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Contribution of Different Anthropometric Measures to BMI towards Assessing Overweight and Obesity of (6-10Year) Children in Kolkata, India

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KEYWORDS Body Mass Index (BMI). Weight-for-Age. Height-for-Age. ROC Curve

ABSTRACT Childhood obesity is emerging as one of the major health problems in India, especially in the urban India. A sample survey has recently been carried out in which 5218 children of classes I to IV were randomly drawn from 20 different schools in Kolkata. The Body Mass Index (BMI), Weight-for-Age Z-score (WAZ), Height-for-Age Z-score (HAZ) and various skinfold and body circumference measures are taken to assess the nutritional status of these children. In this paper, the researchers make an effort to find the reliability and validity of other anthropometric measures taking BMI measure as standard. The validity of WAZ percentiles to measure overweight and obesity compared to BMI percentiles has been found to be quite high (90% or more) and higher than other anthropometric measures. The validity increases as percentiles increase, whereas sensitivity decreases as percentiles increase. The sensitivity for WAZ at 99.9 percentile is only forty-four percent. The specificities supersede all these values. The values of specificity are found to be ninety-six percent or more and it has an increasing trend with the percentiles. The researchers have also found from ROC Curves that, apart from the combined variables, Mid-Upper-Arm-Circumference (MUAC) explains BMI best.

INTRODUCTION

Obesity has an increasing trend all over the world and is becoming a major threat to health of human beings (Vide OECD 2011; Lien et al. 2010; Cattaneo et al. 2010 for Europe; Olds et al. 2010 for Australia; Kovalskys et al. 2011 for Argentina; de Onis 2010 for Asia and Africa). The children are also becoming part of this awesome trend. The worldwide prevalence of overweight and obesity of preschool children has risen sixty percent from 1990 to 2010. It was 4.2 percent in 1990 and became 6.7 percent in 2010 (de Onis et al. 2010). The increase in the prevalence of overweight and obesity in children and adolescents has been observed in both developed and developing countries (Ng et al. 2014) and also in rural areas (Ranjani et al. 2016). Obesity rate is usually more in adults than in children. But in some countries rate of increase is more among children than among adults (Popkin et al. 2006).

Among the anthropometric measures, Body Mass Index (BMI) is considered to be the best and widely used method of finding whether a person is overweight, obese or normal. It is also an effective and easy way to determine the nutritional status. To compute BMI, we need to measure only the height (in meters) and weight (in kilograms) of a person. The following formula is used to determine BMI.

$$\text{BMI} = \frac{\text{Weight in Kilogram}}{(\text{Height in Meter})^2}$$

A person is regarded as normal if BMI of the person is in between 18.5 and 24.9. If it is less than 18.5 then the person is underweight and if it is in between 25.0 and 29.9 then the person is overweight. A person is regarded as obese if BMI is 30.0 or higher.[1]

To compare between different methods, we need to have a reference method. The reference method should usually be the most efficient method. However, it is impossible to tell which measure is the most efficient.

It has been seen that BMI and body fat level are strongly correlated. But, BMI is not the most trusted measure of body fat level. Other than anthropometric field methods, there are some sophisticated methods to measure the body fat level. These are Bioelectric Impedance Analyser (BIA), Underwater Weighing (Densitometry), Air-Displacement Plethysmography, Dilution Method (Hydrometry), Dual Energy X-ray Absorptiometry (DEXA), Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) (Hu 2008). In BIA, safe electric current is passed through body. The principle of measurement is that body fat put more resistance to electricity. In underwater weighing the principle that fat is less dense than water is used. Similarly, other techniques also use some principle. Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) are the most accurate measures but very expensive. These techniques are used to validate body measurement techniques (Hu 2008). Since, these measures are not available with us we take BMI as standard.

