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Epidemiology of childhood overweight & obesity in India: A systematic review

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***Background & objectives*: Childhood obesity is a known precursor to obesity and other non-communicable diseases (NCDs) in adulthood. However, the magnitude of the problem among children and adolescents in India is unclear due to paucity of well-conducted nationwide studies and lack of uniformity in the cut-points used to define childhood overweight and obesity. Hence an attempt was made to review the data on trends in childhood overweight and obesity reported from India during 1981 to 2013.**

***Methods*: Literature search was done in various scientific public domains from the last three decades using key words such as childhood and adolescent obesity, overweight, prevalence, trends, *etc*. Additional studies were also identified through cross-references and websites of official agencies.**

***Results*: Prevalence data from 52 studies conducted in 16 of the 28 States in India were included in analysis. The median value for the combined prevalence of childhood and adolescent obesity showed that it was higher in north, compared to south India. The pooled data after 2010 estimated a combined prevalence of 19.3 per cent of childhood overweight and obesity which was a significant increase from the earlier prevalence of 16.3 per cent reported in 2001-2005.**

***Interpretation & conclusions*: Our review shows that overweight and obesity rates in children and adolescents are increasing not just among the higher socio-economic groups but also in the lower income groups where underweight still remains a major concern.**

Key words Childhood - cut-points - India - obesity - overweight - prevalence

The term overweight refers to excess body weight for a particular height whereas the term obesity is used to define excess body fat[1]. Overweight and obesity primarily happen either due to excess calorie intake or insufficient physical activity or both. Furthermore, various genetic, behavioural, and environmental factors play a role in its pathogenesis. Childhood obesity is a forerunner of metabolic syndrome, poor

physical health, mental disorders, respiratory problems and glucose intolerance, all of which can track into adulthood[2]. Developing countries like India have a unique problem of 'double burden' wherein at one end of the spectrum we have obesity in children and adolescents while at the other end we have malnutrition and underweight.

Globally, the prevalence of childhood obesity has risen in recent years. The International Association for the Study of Obesity (IASO) and International Obesity Task Force (IOTF) estimate that 200 million school children are either overweight or obese[3]. It is difficult to compare prevalence rates of childhood obesity in different countries due to several limitations: lack of nationally representative surveys of school children and paucity of serial measurements over time. Ogden *et al*[4] reported that the percentage of obese children in the US (6-11 yr age group) was 7 per cent in 1980 which increased to 20 per cent by 2008. Parallely, among adolescents (age groups of 12-19 yr) obesity rates increased from 5 to 18 per cent. Recent figures from the IOTF website[3] showed prevalence rates of overweight/obesity as 40 per cent in both genders in US. Studies conducted on childhood obesity suggest that it may be plateauing off in some developed countries, while steep increases continue to occur in developing countries[5,6]. However, these trends are not well documented.

Lower BMI (body mass index) cut-offs of 23 and 25 kg/m^2 have been suggested by the World Health Organization (WHO) and IOTF for Asian Indian adults for overweight and obesity, respectively[7,8] but these are not applicable for children and adolescents. Over the years, there has been a lack of consensus on the various cut-points or definitions used to classify obesity and overweight in children and adolescents. This makes it difficult to interpret and compare the global or national prevalence rates[9,10]. For children and adolescents, overweight and obesity are usually defined using age and gender specific normograms of BMI.

There is lack of national representative data on obesity in children from India with its widely varying geographical, social and cultural norms. Here we attempt to review available literature on childhood overweight and obesity from India using the various cut-points used to define childhood and adolescent obesity. We also used the published data from India from 1981 to 2013 to plot the trend in childhood obesity and to look at its key socio-demographic patterns.

Material & Methods

A review of the studies published in the last three decades between 1980 and 2013 reporting on prevalence of childhood overweight and obesity (age 1-18 yr) in India was conducted using a systematic approach. As the aim was to present the current scenario in this area, we restricted our search to 1980 and beyond. Literature search was done in available scientific public domains such as Google Scholar, PubMed, IndMED and Cochrane systematic reviews using key words such as childhood and adolescent overweight, childhood obesity, epidemiology in India and globally, body mass index (BMI), trend and prevalence. A combination of MeSH terms and free texts was used for the search. Cross references from identified articles were also used to expand the coverage. Also, websites of official agencies such as IOTF, WHO and Centres for Disease Control and Prevention (CDC) were accessed for related information. The review search initially revealed 612 titles or abstracts. The first two authors critically reviewed the studies to decide if these could be included based on the criteria detailed in the flow chart indicating the review process (Fig. 1). Prevalence in the age group of 1-5 yr were obtained only from national surveys; most studies from India reported only on undernutrition in this age group. Finally, 52 studies were selected and were grouped based on the age groups studied and presented as childhood (1-12 yr), adolescent (10-18 yr) and childhood and adolescent (studies inclusive of both age groups) obesity trends in India according to the year in which that study was published. All reported prevalences were taken directly from the study and no recalculations were performed. Due to the lower obesity prevalence rates in rural or government schools, these were excluded only from the trend analysis (Fig. 2) but have been reported in the Tables. Thus, to plot the figure demonstrating combined childhood and adolescent obesity trends, only urban prevalences from 42 studies (49 datasets as 7 studies reported multiple datasets in the form of repeat surveys) from 1981 to 2013 were used and the year the study was conducted in was considered for analysis; in case, this was not mentioned, the publication year was included.

