Original Article

Body Mass Index as a Measure of Percentage Body Fat Prediction and Excess Adiposity Diagnosis among Iranian Adolescents

Hanieh-Sadat Ejtahed MSc[1], Golaleh Asghari MSc[1], Parvin Mirmiran PhD•[2], Somayeh Hosseinpour-Niazi MSc[1], Roya Sherafat-KazemZadeh PhD[1], Fereidoun Azizi MD[1]

Abstract

Background: Although various anthropometric methods are available for assessing body composition, these have not been compared in Iranian adolescents. The objective of the present study was to compare body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), waist to height ratio (WHtR) and sum of four skinfolds as predictors of percentage body fat (PBF) and diagnosis of excess adiposity in Iranian adolescents.

Methods: In this cross-sectional study, all anthropometric measurements were made in133 adolescents (65 boys and 68 girls), aged 10–18 years.PBF was determined using the bioelectrical impedance analysis method. Linear regression and receiver operating characteristic (ROC) analysis were used to analyze the data. Potential covariates including sex, age, and pubertal stage were adjusted.

Results: R^2_{adj} of models for BMI, WC, WHR, WHtR, and skinfolds were 0.67, 0.56, 0.19, 0.56, and 0.56, respectively ($P < 0.001$). The AUC value of BMI to differentiate between normal and obese adolescents was 0.92 ($P < 0.001$). The AUC of BMI was significantly higher than those of WC, WHR, and WHtR ($P < 0.05$).

Conclusions: The performance of BMI is better than other anthropometric indices in predicting PBF and diagnosing excess adiposity in Iranian adolescents.

Keywords: adolescents, body mass index, percentage body fat

Cite this article as: Ejtahed HS, Asghari G, Mirmiran P, Hosseinpour-Niazi S, Sherafat-KazemZadeh R, Azizi F. Body Mass Index as a Measure of Percentage Body Fat Prediction and Excess Adiposity Diagnosis among Iranian Adolescents. *Arch Iran Med*. 2014; **17(6):** 400 – 405.

Introduction

Obesity is increasing rapidly among the youth, and existing evidence shows that adolescent obesity continues into adulthood.[1,2,3] Obesity in childhood and adolescence is associated with increased risk of hypertension, cardiovascular disease, diabetes and other metabolic diseases during adulthood.[4,5] Moreover, the consequences of obesity are not only physical, but also psycho-social.[6]

Measurement of percentage body fat (PBF) is an ideal way to diagnose obesity. However, methods of percentage body fat measurement such as dual energy X-ray absorptiometry (DEXA) and underwater weighing are expensive and not readily available in all settings such as physicians' offices and for epidemiologic studies.[7] Bioelectric impedance analysis (BIA), a simple method of estimating percentage body fat, is moderately accurate in comparison to gold standard methods including DEXA.[8] In addition, BIA is appropriate for use in adolescents because it does not require exposure to radiation.[8]

Multiple anthropometric indices, including body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), waist to height ratio (WHtR) and skinfold thickness, have been used to identify adolescents at risk of obesity. Body mass index is used commonly as an indicator of the presence of overweight and obesity in adolescents, due to the ease, safety and accuracy of measurement. However, it has variable sensitivity in children and adolescents.[9] Waist circumference and WHR are predictors for central fatness and WHtR has been proposed as another simple index for abdominal obesity.[10]Skinfold thickness has long been used as an index of subcutaneous fat.[11]Nevertheless, it is not known which index is the best measure of fatness in Iranian adolescents.

Various screening tools are available for assessing body composition and identifying adolescents at risk of excess adiposity, but these have not been compared in Iranian adolescents. Furthermore, correlations between these measurements are specific to the population and cannot be extrapolated to other ethnic groups.[12,13] Therefore, the aim of the present study was to compare BMI, WC, WHR, WHtR and skinfold thickness as predictors of percentage body fat measured by BIA in Iranian adolescents. Moreover, we compared the diagnostic quality of these variables in screening adolescents at risk of excess adiposity.

