

## Body mass index and skinfold thickness measurements as indicators of obesity in adolescents

Neelabh Mehru<sup>1</sup>, Lata Ratanoo<sup>\*2</sup>, P P Gupta<sup>1</sup> and Mukesh K Gupta<sup>1</sup>

<sup>1</sup>Department of Pediatrics, Mahatma Gandhi Medical College and Hospital, Sitapura, Jaipur, India

<sup>2</sup>Department Obstetrics and Gynecology, Sawai Man Singh (SMS) Hospital, Jaipur, India

### \*Correspondence Info:

Dr. Lata Ratanoo

Assistant Professor,

Department Obstetrics and Gynecology,

Sawai Man Singh (SMS) Hospital, Jaipur, India

E-mail: [drlataratanoo@gmail.com](mailto:drlataratanoo@gmail.com)

### Abstract

**Objective:** To assess prevalence of overweight and obesity in government and private school adolescents by using BMI and measurements of skinfold thickness as parameter of obesity and to evaluate diagnostic value of skinfold thickness measurement as compared to BMI in identifying overweight and obese adolescents.

**Methods:** This was questionnaire based, voluntary response prospective study. Data were collected from 600 adolescents aged between 10-19 years divided equally between government and private school of both genders. Height, weight and skinfold thickness (Triceps skinfold and Subscapular skinfold) were measured. BMI calculated. Prevalence of overweight and obesity were determined and TSFT and SSFT compared with BMI as obesity parameters.

**Results:** Prevalence of overweight and obesity were significantly less in government school adolescents as compared to private school (7% vs 21.67% and 3.33% vs 8.33% respectively) ( $p < 0.001$  significant). TSFT in comparison to BMI carried sensitivity 49.59%, specificity 100%, positive predictive value 100%, negative predictive value 88.70% and efficacy 89.83%. SSFT in comparison to BMI carried sensitivity 41.32%, specificity 100%, positive predictive value 100%, negative predictive value 87.09% and efficacy 88.17%. Correlation of BMI with TSFT ( $r=0.508$ ) and SSFT ( $r=0.604$ ) was significant ( $p < 0.001$ ). Correlation of TSFT and SSFT with age was not significant. Correlation of TSFT and SSFT with genders (in both boys and girls) was found significant ( $p < 0.001$ ).

**Conclusion:** BMI measures body weight. It cannot give accurate assessment of body composition or body fat. Skinfold thickness measurements are better predictors for body fat in both boys and girls which do not correlates with age.

**Keywords:** Adolescents, obesity, anthropometric measurements, BMI, TSFT (Triceps skinfold thickness), SSFT (Subscapular skinfold thickness).

### 1. Introduction

WHO identifies adolescence as the period in human growth and development that occurs after childhood and before adulthood, from ages 10 to 19. It represents one of the critical transitions in the life span and is characterized by a tremendous pace in growth and change that is second only to that of infancy.[1] The process of adolescence is a period of preparation for adulthood during which time several key developmental experiences occur. 1.2 billion Adolescents (10-19 years old) today make up 18 percent of the world's population. In absolute numbers, India is home to more adolescents around -243 million than any other country.[2]

Both under nutrition and obesity or overweight are problems among adolescents in low and middle income countries.[2] The early 21<sup>st</sup> century in industrialized communities provides an environment that is highly

conducive to obesity. It has been seen as a global epidemic in both developed and developing countries.[3] In Great Britain overweight and obesity was 9.6% and 0.9% respectively in boys. In girls overweight and obesity was 11.7% and 1.2% respectively. In Hong Kong overweight and obesity was 11.7% and 3.1% in boys respectively. Similarly it was 9.8% and 1.8% respectively in girls. In Australia studies showed increasing trends of obesity. In 1995 study showed that the percentage of overweight was 19.5% and for obesity it was 4.5% in boys. In girls overweight and obesity were 21.1% and 5.3% respectively. In USA overweight and obesity were 22.1% and 7.0% respectively in boys while in girls 24.0% and 8.2% were found respectively.[3] NFHS-3 (2007) Rajasthan reported the prevalence of overweight and obesity in male was 8.4% and 10.4% in females. In India according to NFHS-3 percentage of overweight and obesity in males is 12% and in females is 16%.[4]