For each time period, the median of the reported values for the individual studies was calculated along with the quartile limits. Trends for overweight, obesity and combined prevalence in children and adolescents were calculated and presented using box plots (Fig. 2). The box plot included the 25th and 75th percentiles

and data labels plotted were median values with the minimum and maximum. When multiple cut-offs were used in the same study, only IOTF-Cole *et al* 2000 criteria[51] were considered to prevent duplication of study data. Also, two outliers[52,53] were not included in this trend analysis but shown in Table I. We further looked at the distribution of prevalence of obesity by sex and area of residence (rural/urban).

Prior to 2001, prevalence studies reported more on obesity (5 studies) rather than overweight (2 studies) while post-2001, there were almost equal numbers of reported values for both (45 for obesity versus 41 for overweight). Due to this drop in the sample size and number of studies conducted, plotting separate trend graphs for children and adolescents did not show a good trend. Therefore, the results are presented for all 52 studies combined with a total count of 435162 participants. Overweight numbers were available for 43 studies comprising 353738 participants while obesity numbers were reported for 50 studies with 431262 participants. Both numbers were available for 42 studies with 351454 participants. The combined prevalence was the sum of the overweight and obesity prevalence.

Results

Overall, 52 studies were included based on the defined inclusion and exclusion criteria (Fig. 1). The geographical spread of these studies is shown in Fig. 3. The studies appear to be spread across the country with 16 of 28 States being covered by at least one survey. Fig. 3 shows the lack of prevalence data on childhood obesity from many northern and north-eastern States of India.

Cut-points used to define childhood obesity in India

The most commonly used definition for childhood overweight and obesity in India was IOTF-Cole *et al*[51] (28 studies) followed by WHO[61,62] (10 studies) and CDC[63] (8 studies). Others included Gomez classification[59], and that of Must *et al*[60] and Rosner *et al*[72]. India specific cut-points were found in the Agarwal charts 1992[73], 2001[74] [used by Indian Academy of Paediatrics (IAP) for growth monitoring in children and adolescents], Eliz Health Path for Adolescents and Adults (EHPA)[75], Pandey *et al*[76] cut-points for Asian Indian adolescents and the data provided by Khadilkar *et al*[77]. Of the 52 studies reported in this review, six studies used multiple cut-points.

Epidemiology of childhood obesity: Indian data

Studies reporting prevalence of childhood and adolescent obesity in India were included as part of Table I (1-12 yr), Table II (10-17 yr) and Table III (combined age group) in accordance to the year the study was published.

Children (Table I): The key studies are from the National Family Health Surveys (NFHS) and National Nutrition Monitoring Bureau (NNMB) surveys[54-58]. These surveys covered under-five children only. In the older age groups, the study by Preetam *et al*[11] from Puducherry was the largest. In under-fives the prevalence of obesity was below 2 per cent in all the studies. In children above 5 yr, the prevalence of obesity varied between 2 to 8 per cent. Overweight rates were around two times higher and seem to be more in northern and eastern India than in southern India. One study from Srinagar[52] reported a high prevalence rate of 25 per cent, probably due to the smaller numbers studied and being from affluent families.

Adolescent (Table II): The largest study in this age group was the Global School Based survey in 2007 on 8130 students. Overall, overweight prevalence varied between 3 to 24.7 per cent and obesity ranged from 1.5 to 14 per cent in these 28 studies highlighting the wide variability in their prevalence in India. In most studies, slightly higher prevalence rates were reported in boys, compared to girls.

Combined (Table III): A total of 17 studies reported prevalence of overweight/obesity in childhood and adolescence but were combined in such a way that we could not separate the two. The least prevalence of obesity was reported from Nagaland (2.3%) and the maximum from New Delhi (29%) and both used the IOTF-Cole *et al* criteria[51].

Some socio-demographic differentials

Sex/gender: Khadilkar *et al*[17] reported on affluent Indian 2 to 17 yr old children and showed that the prevalence of overweight and obesity was 18.2 per cent by the IOTF classification while it was 23.9 per cent using WHO cut-points and the prevalence was higher in boys. Chhatwal *et al*[18] reported overall prevalences of childhood obesity and overweight in Punjab as 11.1 and 14.2 per cent, respectively and again a higher prevalence in boys (12.4 vs 9.9%, 15.7 vs 12.9%). Sidhu and colleagues[19] from Amritsar reported overweight in 10 per cent among boys and 12 per cent among girls and obesity in 5 per cent boys and

Table I. Childhood (1-12 yr) obesity trends in India

S. No.	Author	Year	Region	Age group (yr)	Sample size (n)	Methods/cut-points^	Overweight prevalence (%)			Obesity prevalence (%)		
							Overall	Boys	Girls	Overall	Boys	Girls
1	Monga[12]	2004	New Delhi, NI	7-9	1238	11.3‡	6.2	-	-	8.2	-	-
2	Sidhu *et al*[13]	2006	Punjab, NI	6-11	1000	IOTF-Cole *et al**	-	12.2	14.3	-	5.9	6.3
3	Bose *et al*[14]	2007	Kolkata, EI	6-9	431♀	IOTF-Cole *et al**	-	-	17.6	-	-	5.1
4	Kumar *et al*[15]	2008	Mangalore, SI	2-5	425	WHO cut-points*	4.5	-	-	1.4	-	-
5	Wang *et al*[16]	2009	National[54] NFHS-1 (1992-1993)	<4	25584	WHO*	-	-	-	1.6	-	-
			National[55] NFHS-2 (1998-1999)	1-5	-		-	-	-	1.6	-	-
			National[56] NFHS-3 (2005-2006)	<5	46655		-	-	-	1.5	-	-
			National[57] NNMB 2000-2001	1-5	28392	Gomez *et al**	-	5.7	8.2	-	0.4	1.2
			National[58] NNMB 2005-2006	1-5	32642	Must *et al**		7.8	10.9		0.8	1.8
6	Dhingra *et al*[52]	2011	Srinagar, NI	7-11	128	WHO*	-	-	-	25	-	-
7	Preetam *et al*[11]	2011	Puducherry, SI	6-12	12685	CDC Growth Charts	4.4	4.2	4.6	2.1	2.0	2.3