Authors' affiliations: [1]Obesity Research Center, Nutrition and Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran. [2]Department of Clinical Nutrition and Dietetic, Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran. [3]Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Corresponding author and reprints: Parvin Mirmiran MD, Department of Clinical Nutrition and Dietetic, Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran. P.O. Box: 19395-4741, Tehran, I.R. Iran. Tel: +98 21 22432503, Fax: +98 21 22402463, Email: parvin.mirmiran@gmail.com, mirmiran@endocrine.ac.ir

Materials and Methods

Study design and subjects

In this cross-sectional study, a random sampling technique was used to select adolescents, aged 10–18 years from Tehran's urban population of District 13 in 2007. This study was conducted within the framework of the Tehran Lipid and Glucose Study (TLGS). Complete data were collected for 133 adolescents (65 boys and 68 girls). Participants underwent a physical examination by trained physicians to reasonably exclude any health problems. Subjects were excluded if they had a medical history of chronic disorders including cardiovascular, renal, rheumatologic and congenital diseases. Oral assent was attained from adolescents and informed written consent was obtained from the parents of adolescents before the initiation of the study. The study was conducted according to the Declaration of Helsinki and was approved by the ethical committee of the Research Institute for Endocrine Sciences (RIES), Shahid Beheshti University of Medical Sciences.

Anthropometric evaluation and pubertal assessment

Body weight was measured to the nearest 0.1 kg using a digital scale (Seca, Hamburg, Germany) with minimal clothing and without shoes. Height was measured with a measuring tape to the nearest 0.1 cm in a standing position, without shoes and with shoulders in a normal position. Body mass index was calculated as weight/height^2 (Kg/m^2). Waist circumference was measured at the narrowest level and hip circumference was measured over light clothing at the widest girth of the hip, using a flexible tape meter.[14] These measurements were recorded to the nearest 0.1 cm. Waist to hip ratio was calculated as waist circumference divided by hip circumference value and waist to height ratio was calculated as waist circumference divided by height value. The skinfold thickness of the triceps, biceps, subscapular and suprailiac areas was measured in duplicate to the nearest 1 mm with a Harpenden caliper (British Indicators, Burgess Hill, West Sussex, UK). Sites on the right side of the body were measured.[15] The triceps, biceps, subscapular and suprailiac skinfold measurements were summed up to obtain the sum of four skinfolds (SF4). All anthropometric measurements were taken by the same trained person.

All adolescents underwent a physical examination by a specialized physician to determine their pubertal stage. Pubertal development was clinically assessed on the basis of Tanner stages which defines 5 pubertal stages, based on external primary and secondary sex characteristics, including the size of breasts, changes in genitalia, and development of pubic hair.[16]

Bioelectrical impedance analysis

Percentage body fat was determined using the BIA method. Anthropometric measurements and BIA were performed on the same day and by the same technician. Bioelectrical impedance analysis was carried out with the Tanita TBF-531 bioelectrical impedance analyzer (Tanita UK Ltd., Middlesex, UK). Whole body impedance at 50 kHz was measured. Measurements were taken after at least 5 hours of overnight fasting, with an empty bladder, and after removal of any jewelry and metal accessories. Each participant was instructed to remove socks and shoes and then lie supine with arms away from the body. Alcohol was used to clean the skin where the electrode would be placed. Two electrodes were placed on the hand, one at the level of the ulnar head on the wrist and the other just behind the middle finger. On the foot, the two electrodes were attached at the level of the medial and lateral malleoli and just behind the toes.