Obesity also currently reported 'globesity' is a complex condition with genetic, metabolic, behavioral and environmental factors all contributing to its development. Many co-morbid conditions like metabolic, cardiovascular, psychological, orthopedic, neurological, hepatic, pulmonary and renal disorders are seen in association with childhood obesity.[5,6]

Body mass index is a measure used to determine overweight and obesity and is widely used as per CDC criteria. Growth patterns are different among different populations, it is necessary to have country-specific growth charts to monitor growth of children between 5-18 years so IAP recommends to define overweight and obesity in children from 5-18 years of age, adult equivalent of 23 and 27 cut-offs lines as presented in BMI charts are used.[7] Anthropometric measurements when used along with BMI gives a better picture of adolescent obesity.

Jaipur is a tier II city of India and is fast emerging as developing city of country. Data are insufficient to initiate comprehensive measures to control it in view of serious health hazards. Therefore the present study is undertaken to determine the prevalence of overweight and obesity in adolescents of the private and government schools of Jaipur city and its anthropometric characteristics.

## 2. Material and methods

The study was conducted in the Department of Pediatrics, Mahatma Gandhi Medical College and Hospital of Mahatma Gandhi University of medical Sciences and Technology, RIICO Industrial Area, Sitapura, Jaipur from August 2015 to January 2016.

The calculated sample size was  $n=600$ . The subjects for study were selected from a private school and a government school. Permission from the ethical committee of Mahatma Gandhi University of Medical Sciences and Technology, RIICO Industrial Area, Sitapura, Jaipur was obtained before starting the present study. We included 600 students aged between 10-19 years divided equally between government school and private school of both genders. This study was a questionnaire based study, only those adolescent children were included who volunteered keeping in mind the inclusion exclusion criteria. Schools were recruited after prior consent of the respective principals allowing conducting the present study. All the respondents were introduced to the topic of study and the need to collect sensitive information and were promised confidentiality of the entries. In each case the permission of head of the family was obtained in writing. We included boys and girls in the age group of 10 – 19 years with consent of school authorities / parents and excluded children consuming drugs that can cause weight loss/gain and having any chronic diseases and amputees.

Materials required were weighing scale, Stadiometer, Non stretchable measuring tape, Skinfold caliper, Calculator, Cosmetic pencils (wax based). A female

teacher was recruited to accompany the investigation while measuring various parameters of female adolescents. Body weight was weighed in kilograms using a self zeroing weight scale (KRUPS), minimal clothing without footwear (to the nearest 0.1kg) with the subject standing motionless on the weighing scale in erect posture without any support, without shoes and with minimal clothing. Three measurements of body weight were taken and averaged out.[8] According to revised IAP growth charts recommendations, weight centile for boys and girls analyzed.[7]

Height was taken (to the nearest 0.1cm) with subject standing in an erect posture so that the back of head, shoulder blades, heels, buttocks were brought in contact with vertical surface of stadiometer. The head was so positioned that the child looked directly forwards in the Frankfort plane (the line joining floor of external auditory meatus to the lower margin of orbit) and the biauricular plane being horizontal. The head piece was kept firmly over the vertex just enough to compress the hair, take a deep breath and hold this position. The height was then recorded three times and then averaged out. [8] According to revised IAP growth chart recommendations height centile for boys and girls analyzed.[7] By height and weight BMI was calculated ( $\text{weight in kg}/\text{height in m}^2$ ). As per IAP recommendation to define overweight and obesity in children from 5-18 years of age, adult equivalent of 23 and 27 cut-offs lines respectively, presented in BMI charts are used. The 3<sup>rd</sup> percentile was used to define underweight.[7]

Skinfold thickness was measured with Accu-Measure skinfold caliper. The folds of skin and underlying subcutaneous adipose tissues were generally grasped between left thumb and forefinger. The examiner grasped enough skin and adipose tissue to form a distinct fold that separated from the underlying muscle. The jaws of the calipers were placed at the marked level, perpendicular to the length of the folds and the skinfold thickness is measured to the nearest 0.1 mm while the fingers continue to hold the skinfold. The skinfolds were measured to the value close to 0.1mm, result recorded three times and then averaged out.[8] Triceps & subscapular skin fold measurements were taken.