*BMI (kg/m^2), ♀Girls only, ‡Ponderal index (kg/m^3) - is a measure of leanness of a person calculated as a relationship between mass and height. It is similar to the body mass index, but the mass is normalized with the third power of body height (m^3) rather than the second power (m^2).
^ >95th or >90th percentile = obesity, ≥85th or 80th percentile = overweight & obesity; NFHS, National Family Health Survey; NNMB, National Nutrition Monitoring Bureau; NI, North India; NEI, North East India; SI, South India; CI, Central India; EI, East India; WI, West India
Various cut-points used:
Gomez *et al* (2000)[59], Must *et al* (1991)[60], International Obesity Task Force (IOTF)-Cole *et al* (*2000*)[51], World Health Organization (WHO) Age and Gender Specific Cut-offs for Overweight & Obesity (1995[61], 2006[62]), Centres for Disease Control and Prevention (CDC), Atlanta, USA, CDC Growth Charts for the United States[63]

Table II. Adolescent (10-18 yr)[#] obesity trends in India

S. No.	Author	Year	Region	Age group (yr)	Sample size (n)	Methods/cut-points^	Overweight prevalence (%)			Obesity prevalence (%)		
							Overall	Boys	Girls	Overall	Boys	Girls
1	Gupta *et al*[66]	1998	Jaipur, NI	13-17	237	WHO	-	-	-	10.1	-	-
2	Kapil *et al*[29]	2002	New Delhi, NI	10-16	870	IOTF-Cole *et al*[*]	24.7	23.1	27.7	7.4	8.3	5.5
3	Ramachandran *et al*[27]	2002	Chennai, SI	13-18	4700	IOTF-Cole *et al*[*]	-	17.8	15.8	-	3.6	2.9
4	Subramanyam *et al*[26]	2003	Chennai, SI	10-15	707♀ (1981)	IOTF-Cole *et al*[*]	9.6	-	-	5.9	-	-
					610♀ (1998)		9.7	-	-	6.2	-	-
5	Chhatwal *et al*[18]	2004	Punjab, NI	9-15	2008	WHO[*]	14.2	15.7	12.9	11.1[a]	12.4	9.9
6	Mohan *et al*[30]	2004	Punjab, NI	11-17	3326	IOTF-Cole *et al*[*]	11.6 (U)	-	-	2.4 (U)	-	-
							4.7 (R)	-	-	3.6 (R)	-	-
7	Khadilkar & Khadilkar[31]	2004	Pune, WI	10-15	1228♂	IOTF-Cole *et al*[*]	19.9	19.9	-	5.7	5.7	-
8	Sidhu *et al*[19]	2005	Punjab, NI	10-15	640	Must *et al*[*a]	10.9	9.9	12.0	5.6	5.0	6.3
9	Gupta *et al*[28]	2006	Jaipur, NI	11-17	1224♀ (1997)	IOTF-Cole *et al*[*]	10.9	-	10.9	5.5	-	5.5
					915♀ (2003)		10.5	-	10.5	6.7	-	6.7
10	Kaneria *et al*[32]	2006	Rajasthan, NI	12-17	268	IOTF-Cole *et al*[*]	3.25	-	-	3.73	-	-
11	Iyer *et al*[33]	2006	Baroda, WI	12-18	5329	IOTF-Cole *et al*[*]	8.5	8.0	9.0	1.5	1.4	1.7
12	Singh *et al*[65]	2006	New Delhi, NI	12-18	510	CDC Growth Charts	-	-	-	-	18.6	16.5
13	Sood *et al*[34]	2007	Bangalore, SI	9-18	794♀	IOTF-Cole *et al*[*]	13.1	-	13.1	4.3	-	4.3
14	Rao *et al*[67]	2007	Pune, WI	9-16	2223	IOTF-Cole *et al*[*]	-	27.5	20.9	-	-	-
15	Laxmaiah *et al*[10]	2007	Hyderabad, SI	12-17	1208	IOTF-Cole *et al*[*]	-	6.1	8.2	-	1.6	1.0
16	Global School Based Student Health survey (CBSE)[b50]	2007	-	13-15	8130	WHO[*]	10.8	11.6	9.7	2.1	2.5	1.5
17	Unnithan & Syamakumari[23]	2007	Kerala, SI	10-15	3886	IOTF-Cole *et al*[*]	17.7	-	-	5.0	-	-
18	Aggarwal *et al*[35]	2008	Punjab, NI	12-18	1000	Rosner *et al*[*]	12.7	-	-	3.4	-	-
19	Bharati *et al*[36]	2008	Wardha, WI	10-17	2555	CDC Growth Charts	3.1	-	-	1.2	-	-
20	Goyal *et al*[9]	2010	Ahmedabad, WI	12-18	5664	IOTF-Cole *et al*[*]	-	14.3	9.2	-	2.9	1.5
21	Jain *et al*[37]	2010	Meerut, NI	10-16	2785	EHPA*	-	18.4	19.7	-	10.8	5.3
22	Gupta *et al*[38]	2011	New Delhi, NI	14-17	3493 (2006)	Pandey *et al*[*]	24.2	-	-	9.8	-	-
					4908 (2009)		25.2	-	-	11.7	-	-

