Validity of Some Anthropometric Indicators in the Prediction of High Systolic Blood Pressure Among Indian Adolescents

Shobha Rao, Asawari N.Kanade and Priti P. Apte

Agharkar Research Institute, Pune, India.

Abstract

Background: In view of the increasing prevalence of obesity in children, it is necessary to investigate the relative performance of different indicators used for its assessment and health consequences.

Objectives: To examine concordance between various indicators used for assessing obesity among adolescents and to examine their ability to predict risk of high systolic blood pressure.

Design: Cross-sectional study, from two schools catering to affluent class.

Subjects: Children in age 9–16 yr (n = 1146 boys and 1036 girls).

Measurements: Body weight, height, skinfold thickness at triceps (TSFT) and body fat percent by trained investigators and blood pressure measurement by a pediatrician using sphygmomanometer.

Results: Prevalence of overweight was lowest with criterion of TSFT (11.7% in boys; 7.6% in girls) and was highest using criterion of body fat percent (53.7% in boys and 28.4% in girls). Body mass index (BMI) had high significant correlation with each of the indicator and with systolic blood pressure (SBP) as well, in both sexes. All the indicators with conventional cut offs showed poor sensitivity for predicting high SBP. However, receiver operating characteristics (ROC) cut-offs improved sensitivity considerably, but the values were much lower compared to conventional cut-offs.

Conclusions: There is considerable disparity in the estimates of overweight children obtained by different indicators. Lower values of ROC cut-offs highlights the need for population specific customized classification systems for assessing obesity in view of the probable population differences in relative risks of non-communicable adult diseases.

Keywords: Indian affluent adolescents, systolic blood pressure, ROC, sensitivity and specificity

Introduction

The growing affluence in big metropolitan cities in India is affecting both diet and lifestyle. In particular, popularity of fast foods and sedentary life style is likely to promote obesity in younger children from urban affluent populations. Investigation on adolescent obesity is of high relevance for several reasons. Firstly, persistence of childhood obesity into adulthood has been shown by several studies (Rolland Cachera MF et al. 1987; Siervogel RM et al. 1991; Serdula MK, 1993 and Guo SS, 1994). Secondly, childhood obesity carries important health and social implications. Therefore, its prevention in childhood may help in preventing severe diseases in later years (Golan M, 1998). In view of growing epidemic of non-communicable adult diseases in India, investigations of adolescent obesity appear imperative.

Reported studies show large variation in criteria used to assess obesity in children and adolescents (Dietz WH, 1999). There is no uniform definition and assessment of overweight or obesity in children (Mast MA, 2002). Even a most popular indicator like body mass index has not been carefully examined in younger children and adolescents. Almost all reported data pertains to adolescents from Europe or North America and therefore validation studies in other populations are needed (Dietz WH, 1999). In particular, consistency of these indicators has not been proven in field studies (Mast MA, 2002). Present study therefore attempts to examine relative performance of several indicators used for assessing

Correspondence: Dr. (Mrs.) Shobha Rao, Biometry and Nutrition Unit, Agharkar Research Institute, G.G. Agarkar Road, Pune- 411004, India. Tel: (020) 25673959; Fax: (020) 25651542; Email: raoari@yahoo.com.srao@aripune.org

obesity among adolescents. Further, it is believed that the choice of cut-off for obesity screening indicator should be based on health related criteria (Sardinha LB, 1999). We therefore, examined the clinical validity i.e. ability to predict health risk associated with obesity, by assessing relative efficiency of these indicators to predict risk of high blood pressure.

Subjects and Methods

Subjects

Two convent public schools (one for boy's and another for girl's) catering to children from urban affluent High Socio-Economic class (HSE) were considered for the study. The major reason for considering adolescent from HSE was that adiposity is likely to be more prevalent among richer section of the population than the poorer section. Majority of the parents had education up to graduation and were either professionals or businessman. All children from 5th to 10th standard covering the age 9–16 years (1146 Boys and 1036 Girls) from these schools were included in the study. Absentees (5.7% boys and 6.8% girls) on the actual survey days were the only exclusions. Approval of the Institutional Research Advisory Committee for the study was taken.

