Original Article

Sensitivity and specificity of body mass index in determining obesity in children

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Background: The purpose of this study is to determine sensitivity and specificity of body mass index (BMI) based on Center for Disease Control 2000 (CDC) percentiles compared to fat mass index (FMI) as an indicator of being really obese in children. Obesity was compared based on these two indexes among children under study. **Materials and Methods:** This cross-sectional study was conducted on 410 primary school girls aged 8-10 years, in the city of Esfahan. Weight and height were measured and BMI was calculated based on weight divided by height squared. Fat mass was measured by body composition analyzer (BCA) and FMI was calculated by dividing fat mass by height squared. FMI at or above the 90th percentile and FMI less than 90th percentile of reference data were considered as criterion for defining real obesity and normal adiposity, respectively. Receiver operating characteristic (ROC) curve was used to assess the performance of BMI in detecting obesity on the basis of FMI. Furthermore, the rate of agreement between two indices was calculated using Kappa coefficient *P* number. **Results:** Mean and standard deviation of FMI and BMI in all children were 6 ± 2.1 (kg/m^2) and 19.4 ± 3 (kg/m^2), respectively. The area under the ROC curve for obesity was 0.75. The cutoff point, sensitivity, and specificity of BMI to classify children as obese compared to FMI were 21.2 kg/m^2, 79%, and 73%, respectively. In this cutoff point for BMI (21.2 kg/m^2), the agreement rate between BMI and FMI for determining obesity status was 0.5 ($P < 0.001$). **Conclusion:** Our results indicated 79% of children who were recognized as obese based on FMI, were also classified as obese according to BMI. Twenty-seven percent of children, who were non-obese, were identified as obese based on BMI. It appears that FMI compared to BMI is more accurate in determining obesity, but further studies are required.

Key words: Body mass index, children, fat mass index, obesity

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INTRODUCTION

Obesity is the most important nutritional-health problem of children and teenagers in developed countries. Because of urbanization, life style change, and modernization, the increasing trend of obesity in developing countries is a warning for health authorities. Prevalence of obesity among children is rapidly increasing all over the world[1] so that, in the USA, it reached 18.8% during 2003-2004 among 6- to 11-year-old children.[2] Based on CDC (Centers for Disease Control) standards, the BMI of equal to or more than the 95th percentile and within 85 to 95 are categorized as obesity and overweight, respectively. A study conducted in 2004 in Iran showed the prevalence of overweight and obesity among elementary school children as 9.8% and 4.4%, respectively.[3] The prevalence of obesity among elementary school girls of Region 6 in Tehran has been reported to be 16%, 6.9%, and 6.6%, according to Iranian references, CDC 2000 (Centers for Disease Control) and IOTF 2000 (International Obesity Task Force), respectively.[4] Moreover, the prevalence of obesity in elementary school children was reported to be 9.9%, 9.2%, and 8% in Chaharmahal-va-Bakhtiary Province,[5] city of Yazd[6] and city of Isfahan,[7] respectively. Besides its negative mental effects, obesity in childhood has a direct relationship with hypertension and osteopathy in adulthood; furthermore, it is considered a risk factor for other diseases in adulthood.[8] Considering the increasing prevalence of obesity among children, it seems necessary to use a criterion for proper obesity determination in children.[9] The studies which have analyzed the role of fat tissue in determining obesity emphasize that distribution of fat tissue in the body could predict cardiovascular diseases, metabolic syndrome, and some types of cancers;[10] as a result, waist circumference and waist – hip ratio are more precise predictors for mortality and risk of diseases than BMI.[11] That is because, BMI cannot distinguish fat mass from non-fat mass and evaluate