For measuring BMI of children, we should take age and sex also into consideration, because, during childhood, height and weight increase rapidly with age and it is different for boys and girls. For a given height and age, the higher is the weight, the higher is the body fat on the average[2]. Waist Circumference (WC), Waist-to-Hip Ratio, Skinfold Thicknesses (example, Triceps and calf skinfold measures) etc., are useful to assess overweight and obesity. These are called "field methods" (Yeung and Hui 2010). Body fat level is closely related to each of these measures. However, the most commonly used field measures for estimating body fatness are skinfold measurements and bioelectrical impedance analyzers. The skinfold procedure uses triceps and calf skinfold measures to predict body fatness using formula. All the measures as discussed above are also positively interrelated. In this paper the researchers try to compare the efficacies of these measures taking BMI as standard.

METHODOLOGY

Among the different child growth references available in the literature, World Health Organization (WHO) Charts (http://www.who.int/childgrowth/en/) top the list. Among other references, UK90 (Wright et al. 2002), IOTF (Li et al. 2016) and Centers for Disease Control (CDC) Charts (Kuczmarski et al. 2002) may be mentioned. Age-sex specific cut-off points have been recommended by the International Obesity Task Force (IOTF) for overweight and obese children and adolescents (Cole et al. 2000). None of these are however full proof. Wang and Chen (2012) specifies growth reference cut-offs for children as prescribed by WHO (1995). For infants and children of age < 10 years, the Weight-for-age Z-score (WHZ) cut-off is taken as 2 for overweight. For adolescents (age >= 10) the BMI for age cut-off is 85th percentile for overweight. For obese also the same cut-off point is taken, but it is augmented with Triceps and subscapular skinfold thickness-for-age > =90th percentiles.

The standard practice is to take cut-off Z-values as 2 for overweight and 3 for obese, that is, if the Z-value, corresponding to the given BMI using the formula as prescribed by WHO (2007) taking due consideration of age (in month) and sex, is 2 or more then we say that the child is overweight and if it is 3 or more then we say that the child is obese (de Onis et al. 2010)[3]. Percentiles as cut offs may also be taken. There is a recent practice of taking eighty-five and ninety-five percentiles as cut offs for defining overweight and obese (WHO 2006; Khadilkar and Khadilkar 2011). But the two sets of norms are quite different. The cut-off point Z-value as 3 means approximately 99.9 percentile whereas the cut-off point 2 means 97.7 percentile. Both the cut-offs are much above the ninety-five percentiles. The researchers shall, however, see the situation taking percentiles as cut-off points. The percentiles are however chosen so that these correspond to the Z-value cut-off points 2 and 3 approximately.

Indian Statistical Institute in 2013 took up a project to see the extent and causes of childhood obesity in Kolkata, India. It took about two years to complete. The target population is the 6-10 year children who are studying in some schools situated in Kolkata. The survey was based on a sample of children properly drawn by taking multistage stratified sampling. In the first phase some schools were selected and a listing of all the students is made noting name, class, section, age, sex, height, weight, expenditure class and family socio-demographic conditions. Besides height and weight, other measures such as Waist Circumference (WC), Hip Circumference (HC) and Skinfold Thicknesses (Triceps and calf skinfold measures) were taken. The type of school, that is whether it is private or public school and the medium of instruction (mainly Bengali and English) are also noted. In the second phase, about thirty percent of the children were selected randomly and a detailed survey was carried out. The number of children in the sample in the first phase has been slightly above 5200 (5218 to be exact) in which girls and boys took almost equal share.