Measurements

Anthropometric measurements were recorded in duplicate by trained investigators using standard procedures. Nevertheless, an inter observer variability (IOV) study was done before starting the study. Weight (kg) was recorded in duplicate with an electronic scale (Suysan, India) to the nearest 0.02 kg after ensuring the weighing scale is placed on a firm and leveled ground. The subject stood on the scale bare-footed and wearing their school uniform. Height was measured using stadiaometer to nearest 0.1 cm. The stadiometer was placed on a plain and firm surface and the subject was asked to stand on the wooden platform bare-foot, with their feet parallel to each other, head erect and the heels, buttocks and shoulders touching the vertical steel rod. The investigator held the chin to ensure that the position of the chin appears perpendicular to the steel rod. The horizontal metal road was lowered gently so as to touch the highest point of the top of head and the reading within the window was recorded. Body fat was measured using Omron (HBF 300, Japan) equipment that works on principle of bio-electrical impedance analysis (BIA). Skinfold thickness at triceps was measured (up to 0.2 mm) using Harpenden Skinfold Calipers (CMS Instruments, London, U.K.). Age assessment was done using birth date records from the school.

Assessment of Overweight

Body mass index (BMI)

Body mass index defined as kg/m^2 offers a reasonable measure of fatness in children and adolescents. For assessing prevalence of overweight children, the conventional cut off of BMI above 85th percentile was used (Must A, 1991). Similarly age-sex specific cut-offs for BMI eveloped by Cole TJ, (2002) are also used to define overweight children. These cut-offs are linked with adult cut-off and extrapolated to childhood as proposed at International Obesity Task Force (IOTF) meeting in 1997 (Bellizzi MC, 2000).

Body fat (%)

Age-sex specific cut off for body fat percent (>85th percentile) given by McCarthy HD, (2006) was used for estimating prevalence of overweight in adolescents.

Skin fold at triceps (TSFT)

An easy method of assessing the percentage of body fat in children would be measurement of the subcutaneous fat layer, namely, skinfold thickness. The cut-off used for skinfold at triceps for defining overweight is often same as that of BMI i.e. 85th percentile given by Must A, (1991) for overweight .

Blood pressure

In order to examine the health consequences of adolescent obesity blood pressure measurement was taken with the help of a pediatrician. Taking blood sample for examining lipid profile was difficult in case of children as school authorities were reluctant to permit such examination. A pediatrician accompanying the team measured the systolic blood pressure (SBP) and diastolic blood pressure (DBP) using sphygmomanometer (mercury).

It was measured in a sitting position, on left hand using an appropriate size child cuff, after a child had rest for at least ten minutes. Since the measurements of the students were taken during school timings, we were constrained to take a single measurement of blood pressure. We defined high systolic blood pressure (HSBP) and high diastolic blood pressure (HDBP) independently when measured SBP or DBP of a child was above 95th percentile of value of blood pressure corresponding to his/her age, sex and height percentile given by the Task Force Recommendations. This corrects for the effect of height on BP and allows severity of BP elevation to be compared between groups of children of different heights.

Statistical analysis

All measurements were tested for normality. Anthropometric variables having high correlation with age were considered after adjusting for age. Mean values of measurements for two groups were tested using Student's 't' test. All the analysis was carried out using SPSS/PC+ 11.0 version for Windows.

Receiver operating characteristics (ROC) analysis is a way of evaluating the accuracy of a diagnostic test by summarizing the potential of the test to discriminate between the absence and presence of a health condition (Zweig MH, 1993 and Hanley J, 1988). In present study, we examined indicators of obesity for their sensitivity to identify individuals with high blood pressure. Thus, the sensitivity is the probability that the anthropometric indicator will classify a subject as overweight as well as having high blood pressure (true-positive); while the specificity is the probability that a subject is non-overweight and is having normal blood pressure (true-negative). In ROC analysis the true positive rate is plotted against the false positive rate across range of values from the diagnostic test. This provides an estimate of the cut-off that corresponds to the best trade off between sensitivity and (1-specificity). The decision threshold for the best trade off is the criterion value with the highest accuracy that maximizes the sum of the sensitivity and specificity (Altman DG, 1991). The area under the ROC curve (AUC) was used as a measure of the overall performance of the ROC curve because it reflects the probability that the diagnostic test will classify correctly. The AUC can take values between 0 and 1, where one is a perfect screening test and 0.5 is a test equal to chance.