S. No.	Author	Year	Region	Age group (yr)	Sample size (n)	Methods/cut-points^	Overweight prevalence (%)			Obesity prevalence (%)		
							Overall	Boys	Girls	Overall	Boys	Girls
23	Saraswathi *et al*[64]	2011	Mysore, SI	13-17	1439(U)	WHO*	-	-	-	8.8 (U)	7.7 (U)	10.4 (U)
					750(R)		-	-	-	0.8 (R)	0.5 (R)	1.0 (R)
24	Kumar *et al*[39]	2011	Udipi Dist., SI	12-15	500	WHO*	3.0	-	-	2.6	-	-
25	Kumar *et al*[40]	2012	Surat, WI	13	277♀	IAP*	-	-	12.6	-	-	6.5
				14	271♀		-	-	13.3	-	-	6.6
				15	215♀		-	-	14.0	-	-	6.7
26	Jain *et al*[41]	2012	Chattisgarh, EI	13-17	500	CDC Growth Charts	-	-	23.8	-	-	8.4
27	Alok *et al*[25]	2012	Surat, WI	14-16	213 (U)	IOTF-Cole *et al**	26.3 (U)	27.4 (U)	24.9 (U)	14.6 (U)	14.3 (U)	15.0 (U)
					176 (R)		25.8 (R)	25.6 (R)	26.2 (R)	12.8 (R)	11.2 (R)	14.1 (R)
28	Gupta *et al*[42]	2013	Bankura, EI	10-≤18	452	WHO*	7.7	8.9	6.3	4.0	4.0	3.9

#Most studies include age group 10 years onwards in the adolescent age group except for two studies which included age 9 years onwards.
*BMI (kg/m^2), ♀Girls only, ♂Boys only, [a] based on triceps skin fold thickness (TSFT), [b]based on a representative sample of students going to CBSE schools in India, ^ >95th or >90th percentile = obesity, ≥85th or 80th percentile = overweight & obesity; NI, North India; NEI, North East India; SI, South India; CI, Central India; EI, East India; WI, West India

Various cut-points used:

Must *et al* (1991)[60], International Obesity Task Force (IOTF)-Cole *et al* (2000)[51], World Health Organization (WHO) Age and Gender Specific Cut-offs for Overweight & Obesity (1995[61], 2006[62]), Centres for Disease Control and Prevention (CDC), Atlanta, USA, CDC Growth Charts for the United States[63], Eliz Health Path for Adolescents and Adults (EHPA)[75], Pandey *et al*[76], Indian Academy of Paediatrics (IAP) 2001[74], Rosner *et al*[72]

Table III. Childhood & adolescent obesity trends in India (Studies inclusive of both age groups)

S. No.	Author	Year	Region	Age group (yr)	Sample size (n)	Methods/cut-points^	Overweight prevalence (%)			Obesity prevalence (%)		
							Overall	Boys	Girls	Overall	Boys	Girls
1	Gupta & Ahmad[68]	1990	New Delhi, NI	5-15	3861	>2.26‡	-	-	-	-	8.0	7.0
2	Chatterjee[43]	2002	New Delhi, NI	4-18	5000	IOTF-Cole *et al*[*]	29.0	-	-	6.0	-	-
3	Marwaha *et al*[20]	2006	Delhi, NI	5-18	21485	IOTF-Cole *et al*[*]	-	16.8	19	-	5.6	5.0
4	Sharma *et al*[44]	2007	Delhi, NI	4-17	4000	IOTF-Cole *et al*[*]	22.0	-	-	6.0	-	-
5	Raj *et al*[45]	2007	Kerala, SI	5-16	24842 (2003)	CDC Growth Charts[*]	4.9[*]	5.4	4.6	1.3[*]	1.7	0.9
					20263 (2005)		6.6[*]	7.3[*]	5.9	1.9[*]	2.5	1.3
6	Kaur *et al*[46]	2008	Delhi, NI	5-18	16595	IOTF-Cole *et al*[*]	2.7 (LI) 6.5 (MI) 15.3 (HI)	-	-	0.1 (LI) 0.6(MI) 6.8 (HI) 29.0 (P) 11.3 (G)	-	-
						Must *et al*[*]	2.4 (LI) 4.9 (MI) 13.1 (HI)	-	-	1.2 (LI) 2.5 (MI) 9.3 (HI)	-	-
7	Premanath *et al*[24]	2010	Mysore, SI	5-16	43152	Agarwal Charts[*]	8.5	8.8	8.2	3.4	3.7	3.0
8	Khadilkar *et al*[17]	2011	Delhi & Chandigarh,NI, Kolkata, EI, Chennai, Bangalore, Hyderabad, SI, Mumbai, Pune, Baroda, WI, Raipur, CI	2-17	20243	IOTF-Cole *et al*[*]	14.9	15.2	14.4	4.7	5.4	3.9
						WHO[*]	11.1	10.8	11.4	15.9	18.4	12.8
9	Misra *et al*[47]	2011	New Delhi, Jaipur, Agra, Allahabad, NI, Mumbai, WI	8-18	38296	IOTF-Cole *et al*[*]	14.4	-	-	2.8	-	-
						CDC	14.5	-	-	4.8	-	-
						WHO[*]	18.5	-	-	5.3	-	-
						Pandey *et al*[*]	21.1	-	-	12.3	-	-
10	Patnaik *et al*[53]	2011	Bhubaneswar, EI	5-15	468	CDC[*]	14.1	-	-	14.5	-	-