Statistical analyses were done using computer software (SPSS version 20 and primer). The qualitative data were expressed in proportion and percentages and the quantitative data expressed as mean and standard deviations. The difference in proportion was analyzed by using chi square test and the difference in means were analyzed by using student T Test and Correlation analyses were performed using Pearson correlation coefficient. The diagnostic accuracy (Sensitivity, Specificity, PPV, NPV and efficacy) were used for assessing obesity indicators against the BMI considering as gold standard. Significance level for tests were determined as 95% ( $P < 0.05$ ).

**3. Results**

The average age of the study group was 15.20 ±2.60 years in government school and 15.28 ± 2.53 years in private

school. (P=0.546, Non Significant) (Table No. I) Significant difference was observed according to the sex. (P=0.009, Significant) (Table No. I)

**Table I: Age and Sex wise distribution of respondents**

Age (years)	Government school (N=300)		Private school (N=300)		Total (N=600)		P Value
	No	%	No	%	No	%	
Early	61	20.33	69	23	130	21.67	1.211 with 2 degrees of freedom; P = 0.546 (NS)
Mid	123	41	127	42.33	250	41.67	
Late	116	38.67	104	34.67	220	36.67	
<b>Sex</b>							6.798 with 1 degree of freedom; P = 0.009 (S)
Male	202	67.33	170	56.67	372	62	
Female	98	32.67	130	43.33	228	38	

Significant difference was observed in socioeconomic status of respondents of both groups. (p=0.025). (Table No II)

**Table No. II: Distribution of the cases according to Socioeconomic Status**

SES	Government school (N=300)		Private school (N=300)		Total (N=600)		P-Value
	No	%	No	%	No	%	
Upper	10	3.33	10	3.33	20	3.33	11.112 with 4 degrees of freedom; P = 0.025 (S)
Upper Middle	31	10.33	58	19.33	89	14.83	
Lower Middle	175	58.33	168	56.00	343	57.17	
Upper Lower	82	27.33	62	20.67	144	24.00	
Lower	2	0.67	2	0.67	4	0.67	
	300	100.00	300	100.00	600	100.00	

Table No. III shows in both boys and girls mean BMI was significantly more in private school children 10 to 14 year of age. No significant mean difference was observed according to age groups in higher age groups. Considering as total mean BMI was significantly more in private school in boys as well as girls.(P<0.001Significant)

**Table No. III: BMI values of adolescents**

	BMI	Government School (N=300)			Private School (N=300)			Chi-Square Test
		N	Mean	SD	N	Mean	SD	P Value
Boy	10 to 11	9	16.74	1.21	7	18.47	1.29	0.015 (S)
	11 to 12	8	14.85	1.38	10	18.75	2.68	0.002 (S)
	12 to 13	10	16.04	2.39	8	20.59	2.05	<0.001 (S)
	13 to 14	7	15.57	1.2	8	18.88	3.78	0.045 (S)
	14 to 15	23	17.87	1.01	19	17.91	2.87	0.95 (NS)
	15 to 16	26	18.58	1.88	16	19.65	2.77	0.143 (NS)
	16 to 17	26	19.18	1.88	28	19.8	2.98	0.36 (NS)
	17 to 18	25	19.69	2.48	20	19.59	2.22	0.889 (NS)
	18 to 19	68	20.79	2.01	54	21.51	3.17	0.12 (NS)
	Total	202	19	2.56	170	19.97	3.07	<0.001 (S)
Girl	10 to 11	6	14.18	1.92	8	18.04	2.24	0.005 (S)
	11 to 12	7	15	2.2	10	16.55	3.38	0.306 (NS)
	12 to 13	8	14.61	2.07	8	20.96	2.2	<0.001 (S)
	13 to 14	6	15.83	3.76	10	21.31	2.81	0.005 (S)
	14 to 15	18	18.99	3.8	20	20.77	3.58	0.146 (NS)
	15 to 16	19	19.54	4.51	25	20.66	3.73	0.37 (NS)
	16 to 17	11	20.02	4.3	19	19.19	2.09	0.41 (NS)
	17 to 18	10	18.55	1.46	15	20.81	3.29	0.054 (NS)
	18 to 19	13	19.9	4.79	15	18.3	3.48	0.32 (NS)
	Total	98	18.16	4.14	130	19.8	3.38	0.001 (S)