Results

Mean measurements of boys and girls by yearly age are plotted in Figure 1. Weight, height and BMI increased as age increased in both sexes. Mean height of boys was significantly ($p < 0.01$) higher than girls beyond 13 yr of age. In contrast, mean body fat (%) and BMI were significantly ($p < 0.01$) higher in girls than boys beyond 13 yr. Mean TSFT and percent body fat increased with age among girls but not among boys. Mean TSFT for girls was higher than that for boys in every age group but differences widened beyond 13 yr age. Similarly, sex differences in mean percent body fat widened beyond 12 yr, with girls having significantly higher values than boys.

Prevalence of overweight was computed using five different indicators. Due to developmental variations during adolescence the prevalence of overweight was computed for three broad categories of age. These categories differed according to sex due to the obvious differences in age of maturity. In our study, the mean recalled age for onset of menarche was 12.2 ± 1.1 yr. Hence, categories for girls were defined as pre-pubertal (<11 yr), pubertal (11–13 yr) and post pubertal (> = 13 yr) while the respective categories were taken one year later in case of boys in view of the fact that they mature later compared to girls.

It can be seen that (Table 1) overall prevalence of overweight was highest based on body fat as an indicator (53.7% and 28.4% for boys and girls respectively), while it was lowest when TSFT was used as an indicator (11.7% and 7.6% for boys and girls respectively). Further, prevalence of overweight among boys was highest among pre-pubertal age group by any indicator and decreased as age advanced. Among girls, such age related trend was seen only when prevalence of overweight was estimated using BMI while the reverse trend was seen when cut off based on body fat measures were used. Prevalence of HSBP was 10.5% in boys and 9.7% in girls which increased with age and was highest in older children in both sexes. Prevalence of HDBP was lower (2.6% in girls and 7.0% in boys) than that of HSBP in both the sexes.

As the prevalence of overweight varied greatly by different indicators, the product moment correlations between them (Table 2) were computed.