S. No.	Author	Year	Region	Age group (yr)	Sample size (n)	Methods/cut-points^	Overweight prevalence (%)			Obesity prevalence (%)		
							Overall	Boys	Girls	Overall	Boys	Girls
11	Ghosh[48]	2011	Kolkata, EI	8-12	753	IOTF-Cole *et al*[*]	9.4	-	-	6.1	-	-
				13-15			9.7	-	-	5.3	-	-
				16-18			10.0	-	-	5.4	-	-
12	Chakraborty *et al*[49]	2011	Kolkata, EI	5-8	271	CDC[*]	14.4	-	-	5.2	-	-
				9-12	381		22.6	-	-	-	-	-
				13-18	327		17.1	-	-	2.5	-	-
13	Singh & Devi[69]	2013	Manipur, NEI	6-12	192	IOTF-Cole *et al*[*]	-	-	-	-	1.6	5.2
14	Longkumer[70]	2013	Nagaland, NEI	8-15	571	IOTF-Cole *et al*[*]	2.3	2.1	2.5	-	-	-
				13-18	192		-	-	-	-	3.1	5.0
15	Siddiqui & Bose[71]	2012	Indore, CI	7-14	2158	IOTF-Cole *et al*[*]	-	-	-	15.0	6.8	8.2
16	Sonya *et al*[21]	2014	Chennai, SI	6-11	8025	IOTF-Cole *et al*[*]	-	16.2 (P) 1.6 (G)	13.7 (P) 2.6 (G)	-	4.2 (P) 0.3 (G)	3.9 (P) 0.4 (G)
						Khadilkar *et al*[*]	-	23.2 (P) 3.6 (G)	23.2 (P) 5.7 (G)	-	11.6 (P) 0.8 (G)	11.5 (P) 1.1 (G)
				12-17	10930	IOTF-Cole *et al*[*]	-	17.9 (P) 3.6 (G)	19.2 (P) 4.1 (G)	-	4.6 (P) 0.4(G)	4.6 (P) 1.1 (G)
						Khadilkar *et al*[*]	-	24 (P) 6.2 (G)	27 (P) 9.8 (G)	-	10.9 (P) 1.5 (G)	14.3 (P) 2.9 (G)
17	Adinatesh & Prashant[22]	2013	Karimnagar, SI	10-16	892	Agarwal Charts[*]	11.9	-	-	2.7	-	-

BMI (kg/m^2), ♀Girls only, ♂Boys only, ‡Ponderal index (kg/m^3) - is a measure of leanness of a person calculated as a relationship between mass and height. It is similar to the body mass index, but the mass is normalized with the third power of body height (m^3) rather than the second power (m^2).

^ >95th or >90th percentile, obesity; ≥85th or 80th percentile=overweight & obesity; NI, North India; NEI, North East India; SI, South India; CI, Central India; EI, East India; WI, West India; U, Urban; R, Rural; P, Private; G, Government; LI, Low Income; MI, Middle Income; HI, High Income

Various cut-points used:

Gomez *et al* (2000)[59], Must *et al* (1991)[60], International Obesity Task Force (IOTF)-Cole *et al* (2000)[51], World Health Organization (WHO) age and gender specific cut-offs for overweight & obesity (1995[61], 2006[62]), Centres for Disease Control and Prevention (CDC), Atlanta, USA, CDC Growth Charts for the United States[63], Agarwal/Indian Academy of Paediatrics (IAP) growth monitoring charts (1992[73], 2001[74]), Pandey *et al*[76], Khadilkar *et al*[77]