**Table No. IV: BMI among Government and Private school**

BMI Category (IAP reference chart)	Government School (N=300)		Private School (N=300)		Total (N=600)		Chi-square test
	No	%	No	%	No	%	p- value
Underweight (<18.5kg/m <sup>2</sup> )	21	7	6	2	27	4.5	41.557 with 3 degrees of freedom; P < 0.001 (S)
Normal (18.5-adult equivalent 23 kg/m <sup>2</sup> )	248	82.67	204	68.00	452	75.33	
Overweight (adult equivalent 23-adult equivalent 27kg/m <sup>2</sup> )	21	7.00	65	21.67	86	14.33	
Obese (>adult equivalent 27 according to age)	10	3.33	25	8.33	35	5.83	
Total	300	100.00	300	100.00	600	100	

Table No. IV shows proportion of the normal (18.5kg/m<sup>2</sup>-adult equivalent 23) and underweight (<18.5kg/m<sup>2</sup>) category of adolescents were significantly more in government school as compared to private school (82.67% vs 68%) were normal and in underweight category (7% vs 2%) and overweight (adult equivalent 23-adult equivalent 27)and obese(>adult equivalent 27) were significantly less in government school as compared to

private school (7% vs21.67% and 3.33% vs 8.33% respectively).(P<0.001 Significant)

TSFT and SSFT values were analyzed as CDC guidelines.[10] Table No. V shows mean triceps skinfold thickness was significantly more in private school as compared to government school children in boys (P<0.001S) and girls (P=0.006S).

**Table No. V: Triceps Skinfold Thickness of Adolescents**

	Triceps Skinfold	Government School (N=300)			Private School (N=300)			Chi-square test
		N	Mean	SD	N	Mean	SD	P Value
Boy	10 to 11	9	10.36	2.21	7	12.33	2.28	0.1 (NS)
	11 to 12	8	9.34	0.47	10	12.07	3.4	0.04 (S)
	12 to 13	10	8.87	2.68	8	13.83	4.51	0.01 (S)
	13 to 14	7	9.21	0.73	8	12.64	4.86	0.08 (NS)
	14 to 15	23	10.48	0.57	19	11.13	1.93	0.13 (NS)
	15 to 16	26	10.4	1.97	16	11.01	3.04	0.43 (NS)
	16 to 17	26	10.1	1.83	28	10.88	2.66	0.21 (NS)
	17 to 18	25	10.81	2.55	20	9.74	1.49	0.10 (NS)
	18 to 19	68	9.47	2.28	54	11.08	3.28	0.002 (S)
Total	202	9.95	2.08	170	11.2	3.06	<0.001 (S)	
Girl	10 to 11	6	10.4	0.36	8	13.8	3.01	0.018 (S)
	11 to 12	7	11.67	0.61	10	13.87	2.73	0.055N (S)
	12 to 13	8	11.29	0.56	8	16.16	3.71	0.003 (S)
	13 to 14	6	12.02	0.33	10	15.58	2.17	0.001 (S)
	14 to 15	18	13.47	3.31	20	15.51	3.45	0.07 (NS)
	15 to 16	19	14.72	3.98	25	15.43	4.6	0.59 (NS)
	16 to 17	11	16.16	3.31	19	15.05	1.8	0.24 (NS)
	17 to 18	10	15.08	0.45	15	16.28	3.14	0.24 (NS)
	18 to 19	13	17.15	4.59	15	15.43	0.8	0.16 (NS)
Total	98	14.08	3.59	130	15.32	3.14	0.006 (S)	

Table No. VI Mean Subscapular thickness was significantly more in private school as compared to government school children in boys and girls (P<0.001S).