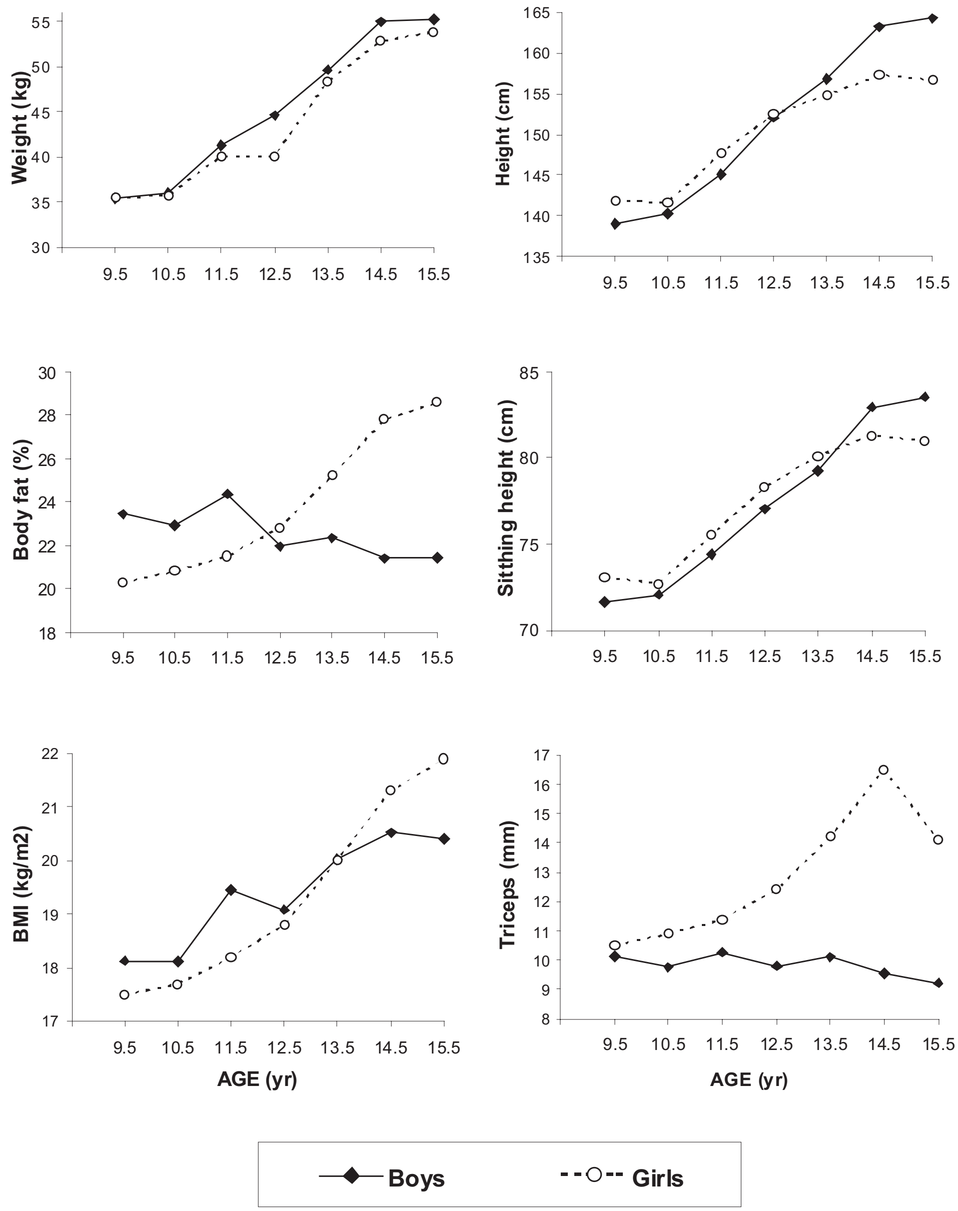

Figure 1. Mean Values of Various Measurements by age for adolescent boys and girls.

BMI showed highest correlations with weight, TSFT and body fat percent, in both the sexes. However, the correlations of SBP with these indicators differed considerably in their magnitude. For example, it was highest with weight followed by that with BMI and was smaller with TSFT and body fat. Therefore, it is necessary to further examine concordance between these indicators for assessing adiposity. For each indicator, subjects identified as overweight are given in the first column and out of these, percentage of children identified as overweight by other indicators as well, are given in the subsequent columns along with Kappa values (Table 3). TSFT identifies smallest number of children as overweight and shows smallest values for Kappa with other indicators. Body fat percent shows highest concordance (over 95%) with high values of Kappa with all other indicators especially among girls than boys.

Finally, the comparison of these indicators was done to examine the nature and extent of misclassification with respect to health related risks viz. systolic blood pressure in this case. Sensitivity and specificity values were calculated with equations of Himes JH, (1994). For almost all indicators, using

Table 1. Prevalence (%) of overweight and high BP among adolescent boys and girls according to age, using different indicators.

Age (yr)	N	BMI > 85th perc	BMI(IOTF)	TSFT > 85th perc	Body fat(%) > 85th	HSBP %	HDBP %
				Boys			
<12	537	31.8	27.9	12.5	59.0	7.4	9.3
12–14	409	24.9	22.7	11.5	47.7	11.0	4.9
> = 14	200	21.0	20.0	10.0	52.0	17.5	5.0
Total	**1146**	**27.5**	**24.7**	**11.7**	**53.7**	**10.5**	**7.0**
				Girls			
<11	137	23.4	21.2	4.4	22.1	7.3	2.9
11–13	357	17.6	17.6	4.5	19.5	6.9	3.2
> = 13	524	23.3	24.0	10.7	36.5	12.1	2.1
Total	**1036**	**21.2**	**21.3**	**7.6**	**28.4**	**9.7**	**2.6**

conventional cut offs, sensitivity was low compared to the specificity (Table 4). Poor sensitivity of the indicators could be due to the fact that the conventional cut-off is not appropriate for Indian population.

The risk cut-offs were therefore obtained by ROC analysis and sensitivity, specificity values were estimated (Table 4) for boys and girls separately. A typical ROC curve for BMI cutoff is shown in Figure 2a and Figure 2b for boys and girls respectively. It was observed that sensitivity for all the indicators using these cut-offs has increased considerably in both sexes. Among boys, maximum increase in sensitivity was seen in case of TSFT (from 30.8% to 67.5%) and BMI (from 58.3% to 74.2%) but was negligible in case of body fat percent (73.3% to 66.9%). Among girls, similar trends in the increase of sensitivity of these indicators were seen. More importantly, these ROC cut offs were much smaller for BMI and TSFT but was similar in case of body fat, when compared with the conventional cut offs given by Must A, (1991).