To determine the status of overweight and obesity of children through BMI values, one needs to know the age and sex of the children. The growth reference data for children and adolescents, that is., for children of age 5-19 years (or 61-228 months) have been revised in 2007 from National Center for Health Statistics (NCHS) reference data of 1977 by augmenting some new data of WHO. These are available in the WHO website http://www.who.int/childgrowth/en/. It contains BMI for age (5-19 years), Weight for age (5-10 years) and Height for age (5-19 years) data by month separately for boys and girls. However, we need the reference period data for 6-10 years (72-131 months) only. The web site also gives the formula for finding percentile points and Z-values given age in month.[4]

The formula for getting percentile is

$P_{100\alpha} = M(1+L^{*}S^{*}Z_{\alpha})^{(1/L)}$,

where $P_{100\alpha}$ is the 100_{α} percentile and Z_{α} is the standard normal equivalent deviate at α defined as the point for which the area of the standard normal distribution from $-\infty$ to Z_{α} is α. 100α is usually written as percentage like eighty-five percent, ninety-five percent, etc. The formula for Z-value is

$$Z = \frac{(y/M)^{L-1}}{SL}$$

Where, y represents the BMI value of the child. L, M and S values, which are specific to age in month and sex, are supplied by WHO (2007).

Table 1 gives the equivalent Z-values corresponding to the given selected percentiles along with the observed percentage of children in the category. It is clear from the table that BMI eighty-five percentile is close to the Z-value 1. So there is some justification of taking cut off value eighty-five percentile for overweight. However, BMI ninety-five percentile corresponds to the Z-value only 1.6445. It is no way near to 2. Percentile value corresponding to Z = 2 is 97.725. The researchers have thus taken 97.5 percentile (which corresponds to 1.9600) to designate obese children, because 97.5 percentile corresponds to Z-value which is usually taken as the significance level (5%, if taken two-tail) in most of the statistical tests. Lastly, Z=3 may be taken for cut-off value for most obese children. BMI 99.9 percentile corresponds to Z-value 3.0902, which is very close to Z=3. In their sample, the researchers have found 31.7 percent, 16.7 percent and 3.8 percent children as Overweight, Obese and Very Obese respectively[5]. The researchers have employed the same classifications for Weight-for-Age (WFA) and Height-for-Age (HFA).

The researchers have converted the BMI, WFA and HFA into binary values and computed the cross classification tables to see how effective is WFA and HFA percentile groups to predict BMI percentile groups. However, this can only be done separately for WFA and HFA. To see the joint effect of WFA and HFA on BMI we need to carry out Binary logistic regression of BMI binary values on the WFA and HFA. WFA and HFA need not be binary while carrying out the Binary logistic regression. This is the advantage of taking Binary logistic regression. The Binary logistic regression also allows us to take more than two repressors, so we can add the values of Waist Circumference (WC), Hip Cir-

Table 1: Z-values corresponding to some percentiles along with the observed percentage of children

WHO reference population	*The present sample*	
	Z-value (greater than)	*Percentage of children*
BMIZ overweight (84.1percentile)	1	32.5
BMI 85 percentile	1.0364	31.7 (Overwt)
BMI 90 percentile	1.2816	27.6
BMI 95 percentile	1.6449	21.3 (Obese)
BMI 97.5 percentile	1.9600	16.7 (Obese)
BMIZ obese (97.725 percentile)	2	16.3
BMI 99 percentile	2.3263	11.3
BMI 99.9 percentile	3.0902	3.8 (Very Obese)
BMIZ very obese (99.865 percentile)	3	4.3

BMI 97 percentile ad Z = 1.8808, BMI 97.7 percentilead Z = 1.9954 cumference (HC) and Skinfold Thicknesses (example, Triceps and calf skinfold measures) and also other variables like type of school or medium of instruction along with WFA and HFA.

RESULTS AND DISCUSSION

The results of cross classification of BMI percentiles with WFA and HFA percentiles are given in Tables 2a, 2b and 2c. Sensitivity and Positive Productivity are found to be more for WFA percentiles. This means that WFA percentiles have more predictive power than HFA percentiles. It is also interesting to note that the predictive power does not improve when we combine WFA and HFA percentiles. As the percentiles increases from 85 to 97.5 and then to 99.9, the sensitivity decreases whereas validity increases. When predictive power towards obesity decreases and validity increases as percentile increases then it is due to the compensatory increase of predictive power of non-obesity. It is easier to predict overweight and obese among boys than among girls.