Statistical analysis

All data were analyzed using SPSS version 15 (SPSS Inc., Chicago, USA). Data are given as mean values and standard deviations for continuous variables and frequency (percentage) for categorical variables. The normality of the distribution of variables was tested by the Kolmogorov-Smirnov test. Significant mean difference between boys and girls was compared using the independent samples *t*-test for normally distributed variables and the Mann-Whitney U test for variables not normally distributed including age, biceps skinfold and subscapular skinfold. Inter-group comparisons of categorical variables were performed using chi-square test. We selected the following potential predictors of percentage body fat for evaluation: BMI, WC, sum of skinfolds, WHR, and WHtR. Sex, age and pubertal stage are major determinants of body composition in adolescents.[17] Linear regression was used to estimate the association between PBF and the study predictor variables along with potential covariates including sex, age, and pubertal stage. We also analyzed data using similar regression models after stratifying by sex. Furthermore, using receiver operating characteristic (ROC) analysis, the ROC curves of BMI, WC, sum of skinfolds, WHR, and WHtR were drawn to show how well they could categorize adolescents into groups of obese and normal, using percentage body fat as the gold standard. Fatness levels at or above 25% in males and 30% in females are indicative of increased risk of excess adiposity in adolescents.[18] The accuracy of the indices used to identify obesity was assessed by area under curve (AUC) values. AUC is independent of prevalence of the disease and can be interpreted according to the following guidelines: non-informative/equal to chance (AUC=0.5), less accurate ($0.5 < AUC \leq 0.7$), moderately accurate ($0.7 < AUC \leq 0.9$), highly accurate ($0.9<AUC<1$), and perfect discriminatory test (AUC=1).[19]The statistical significance of differences between curves was assessed using STATA software package version 10.0 (Stata Corporation, College Station, TX, USA) according to the algorithm developed by DeLong et al.[20] Statistical significance was set at P value < 0.05.

Results

Comparison of basic characteristics between boys and girls

Table 1 represents the anthropometric measurements of 133 adolescents (65 boys and 68 girls). Of these, 20 (15%) were prepubertal (10 boys and 10 girls) and 113 (85%) were pubertal or postpubertal. There were significant differences between boys and girls in age and Tanner stages ($P < 0.05$). The boys tended to be significantly heavier than girls ($P < 0.001$) and tended to have slightly higher fat mass ($P = 0.055$) and significantly higher lean mass ($P < 0.001$) than the girls. While there was no difference in total body fat between boys and girls, percentage body fat was significantly higher in girls ($P = 0.006$).There were significant differences in BMI, WC, WHR, and WHtR between boys and girls ($P < 0.05$). Single skinfolds and their sums were not significantly different between boys and girls ($P > 0.05$).

Table 1. Characteristics of 133 adolescents.

Variables	Total (*n*=133)	Boys (*n*=65)	Girls (*n*=68)	*P*‡
Age (years)†	13.8±2.8	14.6±2.3	13.0±2.9	0.001
Weight (Kg)	58.2±18.9	67.2±18.2	49.5±15.4	< 0.001
BMI (Kg/m^2)	22.8±5.1	24.5±5.2	21.3±4.6	< 0.001
Body fat (%)	28.5±8.1	26.6±9.1	30.4±6.3	0.006
Body fat (Kg)	17.3±8.9	18.9±10.2	15.9±7.2	0.055
Lean mass (Kg)	41.1±13.2	48.9±12.6	33.6±8.7	< 0.001
Waist (cm)	75.6±12.1	81.1±11.8	70.3±9.8	< 0.001
WHR	0.81±0.06	0.82±0.07	0.79±0.06	0.002
WHtR	0.48±0.06	0.49±0.07	0.46±0.05	0.01
SF4 (mm)*	73.9±31.4	75.8±34.0	72.1±28.7	0.495
Biceps skinfold (mm)	13.9±7.8	14.1±8.6	13.6±7.1	0.935
Triceps skinfold (mm)	20.2±9.1	20.7±10.2	19.7±8.1	0.549
Suprailiac skinfold (mm)	19.9±9.7	20.7±11.4	19.1±7.5	0.334
Subscapular skinfold (mm)	20.0±10.3	20.3±10.6	19.7±10.1	0.692
Tanner stages †				
1	20 (15.0)	10 (15.4)	10 (14.7)	
2	16 (12.1)	9 (13.8)	7 (10.3)	
3	27 (20.3)	10 (15.4)	17 (25.0)	0.018
4	18 (13.5)	15 (23.1)	3 (4.4)	
5	52 (39.1)	21 (32.3)	31 (45.6)	

*Sum of biceps, triceps, suprailiac and subscapular skinfolds.† Mean ± SD for continuous variables and number (percentage) for qualitative variable. ‡Using independent samples *t*-test except for age, biceps skinfold, and subscapular skinfold using Mann-Whitney U test and Tanner stages using Chi-square.