Discussion

Lack of simple, accurate methods for assessing body fat directly has resulted in use of anthropometric indices as surrogate for body composition. Although, BMI is a most popular of all these indicators, several researchers (Dietz WH and Bellizzi MC, 1999, Sarria A, 1998 and Deurenberg P, 1998) have reported its limitations especially while using it for children and adolescents. In particular, two individuals with same amount of body fat can have different BMI (Sardinha LB, 1999). Consequently, discordant estimates of prevalence of obesity are obtained from BMI and other measures such as TSFT. Therefore, relative comparison between indicators of overweight is of potential interest for assessing adiposity in adolescents (Malina RM, 1999). In fact it

Table 2. Correlations between various indicators of assessing overweight children.

		BMI	TSFT	Body fat	Weight	SBP
BMI	Boys	1	0.811**	0.807**	0.865**	0.552**
	Girls	1	0.817**	0.936**	0.928**	0.573**
TSFT	Boys	–	1	0.713**	0.621**	0.368**
	Girls	–	1	0.798**	0.773**	0.496**
Body fat	Boys	–	–	1	0.494**	0.322**
	Girls	–	–	1	0.885**	0.547**
Weight	Boys	–	–	–	1	0.657**
	Girls	–	–	–	1	0.609**

**p < 0.01 n = 1146 boys, n = 1036 girls.

Table 3. Concordance between various indicators of assessing overweight children.

Indicator	No. of children overweight	Children who were also overweight by			
		BMI > 85th percentile n (%)	BMI (IOTF) n (%)	TSFT > 85th percentile n (%)	Body fat% (cdc) n (%)
		Boys			
BMI > 85th	315	–	283 (89.8)	126 (40.0)	305 (97.1)
Kappa value			0.928**	0.475**	0.461**
BMI (IOTF)	283	283 (100.0)	–	124 (43.8)	277 (98.2)
Kappa value				0.518**	0.423**
TSFT > 85th	134	126 (94.0)	124 (92.5)	–	132 (98.5)
Kappa value					0.198**
Body fat%	615	305 (49.6)	277 (45.0)	132 (21.5)	–
		Girls			
BMI > 85th	220	–	217 (98.6)	69 (31.4)	203 (92.3)
Kappa value			0.978**	0.392**	0.719**
BMI (IOTF)	221	217 (98.2)	–	70 (31.7)	207 (93.7)
Kappa value				0.396**	0.739**
TSFT > 85th	79	69 (87.3)	70 (88.6)	–	77 (97.5)
Kappa value					0.327**
Body fat%	294	203 (69.0)	207 (70.4)	77 (26.2)	–

**$p < 0.000$.
Notes: Using CDC cut-offs (McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. 2006).

is necessary to investigate validity of these indicators for predicting the health consequences. As associations between overweight (high BMI), excess fatness and high SBP have been reported for adolescents (Dwyer JT, 1998, Webber LS, 1991 and Smoak CG, 1987) we compared various indicators of obesity for predicting risk of high SBP. Our observations suggest that BMI could be a reasonably good indicator but may need a lower cut off for assessing adiposity as well as for predicting risk of high SBP, among adolescents from urban affluent population in India.

It may be worthwhile to consider some of the points before discussing the major findings of our study. Single observation available on blood pressure was the limitation of the study and perhaps may be the reason for higher prevalence of high systolic and diastolic pressures observed in this population. However, it is unlikely to affect the relationship observed with various indicators to predict risk of HSBP. Secondly, measurement of body fat percent by bio-electrical impedance using Omron is also of some concern but is the best possible option available, especially in field studies. Finally, cut off points for defining HSBP or HDBP used are based on International Standards of Task Force Recommendations as no such standards are available for Indian or Asian children in general.

Our observation that girls had significantly higher TSFT and body fat values than boys beyond 12 yrs of age is in confirmation with other reported studies from India Agarwal DK, (1992); Vijayraghavan K, (1974); Kapoor G, (1991) as well as from other population (Must A, 1991). These observations are consistent with greater gains in muscle and bone experienced by boys and greater gains in total body fat experienced by girls during adolescence (Sardinha LB, 1999). The estimates obtained from DXA also show (Dietz WH, 1999) that matured boys had less body fat than girl's and gives confidence in our estimates of body fat based on BIA. In fact, Freedman DS, (2005) has recently reported that higher BMI values beyond 12 yrs among girls were mainly due to higher fat mass levels.

Prevalence of overweight was highest using body fat percent as cut-off and was lowest when based on TSFT cut-off. Malina RM, (1999) also report similar observations based on the analysis of data from six study groups. TSFT showed the poorest concordance with all other indicators of assessing adiposity while body

Table 4. Predictive features for risk of high SBP for various indicators using conventional cut-offs as well ROC cut-offs.