To see the effectiveness of Fitness-gram skinfold and other field methods the researchers have first carried out the Linear Probability Model to see the significance of the coefficients along with multicollinearity diagnostics. The researchers have found multicollinearity problem when they take hip and waist circumferences along with waist by hip ratio. Waist circumference is thus dropped. The calf skinfold measure is also dropped since it is not significant enough. Taking the final set of regressors, they carried out logistic regression. The results are given in Table 3. The regression results show that each of the Fitness-gram measure has significant effect on BMI. As usual, it is more difficult to identify obese persons at the higher percentiles.

The researchers have performed logistic regression of BMI percentile binary values on each of the field measures individually (Table 4). MUAC has the maximum values of Sensitivity and Positive Productivity compared to those of other measures at BMI eighty-five percent and 97.5 percent. It may be noted that many authorsfound the performance of MUAC to be very good (Brito et al. 2016; Mogendi et al. 2015 etc.). Triceps skinfold and Hip circumference measures overpowered it at 99.9 percent. Head circumference and Waist by Hip circumferences do not add much. Hip circumference is thus seen to be a good measure for identification of very obese children.

Next the researchers turn to the socio-demographic variables and carry out the logistic regression of BMI binary values on the socio-demographic variables. The results are not shown here. Surprisingly, Type of school, Mother's occupation and Education, Father's Occupation and Household size do not have much influence on BMI percentile binary values. Father's education is found to be significant for

Table 2a: Cross classifications of BMI 85 percentile with WFA 85 percentile and HFA 85 percentile

BMI_85	*WFA_85*			*HFA_85*			*WFA_85 & HFA_85**		
	0	*1*	*Total*	*0*	*1*	*Total*	*0*	*1*	*Total*
Girls									
0	1857	35	1892	1910	73	1983	1857	35	1892
1	227	509	736	646	109	755	227	509	736
Total	2084	544	2628	2556	182	2738	2084	544	2628
Sensitivity	69.1%		14.4%		69.1%				
Positive Predictivity	93.6%		59.9%		93.6%				
Specificity	96.6%		96.3%		96.6%				
Validity	90.0%		73.7%		90.0%				
Boys									
0	1460	42	1502	1471	93	1564	1460	42	1502
1	217	666	883	747	167	914	217	666	883
Total	1677	708	2385	2218	260	2478	1677	708	2385
Sensitivity	75.4%		18.2%		75.4%				
Positive Predictivity	94.1%		64.2%		94.1%				
Specificity	97.2%		94.0%		97.2%				
Validity	89.1%		66.1%		89.1%				

*Found from Logistic Regression. 0: Below 85 percentile, 1: 85 percentile or more

Table 2b: Cross classifications of BMI 97.5 percentile with WFA 97.5 percentile and HFA 97.5 percentile

BMI_97.5	*WFA_97.5*			*HFA_97.5*			*WFA_97.5 & HFA_97.5**		
	0	*1*	*Total*	*0*	*1*	*Total*	*0*	*1*	*Total*
Girls									
0	2282	16	2298	2383	17	2400	2282	16	2298
1	146	184	330	326	12	338	146	184	330
Total	2428	200	2628	2709	29	2738	2428	200	2628
Sensitivity	55.8%		03.6%		55.8%				
Positive Predictivity	92.0%		41.4%		92.0%				
Specificity	99.3%		95.1%		99.3%				
Validity	93.8%		83.8%		93.8%				
Boys									
0	1824	29	1853	1911	24	1935	1824	29	1853
1	186	346	532	515	28	543	186	346	532
Total	2010	375	2385	2426	52	2478	2010	375	2385
Sensitivity	65.0%		05.2 %		65.0%				
Positive Predictivity	92.3 %		53.8 %		92.3 %				
Specificity	98.4 %		98.8 %		98.4 %				
Validity	91.0%		78.2%		91.0%				