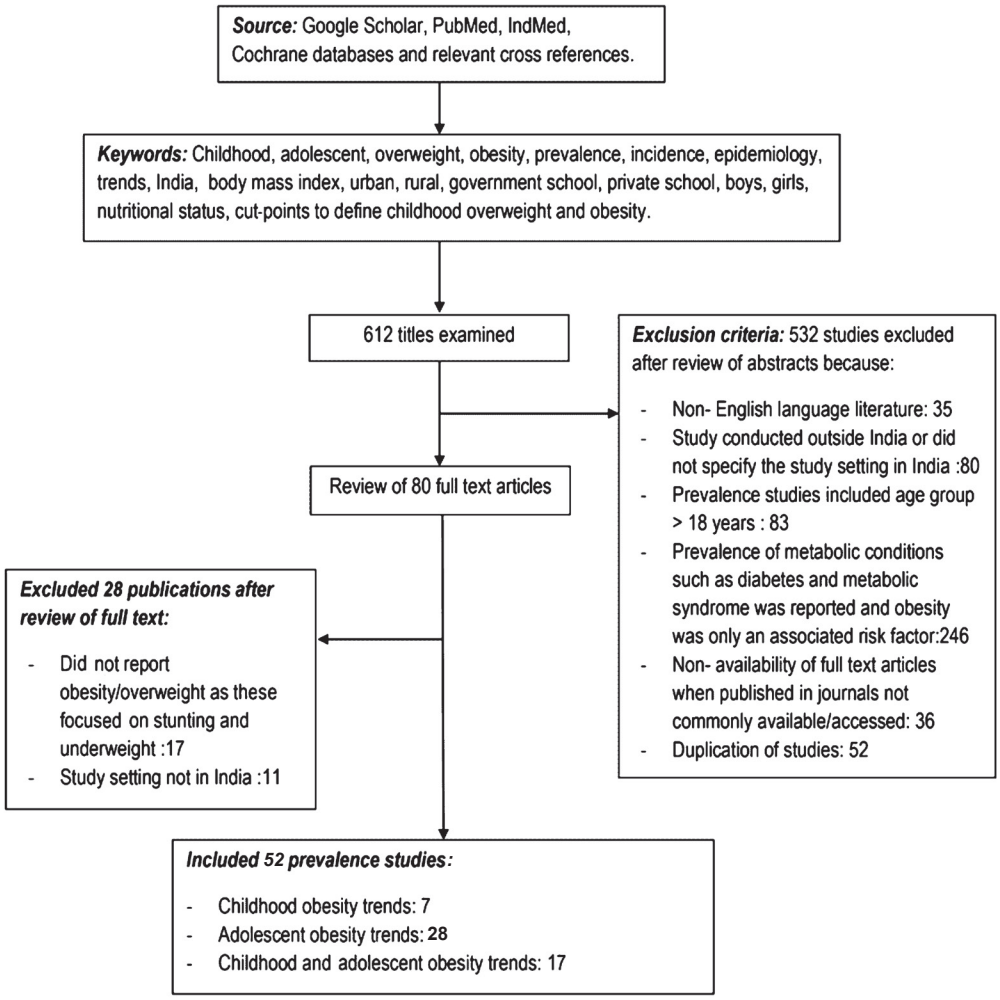

Fig. 1. Flow chart indicative of the review process.

6 per cent in girls. Kotian and co-workers[78] reported that the overall prevalences of overweight and obesity were 9.3 and 5.2 per cent, respectively among boys and 10.5 and 4.3 per cent among girls, in a semi urban city in Karnataka.

Socio-economic status (SES): Marwaha *et al*[20], using IOTF classification showed that among children in the upper SES the prevalences of overweight and obesity were 17 and 5.6 per cent in boys and 19 and 5.7 per cent in girls, respectively, whereas in the lower SES the values were 2.7 and 0.4 per cent in boys and 2.1 and 0.5 per cent in girls, respectively. Goyal and colleagues[9] from Gujarat found the prevalence of obesity to be higher in upper SES group as compared to the middle SES. A recent study based on 18,955 school children in Chennai[21], reported the prevalence of overweight to be 17 per cent while that of obesity was 4.4 per cent among private school children. Conversely, among the government school children the values were 3.1 and 0.5 per cent, respectively using the Cole cut-points. In another study from Karimnagar, Hyderabad, the prevalences of overweight and obesity were 11.9 and 2.7 per cent, respectively among 10-16 yr olds[22]. While obesity was more in higher SES, factors like family size, residence and parent's education did not contribute to obesity.

Place of residence: In a report from Kerala[23] the prevalence of overweight and obesity among children was shown to increase in urban as well as rural areas. This study reported high prevalence of obesity and overweight among boys especially in urban areas whereas underweight was more common in girls especially in rural areas. Premanath and co-workers[24] from Mysuru surveyed 43,152 school children from private and government schools using Agarwal charts[74]. They reported the prevalences of obesity, overweight

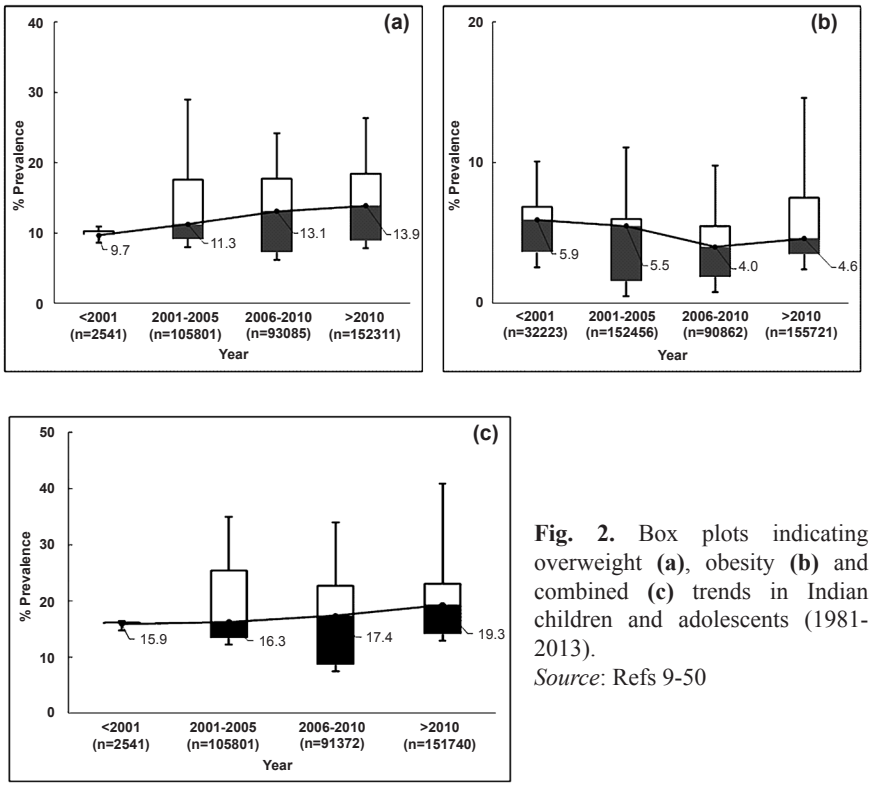

Fig. 2. Box plots indicating overweight **(a)**, obesity **(b)** and combined **(c)** trends in Indian children and adolescents (1981-2013).
Source: Refs 9-50