Parameter	Conventional			ROC		
	Cutoff	Sensitivity (%)	Specificity (%)	Cutoff	Sensitivity (%)	Specificity (%)
			Boys			
BMI	**>85th 21.0**	58.3	76.1	**19.7**	74.2	65.1
	(IOTF) 21.4	55.8	79.0			
TSFT	**>85th 17.1**	30.8	90.6	**10.1**	67.5	64.9
Body fat	**>85th 22.4**	73.3	48.6	**23.8**	66.9	60.1
			Girls			
BMI	**>85th 22.5**	64.4	83.4	**21.2**	75.3	74.6
	(IOTF) 22.7	64.4	83.3			
TSFT	**>85th 21.7**	31.7	95.0	**14.5**	71.3	68.8
Body fat	**>85th 29.2**	72.1	76.4	**28.4**	74.0	72.6

fat and BMI showed higher Kappa values in girls than boys. These observations indicate that for a given BMI, adolescents have relatively higher body fat, not deposited at triceps but perhaps at abdomen, the observation well documented in case of Indian adults (Deurenberg P, 1998) .

Despite the fact that validity of BMI across diverse samples of youth from different age, sex and ethnic groups has not been evaluated, it is used widely because of the relative ease and accuracy of the basic measurements (Smoak CG, 1987). However, compared with estimates of body fat from DXA or densitometry, it is reported to have lower and variable sensitivity among children and adolescents (Sardinha LB, 1999 and Malina RM, 1999). We compared various indicators for their potential to discriminate the health risk associated with adiposity i.e. high SBP. Kraemer HC, (1990) have suggested five criteria for choosing a measure of adiposity and one of this is clinical validity, i.e. ability to predict morbidity. Since correlation analysis is blind to

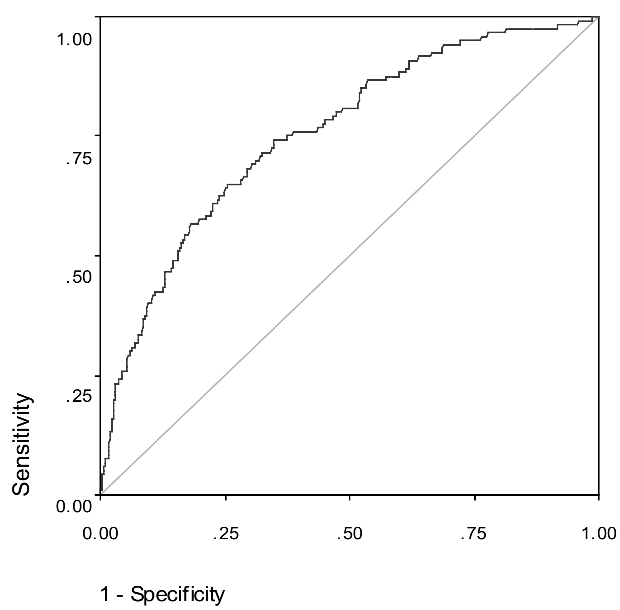

Figure 2a. ROC curves of BMI predicting HSBP (BOYS). Area under curve: 0.755, p value = 0.000.

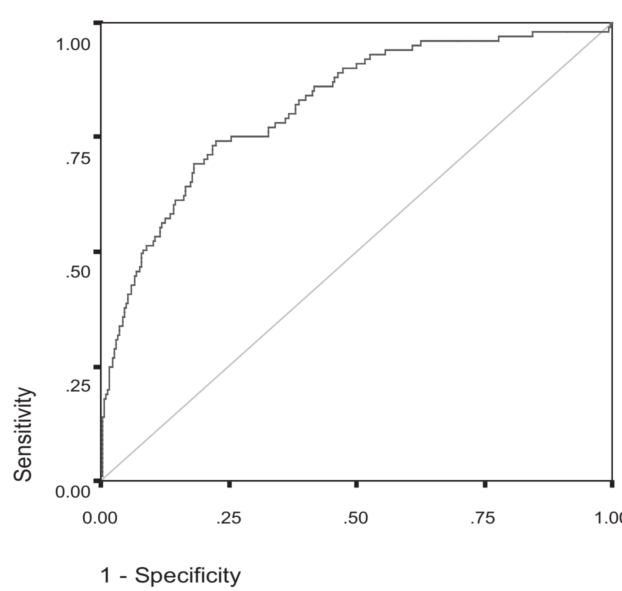

Figure 2b. ROC curves for BMI (GIRLS). Area under curve: 0.817, p value = 0.000.

systematic bias and cannot describe the nature and magnitude of misclassification, we did categorical analysis to compute sensitivity and specificity. For all the indicators, using conventional cut-offs, specificity was greater, but sensitivity was very low. Sardinha LB, (1999) too report similar observations in case of adolescence from Portugal.