**Table No. VI: Age and sex wise distribution of SSFT of adolescents**

Subscapular Skinfold Thickness	Government School (N=300)			Private School (N=300)			P Value	
	N	Mean	SD	N	Mean	SD		
Boys	10 to 11	9	5.8	2.103	7	8.86	4.057	0.07 (NS)
	11 to 12	8	3.38	0.243	10	9.48	6.004	0.01 (S)
	12 to 13	10	4.99	3.46	8	11.6	6.689	0.015 (S)
	13 to 14	7	4.74	0.251	8	8.91	6.786	0.13 (NS)
	14 to 15	23	6.16	0.312	19	6.96	2.327	0.11 (NS)
	15 to 16	26	7.07	2.358	16	7.71	3.646	0.49 (NS)
	16 to 17	26	7.87	2.653	28	8.72	2.961	0.27 (NS)
	17 to 18	25	8.87	2.349	20	8.05	1.718	0.19 (NS)
	18 to 19	68	7.47	3.384	54	10.26	5.308	0.001 (S)
Total	202	7.04	2.902	170	9.03	4.492	0.001 (S)	
Girls	10 to 11	6	6.52	0.407	8	12.65	5.864	0.02 (S)
	11 to 12	7	7.37	0.663	10	12.54	5.611	0.03 (S)
	12 to 13	8	7.09	0.412	8	15.15	6.427	0.003 (S)
	13 to 14	6	8.43	0.703	10	14.49	5.384	0.017 (S)
	14 to 15	18	11	5.111	20	13.98	5.979	0.10 (NS)
	15 to 16	19	11.96	6.911	25	13.98	8.154	0.39 (NS)
	16 to 17	11	14.21	4.726	19	12.95	2.521	0.34 (NS)
	17 to 18	10	12.62	0.339	15	14.67	5.238	0.23 (NS)
	18 to 19	13	15.5	6.381	15	13.41	0.642	0.21 (NS)
Total	98	11.3	5.382	130	13.76	5.518	0.001 (S)	

According to triceps skinfold thickness, proportion of the normal category of adolescents were significantly more in government school as compared to private school (94% vs 86%) and overweight and obese were significantly less in government school as compared to private school (3.33% vs 8.33% and 2.67% vs 5.67% respectively).(P<0.001Significant) (Table No.VII).

**Table No. VII: TSFT and BMI among various categories**

Triceps Category	Government School (N=300)		Private School (N=300)		Total (N=600)		Chi-square test
	No	%	No	%	No	%	
Under Weight	0	0	0	0	0	0	p-value 10.735 with 2 degrees of freedom; P = 0.005
Normal	282	94.00	258	86.00	540	90.00	
Over Weight	10	3.33	25	8.33	35	5.83	
Obese	8	2.67	17	5.67	25	4.17	
Total	300	100.00	300	100.00	600	100.00	

According to subscapular skinfold thickness, overweight and obese were less in government school as compared to private school (3.0% vs 6.67% and 2.33% vs 4.67% respectively). (P=0.001 Significant) (Table No. VIII)

proportion of the underweight category of adolescents were more in government school as compared to private school (8.33% vs 5%) and normal were (86.33% vs 83.66%)

**Table No. VIII: Subscapular skinfold thickness among various groups**

Subscapular Skinfold Thickness	Government School (N=300)		Private School (N=300)		Total (N=600)		Chi-square Test
	No.	%	No.	%	No.	%	
Under	25	8.33	15	5	40	6.66	41.835 with 3 degrees of freedom; P = 0.001 (S)
Normal	259	86.33	251	83.66	510	85	
Overweight	9	3.00	20	6.67	29	4.83	
Obese	7	2.33	14	4.67	21	3.5	
Total	300	100.00	300	100	600	100	

**Table No. IX: Diagnostic values for TSFT as diagnostic tool of obesity**

Triceps Skinfold Thickness	Total	BMI	
		Overweight and obese	Not obese
Overweight and obese	60	60	0
Not obese	540	61	479
Total	600	121	479

By triceps skinfold thickness 60 adolescents were found overweight and obese and also by BMI. Among 540 adolescents who were not obese by triceps, among them 61 were found overweight and obese by BMI and 479 were not found obese by BMI. (Table No. IX)

**Table No. X: Subscapular skinfold thickness as diagnostic tool of obesity**

Subscapular Skinfold Thickness	Total	BMI	
		Overweight and obese	Not obese
Overweight and obese	50	50	0
Not obese	550	71	479
Total	600	121	479

By subscapular skinfold thickness 50 adolescents were found overweight and obese and also by BMI. Among 550 adolescents who were not obese by subscapular skinfold thickness, among them 71 were found overweight and obese by BMI and 479 were not found obese by BMI. (Table No. X)

TSFT in comparison to BMI carried sensitivity 49.59%, specificity 100%, positive predictive value 100%, negative predictive value 88.70% and efficacy 89.83%. SSFT in comparison of BMI carried sensitivity 41.32%, specificity 100%, positive predictive value 100%, negative predictive value 87.09% and efficacy 88.17%.