*Found from Logistic Regression. 0: Below 97.5 percentile, 1: 97.5 percentile or more

Table 2c: Cross classifications of BMI 99.9 percentile with WFA 99.9 percentile and HFA 99.9 percentile

BMI_99.9	*WFA_99.9*			*HFA_99.9*			*WFA_99.9 & HFA_99.9**		
	0	*1*	*Total*	*0*	*1*	*Total*	*0*	*1*	*Total*
Girls									
0	2585	9	2594	2703	1	2704	2585	9	2594
1	19	15	34	34	0	34	19	15	34
Total	2604	24	2628	2737	1	2738	2604	24	2628
Sensitivity	44.1%			0%			44.1%		
Positive Predictivity	62.5%			0%			62.5%		
Specificity	99.7%			100.0%			99.7%		
Validity	98.9%			98.7%			98.9%		
Boys									
0	2208	10	2218	2302	8	2310	2211	7	2218
1	86	81	167	166	2	168	88	79	167
Total	2294	91	2385	2468	10	2478	2299	86	2385
Sensitivity	48.5%			01.2%			47.3%		
Positive Predictivity	89.0%			20.0%			91.9%		
Specificity	99.5%			99.7%			99.7%		
Validity	96.0%			93.0%			96.0%		

*Found from Logistic Regression. 0: Below 99.9 percentile, 1: 99.9 percentile or more.

daughters for lower percentiles. Medium of Instruction, Religion and Mother tongue have been found to have the most significant effect on BMI binary values. The researchers thus pick Medium of Instruction, Religion and Mother tongue from this set of regressors.

The above discussions give us a clear picture about the variables which are important in determining overweight, obese and very obese children taking the respective BMI percentile binary values as standard. At the final stage the researchers thus regress the BMI percentile binary values on the selected important socio-demographic variables and other field measures (Table 5). Head circumference, Religion and Educational level of Father are not so important in determining obese and very obese children. In fact, for determining very obese children, many of the variables become irrelevant. To summarize, all the selected variables are found to be important at least in one of the three percentile levels.

Finally, the researchers have found the Receiver Operating Characteristic (ROC) curves (ROC Curves)[6] for each of these variables. The

Table 3: Result of logistic regression of BMI percentiles with MUAC, triceps skinfold, hip circumference, head circumference and waist by hip ratio

	BMI 85 percentile		*BMI 97.5 percentile*		*BMI 99.9 percentile*	
	Coeff.	*Sig.*	*Coeff.*	*Sig.*	*Coeff.*	*Sig.*
			Girls			
MUAC	.598	.000	.412	.000	.175	.218
Tricepsknfld	.121	.000	.077	.011	.089	.191
Hip	.135	.000	.159	.000	.199	.000
Head Circumf.	-.088	.014	.007	.872	-.088	.364
Waist-By-Hip	10.325	.000	1.814	.438	18.999	.000
Constant	-28.881	.000	-25.096	.000	-38.242	.000
Sensitivity	76.9	56.0	20.6			
Positive Predictivity	81.9	74.0	70.0			
Specificity	93.5	97.2	99.9			
Validity	88.9	92.2	98.9			
			Boys			
MUAC	.509	.000	.381	.000	.335	.000
Tricepsknfld	.279	.000	.198	.000	.104	.003
Hip	.076	.001	.105	.000	.077	.001
Head Circumf.	-.019	.657	-.135	.000	-.035	.430
Waist-By-Hip	3.995	.079	7.261	.002	7.720	.017
Constant	-21.284	.000	-18.808	.000	-22.372	.000
Sensitivity	84.0	75.0	28.6			
Positive Predictivity	88.2	80.8	57.1			
Specificity	93.4	95.0	98.4			
Validity	89.9	90.6	93.7			

Table 4: Result of logistic regression of BMI percentiles with MUAC, triceps skinfold, hip circumference, head circumference and waist by hip ratio when regressed individually