Table 2. Predictors of body fat percent in adolescents.

Variables	Regression coefficients			*P*-value	Adjusted R^2
	Unstandardized	SE	Standardized(Beta)		
BMI					
Model 1*	0.97	0.11	0.61	< 0.001	0.37
Model 2†	1.42	0.09	0.90	< 0.001	0.67
Waist					
Model 1*	0.32	0.05	0.49	< 0.001	0.23
Model 2†	0.56	0.05	0.84	< 0.001	0.56
SF4 ‡					
Model 1*	0.18	0.02	0.70	< 0.001	0.48
Model 2†	0.18	0.01	0.72	< 0.001	0.56
WHR					
Model 1*	3.81	1.05	0.30	< 0.001	0.08
Model 2†	5.20	1.06	0.41	< 0.001	0.19
WHtR					
Model 1*	8.40	0.86	0.65	< 0.001	0.41
Model 2†	9.53	0.78	0.73	< 0.001	0.56

* Unadjusted † Adjusted for sex, age and tanner stage ‡ Sum of biceps, triceps, suprailiac and subscapular skinfolds.

Comparison of BMI, WC, WHR, WHtR and Skinfolds as an estimate of percentage body fat

The regression models with PBF as a dependent variable are presented in Table 2. PBF was first regressed for BMI alone. Results indicated that BMI was significantly associated with PBF ($P < 0.001$), with BMI accounting for approximately 37% of between-subject variance in fatness. Sex, age and Tanner stage were next added to the multiple regression models as covariates. They added significantly to the model ($R^2_{adj} = 0.67$).

Waist circumference explained approximately 56% of between-subject variance in fatness after adjusting for sex, age, and pubertal stage ($P < 0.001$).Sum of 4 skinfolds was significantly associated with PBF, explaining 48% of the variance. When sex, age and Tanner stage were added as covariates in a regression analysis, R^2_{adj} increased substantially to 0.56 ($P < 0.001$).

Waist to hip ratio explained only 8% of between-subject variance in PBF. The model variance increased to 19% with the addition of sex, age and Tanner stage to model ($P < 0.001$). Waist to height ratio was significantly associated with PBF, explaining 41% of the variance ($P < 0.001$). A significant effect of adding sex, age, and pubertal stage to the model was observed ($R^2_{adj}= 0.56$, $P < 0.001$).

The results of data analysis after stratifying by sex showed that BMI could explain more between-subject variance in fatness in boys than in girls ($R^2_{adj} = 0.70$ and 0.67 for boys and girls, respectively, adjusted for age and pubertal stage). When boys and girls were considered separately, R^2_{adj} of models revealed that prediction of PBF by WC, SF4, WHR, and WHtR was better in boys than in girls ($P< 0.001$) (Data not shown).

Diagnostic quality of BMI, WC, WHR, WHtR and Skinfolds in screening excess adiposity

Among the adolescents, 76 (57.1%) were obese (29.3% boys and 27.8% girls) and 57 (42.9%) were normal (19.5% boys and 23.3% girls). There was no significant difference between boys and girls in obesity distribution defined by PBF ($P = 0.515$).Receiver operating characteristic curve was applied to determine the ability of BMI, WC, sum of skinfolds, WHR, and WHtR as discrimination tools for obesity in adolescents, and the global accuracy of these variables to define obesity were assessed by AUC (Table 3).

Table 3. Areas under ROC curve of BMI, WC, SF4, WHR, and WHtR for diagnosing obesity defined by percentage body fat.

Variables*	Area under the curve	SE	*P*	95% Confidence Interval	
				Lower	Upper
BMI	0.916	0.025	< 0.001	0.867	0.965
WC	0.881	0.030	< 0.001	0.822	0.939
SF4	0.885	0.030	< 0.001	0.825	0.944
WHR	0.739	0.044	< 0.001	0.653	0.826
WHtR	0.880	0.031	< 0.001	0.820	0.940

BMI = body mass index, WC = waist circumference, SF4 = sum of biceps, triceps, suprailiac and subscapular skinfolds, WHR = waist to hip ratio, WHtR = waist to height ratio *Adjusted for sex, age, and pubertal stage.

