥ 30

When the original studies did not report the survey year, the publication year was listed in (').

BMI, body mass index (kg m<sup>-2</sup>); E, east region; F, female; M, male; N, north region; NFHS, National Family Health Survey; NFHS-2, NFHS 1998–1999, NFHS-3, NFHS 2005–2006; Ob, obesity; Ow, overweight; R, rural area; U, urban area; W, west region.

**Table 5** Trends in the prevalence (%) of underweight, wasting, and stunting in pre-school-age children in India: NFHS 1992–1993 to 2005–2006\*

	NFHS-1, 1992–1993						NFHS-2, 1998–1999						NFHS-3, 2005–2006						Average annual change (in percentage points)†			
	Weight-for-age		Weight-for-height		Height-for-age		Weight-for-age		Weight-for-height		Height-for-age		Weight-for-age		Weight-for-height		Height-for-age		Underweight	Wasting	Stunting	
	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	% <-2	% <-3	SD	SD	SD	SD	
All ages*	20.6	53.4	3.2	17.5	28.9	52.0	18.0	47.0	2.8	15.5	23.0	45.5	15.8	42.5	6.4	19.8	23.7	48.0	-0.84	0.18	-0.31	
Age (months)																						
<6	2.8	15.6	2.0	9.5	5.7	15.7	2.0	11.9	1.9	9.3	4.2	15.4	10.9	29.5	13.1	30.3	8.4	20.4	1.1	1.60	0.36	
6–11	14.1	43.3	2.9	15.7	14.3	34.3	11.8	37.5	2.8	13.2	11.3	30.9	13.9	35.6	10.5	29.1	11.7	28.6	-0.6	1.03	-0.44	
12–23	26.3	63.4	5.6	28.0	30.7	56.6	23.1	58.5	4.1	21.9	29.8	57.5	16.8	43.0	7.4	22.8	26.0	52.3	-1.6	-0.40	-0.33	
24–35	25.9	62.2	2.5	16.6	34.6	60.2	24.1	58.4	1.9	13.2	32.0	56.5	17.7	44.9	5.0	16.7	28.9	55.9	-1.3	0.01	-0.33	
36–47	21.8	58.5	1.8	11.6	40.7	66.7	-	-	-	-	-	-	16.6	45.6	4.7	15.5	27.8	54.3	-1.0	0.30	-0.95	
48–59	-	-	-	-	-	-	-	-	-	-	-	-	15.3	44.8	4.1	15.7	23.9	50.3	-	-	0.36	
Sex*																						
Male	20.2	53.3	3.7	18.8	28.4	52.3	16.9	45.3	2.9	15.7	21.8	44.1	15.3	41.9	6.8	20.5	23.9	48.1	-0.9	0.13	-0.32	
Female	21.0	53.4	2.6	16.1	29.4	51.7	19.1	48.9	2.7	15.2	24.4	47.0	16.4	43.1	6.1	19.1	23.4	48.0	-0.8	0.23	-0.28	

\*Children of different ages were included in the three rounds of NFHS in: NFHS-1, <48 months; NFHS-2, <36 months; and NFHS-3, <60 months. Z scores (SD) were calculated based on the 1977 WHO/NCHS growth reference in NFHS-1 and -2, and based on the 2006 WHO Growth Standard in NFHS-3.

†In the prevalence of underweight (weight-for-age Z score < -2), wasting (weight-for-height Z score < -2) or stunting (height-for-age Z score < -2) between NFHS-3 and -1, percentage points. NCHS, National Center for Health Statistics; NFHS, National Family Health Survey; WHO, World Health Organization.



that the increase in obesity is notable in some areas or groups, while it appears stable in others. Note that small changes in the prevalence may not be able to capture the large shifts in absolute numbers occurring in the population. Meanwhile, undernutrition remains very high in India and the situation has improved little in the past decade. Therefore, our investigation and other previous research in India in particular suggest the double burden of malnutrition and overweight problems, which may have been contributed by economic development, urban–rural distinction and socioeconomic disparities.

The available data also revealed large variations in the prevalence and time trends between ages, sex, urban–rural residence, SES and geographic regions in India. The gender disparity in obesity may be due to the gender differences in factors such as education, occupation and lifestyles, as well as biological differences and life events (e.g. reproduction) over the life course (18). Nationwide surveys also showed a higher prevalence of regular tobacco smoking in men than women (29.6% vs. 2.2%) (18,53), and smoking may contribute to less weight gain. Griffiths and Bentley suggested that the urban–rural difference in overweight prevalence is mainly explained by other SES factors (54). The NFHS data show that the intake frequencies of all food groups were increasing with the wealthy status (18,19), comparable to the observation in developing countries where lower-SES groups had lower prevalence of obesity (55). Nevertheless, the main challenge is the lack of valid data comprising all age and gender groups at national level for depicting a comprehensive picture.

Under recent rapid economic development, individuals who have experienced nutrition inadequacy as foetus or in their early life stages would be at increased risks for obesity, cardiovascular disease, type 2 diabetes and other metabolic diseases when later their living conditions are improved, according to the DOHaD theory (1–3). The lower weight status in pre-school children could be contributed by the poor intra-uterus nutrition, inadequate breastfeeding and/or complementary feeding (56), inadequate quality or quantity of complementary food, impaired nutritional status due to intestinal infections or a combination of these problems (57). These biological selection factors could expand the susceptible population to obesity and related diseases as long as the food accessibility increases. Therefore, even though the overall prevalence of overweight has not increased a lot yet at a nationwide level in recent years, higher prevalence of obesity in middle-age groups and the higher health risk of obesity-related diseases in the near future are foreseeable.

Greater future national efforts should monitor young people's overweight status in India, as at present such data are scarce. Three studies provided national estimate for pre-school children, while all the studies in older-children groups are based on local and highly selective samples. In

addition, different criteria have been used to define overweight and obesity across studies. Thus, the current available data are not adequate to assess the national situation for this age group. The scarce available data showed a very low prevalence of overweight and obesity in pre-school children. Some studies indicated that boys had higher prevalence of overweight than girls, but the combined prevalence of overweight and obesity (e.g. 15–30%) in urban and high-income groups among school-age children has reached a level comparable to that in many industrialized countries (51). In addition, we cannot rule out concerns regarding the quality and comparability of data used in the studies examined in this review.

In conclusion, India is facing two different nutrition problems at present and a potential increasing obesity-related public health burden in the future, while currently undernutrition remains high among both children and adults. Overweight and its comorbidities might outmatch the public health resources rapidly along with the economic development according to the DOHaD theory. The double burden suggests the need of specific and comprehensive public health policies and programmes at the national and regional levels to address them. Future research is needed to explain the slow rise in obesity and small improvement in undernutrition problem, and to study the future impact of obesity related to India's past and current high prevalence of undernutrition. This would generate insights for other countries under economic and nutritional transitions to prevent the spread of obesity and its consequences. Obesity prevention in urban areas and high-SES groups should be simultaneously launched to stem the rise of overweight that is being observed in other countries with rapid urbanization and development.

### Conflict of Interest Statement

No conflict of interest was declared.

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