	BMI 85%		*BMI 97.5%*		*BMI 99.9%*	
Fitness measure	*Sensitivity*	*Positive predictivity*	*Sensitivity*	*Positive predictivity*	*Sensitivity*	*Positive predictivity*
			Girls			
MUAC	75.3	82.0	53.1	72.2	2.9	20.0
Triceps_sknfld	64.6	75.9	34.4	61.1	2.9	50.0
Hip	68.8	78.7	50.6	71.4	11.8	50.0
Head Circumf.	19.9	62.8	3.9	44.8	0.0	0.0
WaistByHip	5.0	57.6	0.0	0.0	0.0	0.0
			Boys			
MUAC	82.7	86.9	71.1	79.9	26.8	63.4
Triceps_sknfld	81.1	85.7	65.2	76.6	17.3	50.0
Hip	76.9	84.5	64.5	76.9	26.2	62.86
Head Circumf.	39.5	66.1	6.4	50.7	0.5	10.0
WaistByHip	2.4	57.9	0.2	16.7	0.0	0.0

readymade package of SPSS gives ROC curve separately for each variable. To get the effect of the combination of variables, one has to run the logistic regression, get the predicted probability and then use it as a separate variable for prediction.

The ROC Curve for BMI 99.9 percentile on the selected determinants separately for males and females are shown in Figure 1 as an illustration. This can be seen also from the logistic regressions of BMI binary values on each of the determining variables.

Table 5: Result of logistic regression of BMI percentiles on the important determinants

	BMI 85 percentile		*BMI 97.5 percentile*		*BMI 99.9 percentile*	
	Coeff.	*Sig.*	*Coeff.*	*Sig.*	*Coeff.*	*Sig.*
			Girls			
WFA	2.065	.000	2.212	.000	2.431	.016
EDU_Father	.192	.256	.440	.038	.008	.985
MUAC	.485	.000	.260	.001	.090	.541
Triceps_sknfld	.169	.000	.123	.001	.094	.177
Hip	.039	.105	.012	.676	.152	.004
Head_crcmfrnce	-.109	.006	-.039	.421	-.075	.399
WaistByHip	7.935	.001	-2.344	.243	17.511	.004
Religion	1.016	.007	.682	.153	16.130	.993
Mother tongue	.708	.022	.080	.845	.604	.587
Medium	.416	.027	.033	.885	.084	.855
Constant	-23.995	.000	-13.250	.000	-57.656	.975
Sensitivity	88.9		80.6		77.8	
Positive Predictivity	79.7		77.7		20.6	
Specificity	96.2		97.4		99.9	
Validity	91.6		94.9		98.9	
			Boys			
WFA	2.189	.000	1.921	.000	1.858	.000
EDU_Father	-.081	.641	-.196	.309	.100	.636
MUAC	.439	.000	.210	.001	.240	.001
Triceps_sknfld	.294	.000	.183	.000	.062	.088
Hip	-.028	.286	.022	.382	.036	.131
Head_crcmfrnce	-.037	.421	-.156	.000	-.030	.506
WaistByHip	1.191	.645	7.546	.006	5.157	.108
Religion	.379	.326	.229	.608	.339	.536
Mother tongue	.258	.255	.232	.381	.224	.479
Medium	.532	.010	-.238	.275	-.190	.410
Constant	-15.566	.000	-14.250	.000	-21.474	.000
Sensitivity	91.1		84.7		57.1	
Positive Predictivity	85.9		83.3		24.0	
Specificity	95.1		95.8		98.7	
Validity	91.7		93.1		93.6	

CONCLUSION

In this paper the researchers have tried to see the performances of field measures of nutrition and the socio-demographic features of (6-10) year school going children on the classification of overweight, obese and very obese children, where classifications are done by taking BMI 85, 97.5 and 99.9 percentiles, being designated as overweight, obese and very obese respectively. It was presumed that weight for age and height for age would perform better than other variables in determining the nutritional categories. But MUAC has been seen to perform best. The variables, which have significant influence on BMI classifications, are MUAC, Weight for Age, Triceps Skinfold, Hip Circumference, Religion, Mother Tongue, Education of Father, Head Circumference and Waist by Hip Ratio of Circumferences. The variables, which do not have much influences on the BMI classifications, are Type of School, Household size, Per Capita Expenditure, Parents Occupations and most surprisingly, Mother's Education.