The AUC value from the analysis using BMI to differentiate between the normal and obese adolescents was 0.92($P < 0.001$). The AUC values of WC, SF4, and WHtR in identifying excess adiposity were 0.88for all ($P < 0.001$).The AUC of BMI was significantly higher than WC, WHR, and WHtR ($P < 0.05$); however, no statistically significant difference was observed between BMI and SF4 ($P = 0.247$).The accuracy of WHR to define obesity was lower than 0.8 ($P < 0.001$).

Discussion

This study is of practical importance for routine clinical evaluation of adolescent body composition. Body mass index was better than other factors interms of predicting PBF. Our results showed that BMI, WC, SF4, and WHtR provided higher AUC values than WHR index for adolescents after controlling for sex, age and pubertal stage. Overall, the AUC value of 0.92 for BMI indicates that 92% of the time, a randomly chosen adolescent from the excess adiposity group will have higher BMI than a randomly chosen adolescent from the normal-fat group. Area under curve values for WC, SF4, and WHtR were greater than 0.8, indicating that the global accuracy of these indices was good and their differentiation was moderately accurate. The results indicated that WHR differentiated only 74% of subjects correctly, which is fairly good.

This study contributes to the current body of knowledge showing the superiority of BMI over other anthropometric indices in prediction of obesity among adolescents.[21–25] Comparison of these results with previous studies is difficult due to differences in sample size, methods of body fat measurement, age range of participants, statistical analysis and criteria of excess adiposity. Of the many studies of anthropometric indices as predictors of body fatness in adolescents, some used skinfold-derived body fat as the gold standard and others used PBF measured by DEXA or BIA.

Some studies support the use of BMI as a measure to predict adiposity among adolescents.[21–25] However, validation studies in different populations are needed.[21] Ellis et al., concluded that BMI can provide a general description of adiposity in healthy pediatric population, but it is a poor predictor of adiposity for the individual child.[26] On the contrary, in a longitudinal study, Demerath et al., concluded that BMI changes may not accurately reflect changes in adiposity in adolescents over time, especially among boys and children of lower BMI.[27]

As mentioned previously, the ability of BMI to discriminate between fatness groups in this study was excellent, making our findings comparable with those of previous studies.[28,29] Neovius and Rasmussen evaluated the accuracy of the BMI as a diagnostic test to define excess adiposity using the cut offs of Williams et al., and reported that BMI correctly grouped 84.6% of subjects. [28] Laurson et al., showed that 90% of children were classified into their respective PBF groups correctly using BMI, and that body fat estimated from skinfolds is highly related to BMI.[29] Power et al., suggested that an ideal measure for adolescent obesity should meet the following criteria: simplicity, low cost, and ease of use, and acceptability to the subjects.[30] Therefore, BMI is the most appropriate measure for defining obesity in adolescents.

Although no immediate explanation is available for these inconsistent results, an important consideration is that our results may be sample- and population-specific and the level of association between adiposity and BMI is affected by race.[31] Moreover, PBF is highly variable and yields different values even for people with the same BMI.[32] Some studies emphasized that the accuracy of BMI as an indicator of fatness is strongly determined by the degree of fatness.[33,34]

In this study, the ability of BMI to discriminate between fatness groups was slightly but significantly better than WC, WHR, and WHtR. It is important to note that WC, WHtR, and SF4 also performed reasonably well. One study demonstrated that WC provides equivalent diagnostic quality to BMI and is always superior to WHtR.[35] Furthermore, Maffeis et al., observed that WC measured at the age of 8 years, may be a promising index to assess adiposity.[36] However, in another study, WC percentile had no advantage over BMI percentile for diagnosis of high fat mass in children.[37] In the present study, the global accuracy of WHtR in discriminating excess adiposity was 88%. Consistent with our findings, Weili et al. demonstrated that the accuracy of using WHtR to define overweight and obesity was higher than 90% in Chinese children and adolescents, although they used BMI cutoffs to define obesity.[38] In this study, WHtR contributed better to prediction of fat mass and diagnosis of excess adiposity compared to WHR. Our results are in general agreement with those of other studies showing that WHR is a poor index of central fatness in children and adolescents.[39,40]