The sensitivity of almost all the indicators however, improved considerably when cut-offs based on ROC analysis were used. There are hardly any studies that have used ROC for studying clinical validity of these indicators. Sensitivity of all the indicators was much higher among girls than boys and BMI generally showed higher sensitivity compared to other indicators in both sexes. However, these ROC cut-offs obtained for BMI were much lower compared to the conventional cut-off based on 85th percentile for both boys (19.7 kg/m^2) and girls (21.2 kg/m^2).

Knowledge about different indicators used for assessing obesity in children is of public health importance as it may help both in identifying high risk children and in targeting primary prevention strategies. In view of the fact that adolescent obesity is tracked in later life and is associated with morbidity, our observations underscore the importance of examining them for their clinical validity. The cut-offs determined by ROC had higher sensitivity in our population compared to conventional cut-offs, highlights ethnic variations in body composition. However, our observation that ROC cut-offs were lower than the conventional cut-offs highlights the need for population specific customized classification systems for assessing obesity in view of the probable population differences in relative risks of non-communicable adult diseases.

Acknowledgement

Dr. Shobha Rao is responsible for planning of the study and writing of the manuscript, Dr. Asawari Kanade is responsible for complete supervision of data collection and analysis while Priti Apte is responsible for data verification and actual analysis using SPSS/PC+ 11.0 Window version. The authors are grateful to Dr. V. S. Rao, Director, Agharkar Research Institute for giving Institutional funding for carrying out the study and for providing the necessary facilities. We greatly appreciate the help of other staff members in the Department during the data collection.

References

[1] Agarwal, D.K., Agarwal, K.N., Upadhyay, S.K., Mittal, R., Prakash, R. and Rai, S. 1992. Physical and sexual growth pattern of affluent children from 5 to 18 yrs of age. *Ind. Pediatr.*, 29:1203–82.

[2] Altman, D.G. 1991. Practical statistics for medical research. London: Chapman and Hall.

[3] Bellizzi, M.C. and Dietz, W.H. 1999. Workshop on childhood obesity: Summary of the discussion. *Am. J. Clin. Nutr.*, 70:173s–5s.

[4] Cole, T.J., Bellizzi, M.C., Flegal, K.M. and Dietz, W.H. 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. *Brit. Med. J.*, 320:(7244)1240–5.

[5] Deurenberg, P., Yap, M. and Van Staveren, W.A. 1998. Body mass index and percent body fat: a meta analysis among different ethnic groups. *Int. J. Obes. Relat. Metab. Disord.*, 22:1164–71.

[6] Dietz, W.H. and Bellizzi, M.C. 1999. Introduction: The use of body mass index to assess obesity in children. *Am. J. Clin. Nutr.*, 70:123s–25s.

[7] Dwyer, J.T., Stone, E.J., Yang, M., Feldman, H., Webber, L.S., Must, A., Perry, C.L., Nader, P.R. and Parcel, G.S. 1998. Predictors of overweight and overfatness in a multiethnic pediatric population. *Am. J. Clin. Nutr.*, 67:602–10.

[8] Freedman, D.S., Wang, J., Maynard, L.M., Thornton, J.C., Mei, Z., Pierson, R.N., Dietz, W.H. and Horlick, M. 2005. Relation of BMI to fat and fat-free mass among children and adolescents. *Int. J. Obes.*, 29:1–8.

[9] Golan, M., Weizman, A., Apter, A. and Fainaru, M. 1998. Parents as the exclusive agents of change in the treatment of childhood obesity. *Am. J. Clin. Nutr.*, 67:1130–5.

[10] Guo, S.S., Roche, A.F., Chumlea, W.C., Gardner, J.D. and Siervogel, R.M. 1994. The predictive values of childhood body mass index for overweight at age 35 y. *Am. J. Clin. Nutr.*, 59:810–9.