RECOMMENDATIONS

The analysis was carried out for a sample of about 5200 School going children of Kolkata, which is a metropolitan city in India. It is thus necessary to carry out similar exercises in other cities and villages in India to arrive at a decisive conclusion on the best determinants of overweight, obese and very obese children taking BMI classifications as standard.

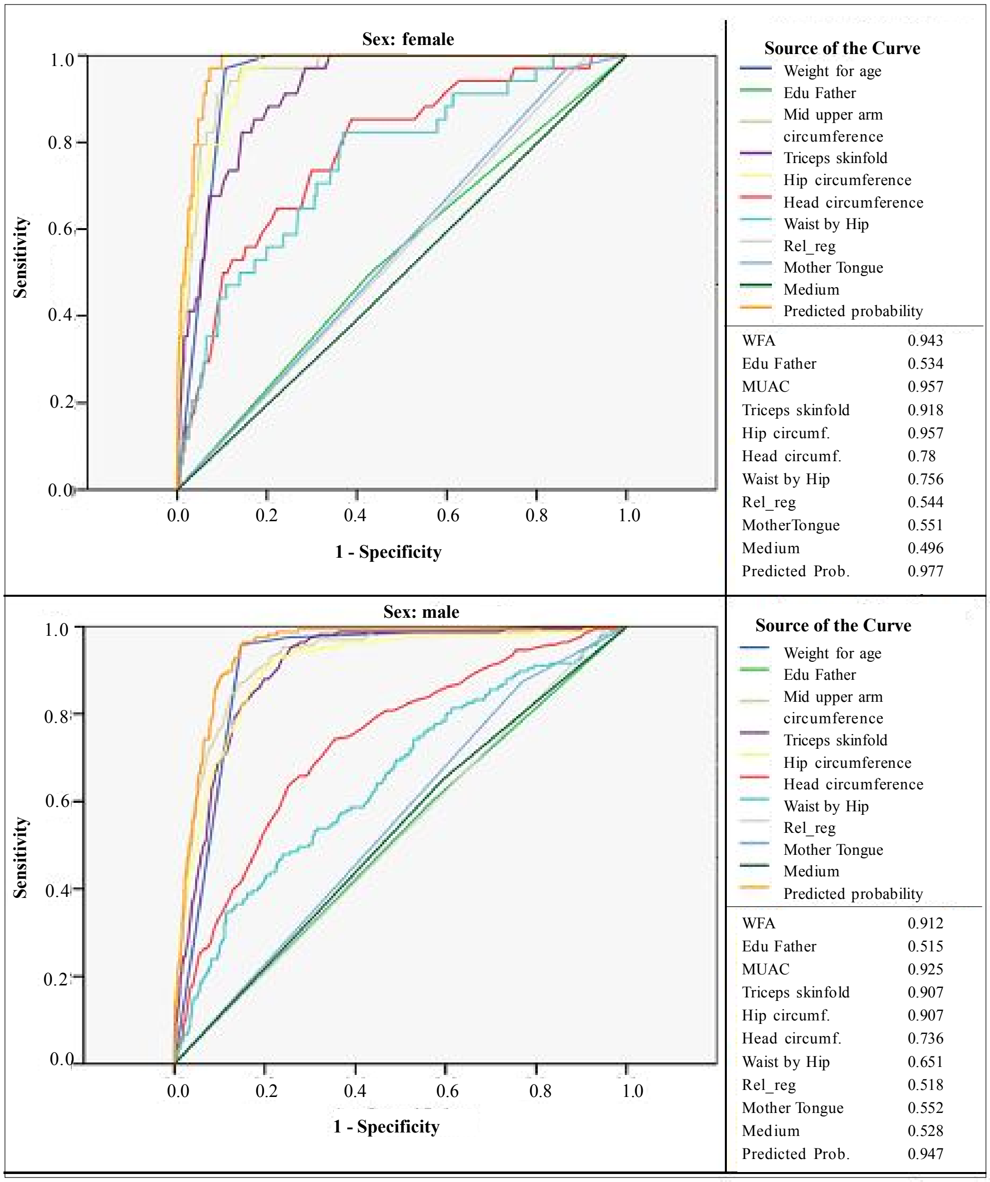

Fig. 1. ROC curve for BMI 99.9 percentile on the selected determinants

When we want to identify overweight and obese children, it seems unnecessary to use validity and specificity values to see how good the fit is. This is because we are not bothered about the children who are normal, that is, who are not overweight or obese. The wrongly diagnosed cases are the marginal cases, that is, those who are nearing to become overweight. Of course there will be some children, who are overweight but diagnosed as normal. The goal should be to maximize the correct prediction. In other words, we should maximise sensitivity and positive productivity. Since both cannot be maximized simultaneously, we can maximise a convex combination of these two to select a cut-off point.

NOTES

1 It has been seen that BMI and body fat level are strongly correlated. But, BMI is not the most trusted measure of body fat level.

2 Percentage of body fat of children may be calculated from BMI using the following formula (Deurenberg et al. 1991):
Child body fat % = (1.51 × BMI)- (0.70 × age) – (3.6 × sex) +1.4.
In the above formula age is taken in completed year and sex is taken as 1 for males and 0 for females.

3 de Onis et al. (2010) defined overweight and obesity cut-off values as 2SDs and 3SDs, respectively, from the World Health Organization growth standard median. Being "at risk of overweight" cut-off was defined as the value > 1SD and <= 2SD. In another article de Onis et al. (2013) gave WHO (2007), CDC (2000) and Spanish (2008) reference criteria. According to him WHO (2007) defines a child to be overweight if the BMI z-value is > 1 and <= 2 and obese if BMI z-value is > 2.