Traditionally, body fatness has often been estimated from measurements of skinfold thickness. However, in this study, the sum of 4 skinfolds explained 48% of the variance in PBF. Furthermore, skinfold thickness offers direct measurement of subcutaneous fat and concerns have been raised about the accuracy of this index because of limited body regions measurement and poor reproducibility by different observers, especially in fatter subjects.[41] Moreover, Watts et al., showed that body fat derived from skinfold measure is a poor predictor of total fat derived from DEXA in obese children and adolescents.[42] On the contrary, some studies have shown that skinfold was better than

BMI and WC in predicting PBF.[43–45]

After stratifying by sex, our results showed that BMI could explain more between-subject variance in fatness in boys than in girls, adjusting for age and pubertal stage; this finding is consistent with the study of Hubert et al., which reported that BMI displayed better accuracy values among French boys, and BMI changes in boys were associated with decrease in PBF and increase in FFM.[35] In contrast, Morimoto et al., examined gender differences in the relationship between BMI and PBF measured by BIA in Japanese children, and they showed that PBF can be predicted by BMI in children, but the correlations in boys were not as strong as those in girls.[7] Furthermore, Srdic et al., reported that girls had stronger correlation between BMI and PBF compared to boys.[46] They indicated that one possible explanation is that individual variation in body composition in boys is more than girls. The reason for these differences in results of various studies is unclear. In this study, BMI was better in predicting PBF in girls before adjusting for pubertal stage; these results, however, were reversed after adjusting for pubertal stage. Therefore, pubertal stage can be an important factor in this relationship. Further studies will be necessary to ascertain the mechanisms underlying this gender difference in various ethnic groups.

The study strengths include using both linear regression and ROC curves to compare the associations between the gold standard and anthropometric indices with adjustment of important confounding variables, especially pubertal stages. Moreover, we used the percentage body fat as gold standard to define excess adiposity. The major limitations of this study were its cross-sectional design, the small sample size relative to some studies, and cut offs used to classify obese and normal adolescents, which were not ethnicity-specific. We chose percentage body fat cutoffs of 25% and 30% for boys and girls, respectively, developed by Williams et al*.,* as the reference standards for excess adiposity; PBF thresholds of Iranian adolescents should be further investigated. Ethnicity-specific cut offs may further increase the agreement of the two anthropometric indices. Further work is required to compare the usefulness of PBF cutoffs to those of BMI and WC classifications of overweight and obesity in adolescents. In addition to the above mentioned limitations, bioelectrical impedance analysis was used for PBF assessment due to its safety in adolescents,[8] although it is not as precise as DEXA. More advanced methods, such as DEXA, could be used to assess body composition in future studies.

Conclusion

As anthropometric indices are commonly used in clinical settings and for epidemiological studies to screen excess adiposity, it is important to compare their ability to predict PBF and their accuracy to discriminate excess adiposity in adolescents. This observation shows that health care practitioners, at least in Iran, could routinely use BMI, which is inexpensive and feasible, to identify adolescents at increased risk of excess total fat. In general, the performance of BMI is slightly better than other indices that reflect visceral fat in predicting PBF and diagnosing excess adiposity in Iranian adolescents.