and underweight to be 3.4, 8.5 and 17.2 per cent, respectively among 5-7 yr old children with higher prevalence of obesity seen in private schools. Another study from Mysuru using the WHO cut-points reported obesity prevalence among urban-rural adolescents to be 9.0 and 0.8 per cent, respectively[64]. A study from Surat, Gujarat, showed an increase in prevalence of overweight/obesity in urban males aged 14-17 yr[25]. Higher SES was found to be significant risk factor for obesity.

These data showed that in India, obesity in children was associated with affluence but the exact prevalence varied based on the definitions used. However, with the rapid epidemiological transition occurring in large metropolitan cities and peri-urban areas, recent studies have shown a steady increase in prevalence among government school children[21,65].

Trends in prevalence of overweight/obesity

Despite the limitations related to cut-points and definitions, when 42 prevalence studies (49 datasets) from India were plotted to observe the trends for combined overweight and obesity in Indian children and adolescents over the last decade, it was seen to be increasing (Fig. 2). The pooled data after 2010 estimated a combined prevalence of 19.3 per cent of childhood overweight and obesity which was significantly (two-sample z-test, $P<0.01$) higher than the earlier prevalence of 16 per cent reported in 2001(Fig. 2). However, these rates tend to vary widely (as also indicated by the length of the box plots) depending on the cut points used, the sampling frame and time period of the survey[59,63,72,74,75,77].

A large variation was noted for combined prevalence (overweight + obesity) values reported from different studies ranging from 4.3 to 40.9 per cent. If further stratified by the cut-offs used, looking at studies using IOTF cut-offs, the combined prevalence range was 6.98 to 40.9 per cent. Region-wise stratification was done on the basis of the region where the studies were performed, excluding studies that were done across multiple regions. The median value for the combined prevalence based on the number of studies reported from that particular region showed that the combined prevalence was higher in north (20.7%, n = 15) compared to south (15.1%, n=16). The combined obesity prevalence from east India (22.0%, n=4) and west (19.7%, n =8) could not be used to make a significant conclusion due to the smaller number of studies reported from these areas.

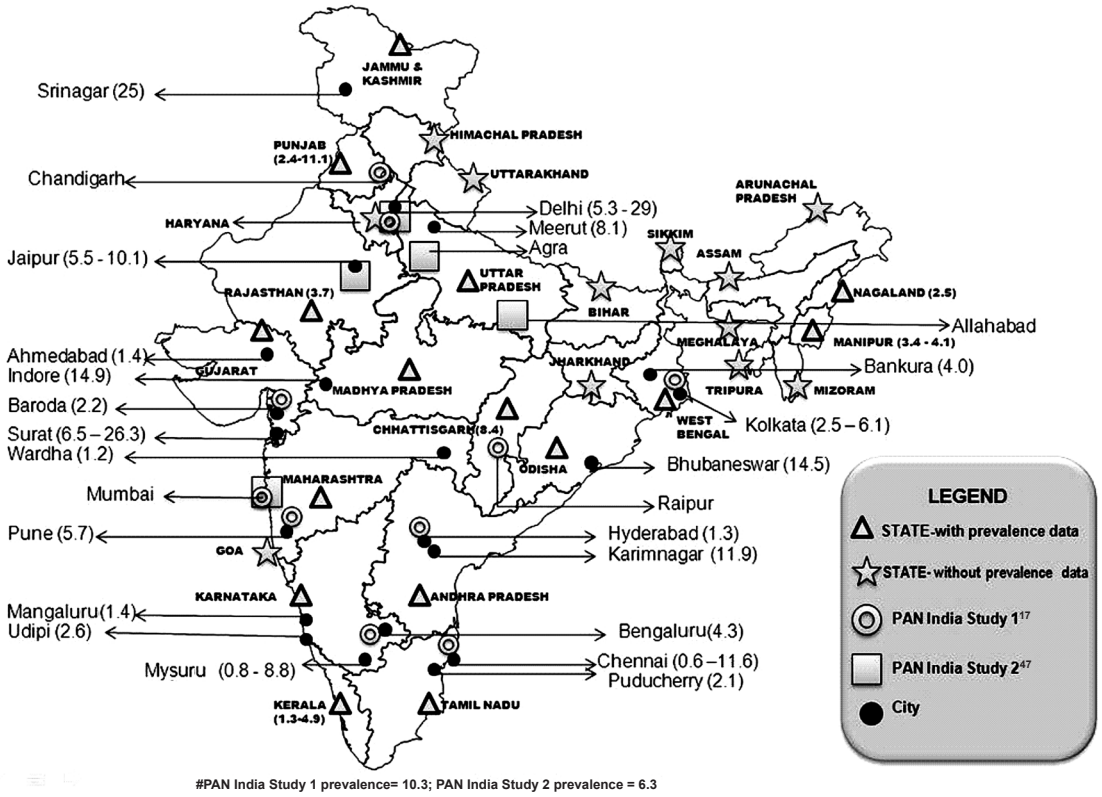

Fig. 3. Map of India indicating prevalence (%) of childhood obesity in various States and cities. Values in parentheses are prevalence in percentages. *Source*: Refs 9-15, 17-49, 52, 53, 64-71.