4 Since the period of 6-10 years is not large we thought it is possible to get the reference values simply by applying formula. Thus we regressed the reference data on age, age-square and age-cube. There was severe multicollinearity problem and some variables were automatically deleted from the set of regressors. We chose to take age and age-square only and it gave excellent result with R^2 value close to 1 giving the predicted value as accurate as two decimal places. The result for boys is as follows.
P95_Boys = 17.810057-0.0289316 *Age_in_ Month + 0.000408795 *Age_in_Month^2.
P85_Boys = 17.066159-0.0274753 *Age_in_ Month + 0.000333542 *Age_in_Month^2.
For girls, however, this formulation did not work. We had to take Age_in_Month and Ln(Age_ in_ Month) instead of Age_in_Month and Age_in_ Month^2, where Ln(Age_in_Month) is the natural logarithm of Age_in_Month. The formulas are as follows.
P85_Girls=46.973166 + 0.142456*Age_in_Month – 9.383813* Ln(Age_in_Month)
P95_Girls=48.805289 + 0.162243*Age_in_Month – 9.845558* Ln(Age_in_Month)
These equations are valid in the range of 6-10 year children only.

5 Needless to say that Overweight includes Obese and Very Obese, whereas Obese includes Very Obese.

6 It is the curve which plots True Positive Rate (Sensitivity) against False Positive Rate (1-Specificity). This curve gives the performance of the classifications at different cut-off points of the cumulative probability. Area under the curve summarizes the relation between two variables. Higher is the area under the curve better is the overall predictive power of the explanatory variable.

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