[11] Hanley, J. 1988. The robustness of the "binormal" assumptions used in fitting ROC curves. *Med. Decis. Making*, 8:197–203.

[12] Himes, J.H. and Dietz, W.H. 1994. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. The Expert Committee on Clinical Guidelines for Overweight in Adolescents Preventive Services. *Am. J. Clin. Nutr.*, 59:307–16.

[13] Kapoor, G., Aneja, Kumari and Mehta, S.C. 1991. Triceps skinfold thickness in adolescents. *Ind. J. Med. Res.*, 94:281–5.

[14] Kraemer, H.C., Berkowitz, R.I. and Hammer, L.D. 1990. Methodological difficulties in studies of obesity. I. Measurement issues. *Ann. Behav. Med.*, 12:112–8.

[15] McCarthy, H.D., Cole, T.J., Fry, T., Jebb, S.A. and Prentice, A.M. 2006. Body fat reference curves for children. *Int. J. Obesity*, 30:598–602.

[16] Malina, R.M. and Katzmarzyk, P.T. 1999. Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents. *Am. J. Clin. Nutr.*, 70:131s–6s.

[17] Mast, M.A., Sonnichsen, K., Langnase, K., Labitzke, U., Bruse, U., Preub, Muller, M.J. 2002. Inconsistencies in bioelectrical impedance and anthropometric measurements of fat mass in a field study of pre-pubertal children. *J. Nutr.*, 87:163–75.

[18] Must, A., Dallal, G.E. and Dietz, W.H. 1991. Reference data for obesity: 85th and 95th percentiles of Body mass index (wt/ht^2) and triceps skinfold thickness. *Am. J. Clin. Nutr.*, 53:839–46.

[19] National High Blood Pressure Education Program. Update on the task force report (1987) of high blood pressure in children and adolescents (September 1996): Washington, DC; US Government Printing office. *National Institute of Health Publication No*, 96–3790:1–24.

[20] Rolland Cachera, M.F., Deheeger, M., Avons, P., Guillood-Bataille, M., Patois, E. and Sempr, M. 1987. Tracking the development of adiposity from one month of age to adulthood. *Ann. Human Biol.*, 14:219–29.

[21] Sardinha, L.B., Going, S.B., Teixeira, P.J. and Lohman, T.G. 1999. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness and arm girth for obesity screening in children and adolescents. *Am. J. Clin. Nutr.*, 70:1090s–5s.

[22] Sarria, A., Garcia-Llop, L.A., Moreno, L.A., Fleta, J., Morellon, M.P. and Bueno, M. 1998. Skinfold thickness measurement are better predictors of body fat percentage than body mass index in male Spanish children and adolescent. *Eur. J. Clin. Nutr.*, 52:573–6.

[23] Serdula, M.K., Ivery, D., Coates, R.J., Freedman, D.S., Williamson, D.F. and Byers, T. 1993. Do obese children become obese adults? A review of the literature. *Prev. Med.*, 22:167–77.

[24] Siervogel, R.M., Roche, A.F., Guo, S., Mukherjee, D. and Chumlea, W.C. 1991. Patterns of change in weight/stature^2 from 2 to 18 yrs: finding from long term serial data for children in the Fels longitudinal growth study. *Int. J. Obes.*, 15:479–85.

[25] Smoak, C.G., Burke, G.L., Harsha, D.W., Srinivason, S.R. and Berenson, G.S. 1987. Relationship of obesity of clustering of cardiovascular risk factors in children and young adults. *Am. J. Epidemiol.*, 125:364–72.

[26] Vijayaraghavan, K., Singh, D. and Swaminathan, M.C. 1974. Arm circumference and fatfold at triceps in well nourished Indian school children. *Ind. J. Med. Res.*, 62:994–1001.

[27] Webber, L.S., Harsha, D.W., Philips, G.T., Srinivason, S.R., Simpson, J.W. and Berenson, G.S. 1991. Cardiovascular risk factors in Hispanic, white and black children: Brooks Country and Bogalusa Heart Studies. *Am. J. Epidemiol.*, 133:704–14.

[28] World Health Organization. 1983. Measuring changes in nutritional status. Guidelines for assessing the nutritional impact of feeding programmes for vulnerable groups. WHO, Geneva, 63–101.

[29] Zweig, M.H. and Campbell, G. 1993. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. *Clin. Chem.*, 39:561–77.