References

1. Kelishadi R, Ardalan G, Gheiratmand R, Majdzadeh R, Hosseini M, Gouya MM, et al. Thinness, overweight and obesity in a national sample of Iranian children and adolescents: CASPIAN Study. *Child Care Health Dev.* 2008; **34:** 44 – 54.
2. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr.* 2002; **76:** 653 – 658.
3. McClure HH, Eddy JM, Kjellstrand JM, Snodgrass JJ, Martinez CR Jr. Child and adolescent affective and behavioral distress and elevated adult body mass index. *Child Psychiatry Hum Dev.* 2012; DOI:10.1007/s10578-012-0299-9.
4. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics.* 1998; **101:** 518 – 525.
5. Barton M. Childhood obesity: a life-long health risk. *Acta Pharmacol Sin.* 2012; **33:** 189 – 193.
6. De Niet JE, Naiman DI. Psychosocial aspects of childhood obesity. *Minerva Pediatr*. 2011; **63:** 491 – 505.
7. Morimoto A, Nishimura R, Sano H, Matsudaira T, Miyashita Y, Shirasawa T, et al. Gender differences in the relationship between percent body fat (%BF) and body mass index (BMI) in Japanese children. *Diabetes Res Clin Pract.* 2007; **78:** 123 – 125.
8. Newton Jr RL, Alfonso A, White MA, York-Crowe E, Walden H, Ryan D, et al. Percent body fat measured by BIA and DEXA in obese, African-American adolescent girls. *Int J Obes.* 2005; **29:** 594 – 602.
9. Sood A, Sundararaj P, Sharma S, Kurpad AV, Muthayya S. BMI and body fat percent: affluent adolescent girls in Bangalore city. *Indian Pediatr.* 2007; **44:** 587 – 591.
10. Mushtaq MU, Gull S, Abdullah HM, Shahid U, Shad MA, Akram J. Waist circumference, waist-hip ratio and waist-height ratio percentiles and central obesity among Pakistani children aged five to twelve years. *BMC Pediatr.* 2011; **11:**105.
11. Durnin JV, Rahaman MM. The assessment of the amount of fat in the human body from measurements of skinfold thickness. *Br J Nutr.* 1967; **21:** 681 – 689.
12. Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? *Am J Epidemiol.* 1996; **143:** 228 – 239.
13. Deurenberg P, Deurenberg-Yap M. Validity of body composition methods across ethnic population groups. *Acta Diabetol.* 2003; **40:** S246 – S249.
14. Jelliffe DB, Jelliffe EFP. *Community Nutritional Assessment.* Oxford, UK: Oxford University Press; 1989: 56 – 110.
15. Lee RD, Nieman DC. *Nutritional Assessment*. 5th ed. New York: McGraw Hill International Edition; 2010: 182 – 192.
16. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity and weight velocity and stages of puberty. *Arch Dis Child.* 1976; **51:** 170 – 179.
17. Lohman TG, Going SB. Body composition assessment for development of an international growth standard for preadolescent and adolescent children. *Food Nutr Bull.* 2006; **27(suppl 4):** S314 – S325.
18. Williams DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS, et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. *Am J Public Health.* 1992; **82:** 358 – 363.
19. Swets JA. Measuring the accuracy of diagnostic systems. *Science.* 1998; **240:** 1285 – 1293.
20. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics.* 1988; **44:** 837 – 845.
21. Dietz WH, Bellizzi MC. Introduction: the use of body mass index to assess obesity in children. *Am J Clin Nutr.* 1999; **70(suppl):** 123S – 125S.
22. Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: A validation study. *J Pediatr.*1998; **132:** 204 – 210.
23. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. *Am J Clin Nutr.* 1994; **59:** 307 – 316.
24. Goulding A, Gold E, Cannan R, Taylor R, Williams S, Lewis-