Significant correlation (p<0.001) was found between BMI and TSFT (r=0.508) and SSFT(r=0.604). Similarly on comparing genders with TSFT and SSFT, a significant correlation was observed. In boys TSFT(r=0.548), SSFT(r=0.657) were significant (p<0.001) and in girls TSFT(r=0.765), SSFT (0.745) were significant (p<0.001). When compared age with TSFT and SSFT insignificant

correlation was found, TSFT(r=-.068)[p=0.96NS] and SSFT(r=0.070) [p=0.86NS].

#### 4. Discussion

The present study shows the correlation of BMI with TSFT and SSFT and comparing the diagnostic values of TSFT and SSFT for diagnosing adolescents obesity in relation with BMI. However, a limitation of BMI is that it cannot differentiate an obese individual from a muscular one. It also cannot locate the site of fat.[11]

Total prevalence of overweight was 14.33% and obesity was 5.83% in our study, it correlates with study done by Bansal *et al*[12] (14.83% and 5.69% respectively) done in same geographical area. In our study significant correlation was found between TSFT and BMI (r=0.508). (p<0.001) significant but correlation of TSFT with age (r= -.068) was not found significant (p=0.096). This partly correlates to Khadilkar *et al* [13] study in which TSFT was significantly

( $p < 0.01$ ) associated with age and BMI in boys and girls both. Similarly in our study good correlation was found between SSFT and BMI ( $r = 0.604$ ) [ $p < 0.001$  significant], this finding is dissimilar to Etchison *et al* [14] where moderate correlation was found between SSFT and BMI as parameters of obesity.

Khadiolkar *et al* [13] found that correlations of anthropometric parameters with TSFT were better in girls than boys. This correlates to our study. TSFT in boys ( $r = 0.548$ ) while in girls ( $r = 0.765$ ) and SSFT in boys ( $r = 0.657$ ) while in girls ( $r = 0.745$ ) were found in our study. Khadgawat *et al* [15] studied that BMI misclassified 13-14% of girls into an incorrect adiposity category in comparison to body fat percentage.

In our study when compared BMI and TSFT, 11.3% were classified as obese by BMI which were not obese by TSFT. Further 12.9% were found obese by BMI which were not obese by SSFT.

Etchison *et al* [14] done cross-sectional study for BMI and percentage body fat as indicators of obesity in adolescent athletic population. According to BMI 13.31% were obese and by using skinfold thickness 5.59% were obese. Of those classified as obese by BMI, 62% were considered false positive by skinfold method and there was 99% probability of being nonobese by BMI not by skinfold so the conclusion was that BMI is a measurement of relative body weight, not body composition. In this study skinfold thickness taken from three sites lateral border of pectoralis major, vertically lateral to umbilicus and anterior mid thigh. In our study of those classified as obese by BMI, 50.4% and 58.68% were considered false positive by TSFT and SSFT respectively.

Further Bogalusa Heart study done by Freedman in 2009 concluded that despite the more accurate prediction of body fatness by skinfold thicknesses, the results indicate that levels of BMI are as strongly related to levels of lipids, fasting insulin, and blood pressure among children as are subscapular and triceps skinfold thicknesses. Because skinfold thickness measurements require careful training of observers and found that skinfold thicknesses do not provide a more accurate assessment of metabolic risk than does BMI. [16]

In 2012 another study done by Freedman for determining body fatness concluded that the use of skin fold sum, rather than BMI, slightly improved identification of elevated levels of body fatness among boys ( $p = .03$ ), but not among girls ( $p > .10$ ). A low sum of the triceps and subscapular skinfold thickness was a better indicator of low PBF-DXA (Percentage Body Fat-Dual energy X-ray Absorptiometry) than was a low BMI, but differences were insignificant. Both BMI and skinfold thickness are fairly accurate in identifying children who have excess body fatness. In contrast, for children with low body fatness skinfold thickness would be preferred. [17]

## 5. Conclusion

BMI measures body weight. It alone cannot give accurate assessment of body fat. Skinfold thickness measurements are better predictors for body fat in both boys and girls which do not correlate with age. Thus BMI followed by skinfold thickness measurement may help to correctly identify body weight along with excess body fat in adolescents so that comprehensive actions can be taken to prevent obesity and its consequences.