We also looked at studies which have been done in the same area with a time interval to assess the trends. Subramanyam *et al*[26] reported on obesity trends in adolescent girls in private schools in Chennai and showed that in 1981, overweight was present in 9.6 per cent and obesity in 5.9 per cent of the girls while in 1998, overweight was seen in 9.7 per cent and obesity in 6.2 per cent of the girls. A similar study from the same city in 2002[27] showed that among children attending private schools the prevalence of overweight/obesity had almost doubled - 17.8 per cent in boys and 15.8 per cent in girls. This increase was attributed to changes in lifestyle factors[27]. Gupta *et al*[28] reported in girls aged 11-17 yr an unchanged trend in prevalence of overweight (10.9% in 1997, 10.5% in 2003) and obesity (5.5% in 1997, 6.7% in 2003) based on a population-based birth cohort in New Delhi. This could be attributed to tracking trends of a cohort study whereas both the studies done in Chennai were cross-sectional and in a school based setting.

Discussion

India is a fast growing economy, currently undergoing major epidemiological, nutritional and demographic transitions. These transitions tend to promote obesity in all age groups. However, when one looks at the prevalence of obesity alone, there is no clear secular trend. The median values ranged from 5.5 per cent in 2001-2005 to 4.0 per cent in 2006-2010 and then rose to 4.6 per cent since 2010. This suggests that the prevalence of obesity has probably been somewhat constant over the last couple of decades. However, the overweight and combined overweight/obesity prevalence showed an increasing trend. The prevalence of overweight increased from 9.7 per cent prior to 2001 to 13.9 per cent in studies reported after 2010. The combined trend followed a similar pattern increasing from 15.9 per cent prior to 2001 to 16.3 per cent from 2001-2005. The value then increased to 17.4 per cent in the 2006-2010 period, finally reaching 19.3 per cent in studies reported after 2010. Hence, there was a trend

of increase in overweight among children/adolescents in India.

The criteria used for diagnosis of obesity in children and adolescents in developing countries like India have been based on American and European BMI standards[51]. In these standards, the >85th percentile for overweight and > 95th percentile for obesity have been derived from the data from National Center for Health Statistics (NCHS)[60] and National Health and Nutrition Examination Survey (NHANES)[79] in USA or from studies in western European countries where BMI > 95th percentile corresponds to >130 per cent ideal body weight and BMI of > 30 kg/m^2[(Ref 8)]. The CDC growth curves have been developed from an apparently overweight population[80]. In an effort to overcome this drawback, Cole *et al*[51] used data from several European and Asian countries to determine childhood BMI cut-points that corresponded to adult BMI of 25 and 30 kg/m^2. Many countries including India use the Cole (2000) criteria. This criterion has also been adopted by the IOTF. However, two studies conducted in India[66,81] showed the IOTF reference classified participants as having a lower weight . Both the studies concluded that the Cole criteria were not suitable for Indian and South Asian children.

The WHO has been persuading paediatricians and governments all over the world to use the WHO growth charts for identifying underweight and overweight[80]. de Onis and group[82] thus came up with the WHO 2007 age and gender specific BMI cut-offs as a global standard. In children selected from across the globe it was seen that they grew at an astonishingly consistent pattern up to the age of five years, suggesting that there may not be ethnic differences in the growth pattern of babies and children[83]. However, it is likely that the WHO cut-off will result in higher overweight and or obesity rates[17,80].

Strengths and limitations of the review

One important limitation of this study was that the trend was plotted using reported prevalence rates which in turn were calculated using various cut-offs. To better understand and compare childhood obesity trends, we need age, gender and country or ethnic specific cut-points from age six onwards to 18 yr to uniformly define childhood overweight and obesity. Also, overweight and obesity studies from important States like Haryana, Himachal Pradesh, Uttarkhand, Bihar, Jharkand and six North-Eastern States could not be found in literature. Data from these States could have enriched the summary observations. Five studies conducted within the years 1992-2006 provided national estimates for pre-school children but many used varying cut-points for overweight and obesity. This practical issue of interpreting the various cut-points is a major obstacle in understanding secular trends in childhood obesity not just in India but also worldwide. A major strength (which may also be interpreted by some as a limitation) of this study was that we included all reported overweight/obesity prevalence studies that were accessible through our comprehensive search strategy. As we aimed to report specifically on data from India we also included reports available as conference proceedings or in Indian journals (may not be high impact and indexed). Thus, bearing in mind these limitations, the current available data on childhood overweight and obesity need to be interpreted with caution.

Conclusions

The present analysis shows that overweight and obesity rates in children and adolescents are increasing not just among the higher socio-economic groups but also in the lower income groups where underweight still remains a major concern. This suggests the need for a balanced and sensitive approach addressing economic and nutrition transitions to effectively tackle this double burden paradox in India.

***Conflicts of Interest*:** None.

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