Parned N. DEXA supports the use of BMI as a measure of fatness in young girls. *Int J Obes.* 1998; **20:** 1014 – 1021.
25. Pmdsay RS, Hanson RL, Roumain J, Ravussin E, Knowler WC, Tataranni PA. Body mass index as a measure of adiposity in children and adolescents: relationship to adiposity by dual energy X-ray absorptiometry and to cardiovascular risk factors. *J Clin Endocrinol Metab.* 2001; **86:** 4061 – 4067.
26. Ellis KJ, Abrams SA, Wong WW. Monitoring childhood obesity: assessment of the weight/height^2 index. *Am J Epidemiol.* 1999; **150:** 939 – 946.
27. Demerath EW, Schubert CM, Maynard LM, Sun SS, Chumela WC, Pickoff A, et al. Do changes in body mass index percentile reflect changes in body composition in children? Data from the Fels longitudinal study. *Pediatrics.* 2006; **117:** e487 – e495.
28. Neovius M, Rasmussen F. Evaluation of BMI-based classification of adolescent overweight and obesity: choice of percentage body fat cutoffs exerts a large influence. The COMPASS study. *Eur J Clin Nutr.* 2008; **62:** 1201 – 1207.
29. Laurson KR, Eisenmann JC, Welk GJ. Body mass index standards based on agreement with health-related body fat. *Am J Prev Med.* 2011; **41(4S2):** S100 – S105.
30. Power C, Lake JK, Cole TJ. Measurement and long-term health risks of child and adolescent fatness. *Int J Obes Relat Metab Disord.* 1997; **21:** 507 – 526.
31. Daniels SR, Khoury PR, Morrison JA. The utility of body mass index as a measure of body fatness in children and adolescents: differences by race and gender. *Pediatrics.* 1997; **99:** 804 – 807.
32. Widhalm K, Schonegger K, Huemer C, Auterith A. Does the BMI reflect body fat in obese children and adolescents? A study using the TOBEC method. *Int J Obes Relat Metab Disord.*2001; **25(2):** 279 – 285.
33. Freedman DS, Wang J, Maynard LM, Thornton JC, Mei Z, Pierson RN, et al. Relation of BMI to fat and fat-free mass among children and adolescents. *Int J Obes.* 2005; **29:** 1 – 8.
34. Schaefer F, Georgi M, Wuhl E, Scharer K. Body mass and percentage fat mass in healthy German schoolchildren and adolescents. *Int J Obes.* 1998; **22:** 461 – 469.
35. Hubert H, Guinhouya CB, Allard L, Durocher A. Comparison of the diagnostic quality of body mass index, waist circumference and waist-to-height ratio in screening skinfold-determined obesity among children. *J Sci Med sport.* 2009; **12:** 449 – 451.
36. Maffeis C, Grezzani A, Pietrobelli A, Proverna S, Tato L. Does waist circumference predict fat gain in chidren? *Int J Obes.* 2001; **25:** 978 – 983.
37. Reilly JJ, Dorosty AR, Ghomizadeh NM, Sherriff A, Wells JC, Ness AR. Comparison of waist circumference percentiles versus body mass index percentiles for diagnosis of obesity in a large cohort of children. *Int J Pediatr Obes.* 2010; **5:** 151 – 156.
38. Weili Y, He B, Yao H, Dai J, Cui J, Ge D, et al. Waist-to-height ratio is an accurate and easier index for evaluating obesity in children and adolescents. *Obesity.* 2007; **15:** 748 – 752.
39. Goran MI, Kaskoun MC, Shuman WP. Intra-abdominal adipose tissue in young children. *Int J Obes Relat Metab Disord.* 1995; **19:** 279 – 283.
40. Taylor RW, Jones IE, William SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. *Am J Clin Nutr.* 2000; **72:** 490 – 495.
41. Lohman TG. Skinfolds and body density and their relation to body fatness: a review. *Hum Biol.* 1981; **53:** 181 – 225.
42. Watts K, Naylor LH, Davis EA, Jones TW, Beeson B, Bettenay F, et al. Do skinfolds accurately assess changes in body fat in obese children and adolescents? *Med Sci Sports Exerc.* 2006; **38:** 439 – 444.
43. Kriemler S, Puder J, Zahner L, Roth R, Meyer U, Bedogni G. Estimation of percentage body fat in 6- to 13-year-old children by skinfold thickness, body mass index and waist circumference. *Br J Nutr.* 2010; **104:** 1565 – 1572.
44. Treuth MS, Butte NF, Wong WW, et al. Body composition in prepubertal girls: comparison of six methods. *Int J Obes Relat Metab Disord.* 2001; **25:** 1352 – 1359.
45. Freedman DS**,** Wang J**,** Ogden CL**,** Thornton JC, Mei Z, Pierson RN, et al. The prediction of body fatness by BMI and skinfold thicknesses among children and adolescents. *Ann Hum Biol.* 2007; **34:** 183 – 194.
46. Srdic B, Obradovic B, Dimitric G, Stokic E, Babovic SS. Relationship between body mass index and body fat in children- Age and gender differences. *Obes Res Clin Pract.* 2011; doi: 10.1016/j.orcp.2011.08.153.