## References

- [1] [http://www.who.int/maternal\\_child/adolescent/topic/adolescence/de...](http://www.who.int/maternal_child/adolescent/topic/adolescence/de...) WHO Maternal, newborn, child and adolescent health.
- [2] Progress for Children - A report card on adolescents unicef April 2012. Number 10.
- [3] Baur LA. Child and adolescent obesity in the 21st Century: An Australian Perspective. *Asia Pacific J Clin Nutr* (2002) II (suppl): S524-S528.
- [4] National Family Health Survey. 2007. [https://en.wikipedia.org/wiki/obesity\\_in\\_India](https://en.wikipedia.org/wiki/obesity_in_India).
- [5] Raj M, Kumar RK. Obesity in children and adolescents. *Indian J Med Res* 2010; 132: 598-607.
- [6] Dietz WH. Symposium: The effects of childhood diet on adult health and disease. Childhood weight affects adult morbidity and mortality. *American Society for Nutritional Sciences*, 1998: 0022-3166/98.
- [7] Khadiolkar V, Yadav S, Agrawal KK, Tamboli S, Banerjee M, Cherian A, Goyal JP, Khadiolkar A, Kumaravel V, Mohan V, Narayanappa D, Ray I, Yewale V. Revised IAP Growth charts for height, weight and body mass index for 5 to 18 year old Indian Children. *Indian Pediatrics*, 2015; 52: 47-55.
- [8] Borade A, Kadam GS, Bhide G, Dhongade R. Study of blood pressure and blood sugar levels in adolescence and comparison with body mass index. *Indian J Med Sci* 2011; 65 (7): 297-310.
- [9] The Asia-Pacific Perspective: Redefining obesity and its treatment. WHO. IASO International Association for the study of obesity. International obesity task force. February 2000.
- [10] CDC. Anthropometric Reference Data for children and Adults: United States, 2007-2010. Vital and Health Statistics. Series 11, Number 252. October 2012.
- [11] Bhave S, Bavdekar A, Otv M. IAP National task force for childhood prevention of adult diseases: Childhood obesity. *Indian Pediatrics*. 2004; 41: 559-575.
- [12] Bansal AK, Manohar R, Yadav R, Sharma D, Yadav N, Lohani H. Prevalence of obesity and its lifestyle risk factors in school-age children in Jaipur, *IJRRMS* 2013; 3 (2):16-19.
- [13] Khadiolkar A, Ekbote V, Chipolkar S, Khadiolkar V, Kajale N, Kulakarni S, Parthasarathy L, Arya A, Bhattacharya A, Agarwal S. Waist circumference

- percentiles in 2-18 year old Indian children. *J Pediatr.* 2014 Jun; 164 (6): 1358-62.
- [14] Etchison WC, Bloodgood EA, Minton CP, Thompson NJ, Collins MA, Hunter SC, Dai H. Body mass index and percentage of body fat as indicators for obesity in an adolescent athletic population. *Sports Health.* 2011. Vol. 3, No. 3: 249-252.
- [15] Khadgawat R, Marwaha RK, Tandon N, Mehan N, Upadhyay AD, Sastry A, Bhadra K. Percentage body fat in apparently healthy school children from Northern India. *Indian Pediatrics.* 2013; 50: 859-866.
- [16] Freedman DS, Katzmarzyk PT, Dietz WH, Srinivasan SR, Berenson GS. Relation of body mass index and skinfold thickness to cardiovascular disease risk factors in children: The Bogalusa Heart Study 1, 2, 3, 4. *Am J Clin Nutr* July 2009; 90 (1): 210-216.
- [17] Freedman DS, Ogden CL, Blanck HM, Borrud LG, Dietz WH. The abilities of body mass index and skinfold thickness to identify children with low or elevated levels of dual-energy x-ray absorptiometry-determined body fatness. *J. Pediatr.* 2013 July; 163 (1): 160-6.