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obesity properly.[9] According to a report by World Health Organization (WHO), extra body fat in childhood is associated with the increase of body fat in adulthood and risk of chronic diseases. Considering the point that body fat can be measured through different methods like dual X-ray absorption (DXA), bioelectric impedance analysis (BIA), and caliper, it seems necessary to measure body fat besides BMI during childhood.[12] Therefore, it is important to consider body fat mass while determining obesity in order to predict outcomes of obesity, which mainly arise from an increase in fat mass in the body.[9] Many studies have defined obesity in children based on BMI percentiles and have attributed high BMI to high body fat. However, since BMI is always influenced by lean body mass, it may not always result in a precise estimate of body fat. Children who have been placed in the normal range based on their BMI may have high body fat mass and low lean mass. Also, most studies have used body fat percent to determine obesity. As the effect of height is not considered when determining obesity in this method, errors may occur in categorizing people. Therefore, it seems necessary to use a criterion for measuring body fat mass separately while considering the height. FMI (fat mass index) which is obtained from dividing body fat mass (kg) by squared height (m^2) can be a proper criterion for predicting body fat mass and obesity. It provides the possibility for considering body fat mass separately and stating it relative to height; it is used in some studies for determining obesity as a better criterion than body fat percent.[13] Few studies have been conducted in Iran with regard to FMI evaluation and its comparison with BMI, where they have used caliper for measuring body fat level.[14] In the present study, body composition analyzer (BCA) was used instead of caliper to evaluate body fat mass. This device has higher accuracy than caliper and provides proper evaluation of body fat mass in comparison with DXA. In children, BCA shows body fat mass 2.6% more than the real value (DXA) on average, while caliper has much lower accuracy and shows more than 6% error in measuring body fat.[15] As a result, using this method for evaluating FMI would result in more accurate FMI values than previous studies from Iran.

In this study, in addition to using the highly accurate BCA device for evaluating body fat mass, FMI was applied for evaluating obesity in children because it is not affected by body lean mass. Moreover, it was the first study conducted in Iran to determine BMI capability for correct diagnosis of individuals with obesity and normal weight compared with FMI as the real obesity criterion in children.

MATERIALS AND METHODS

Subjects

This cross-sectional study was conducted on 410 primary school girls (aged 8-10 years) in the city of Esfahan. The multistage random sampling method was used to obtain subjects. Ten schools were randomly selected from five education and training districts of the city. From each school, 41 individuals were randomly selected. The parents of students were informed of the purpose and procedure of the study and their consent for their children's participation were obtained. The subjects with illness or less than 8 or more than 10-year old were excluded from the study.

The participants with FMI equal to or more than 7.2 (kg/m^2) were defined as obese and those with FMI less than 7.2 (kg/m^2) as non-obese. Setting 7.2 (kg/m^2) as the cut-off point was based on the study by Nakao *et al*. in Japan which was obtained by calculating the 90th percentile of available data on 9- to 11-year-old girls.[16] This study was the only investigation which applied a device for measuring body composition similar to the one used in the present study for different age categories. So their calculated FMI values were used as reference for defining adiposity status in the present study. Among 410 participants of this study, the 90th percentile FMI was 7.4, which was 0.2 different from the reference calculated by Nakao. It should be mentioned that Iranian studies have not reported any references for FMI so far and the only study in this field in Iran used caliper for measuring body fat mass and FMI.[14]

Anthropometric measurements

As the first step, children's date of birth was collected from their school records and their height, weight, and body fat mass were measured. The height of each child was measured using a non-stretchable tape with the accuracy of 0.5 cm while standing barefoot with heals sticking to the wall, straight head, and forward look. Their weight was measured while they had the minimum clothes on without any extra accessories using the BCA device with the accuracy of 50 g (Model Tanita 418 MA, made in Japan). Body fat mass was also measured by the same device. Afterwards, FMI was calculated. For the present study, the FMI equal to or more than 7.2 (kg/m^2), based on the calculated reference of Nakao's study, was regarded as real obesity in children. Finally, obesity based on BMI was compared with obesity based on FMI and their sensitivity and specificity in determining children with obesity were measured.

Statistical analysis

SPSS statistical software, ver. 16, was used for data analysis. Mean and standard deviation was used for data description. Receiver operating characteristic (ROC) curve was used to assess the performance of BMI in detecting obesity on the basis of FMI. Cut-off point, specificity, and sensitivity percentages of BMI in detecting obesity on the basis of FMI were calculated. The area under the ROC curve (AUC) was determined to provide a numerical summary of the indicator's performance. The SE of the AUC was obtained by bootstrapping.[17] Furthermore, the rate of agreement between two indices was calculated using Kappa coefficient *P* number. The agreement rates 0.8-1, 0.6-0.8, 0.4-0.6, 0.2-0.4, and 0-0.2 indicate there are excellent agreement, good agreement, moderate agreement, poor agreement, and disagreement between two methods, respectively.[18] $P < 0.05$ were considered significant.

RESULTS

Means and standard deviations of BMI and FMI in all children were 6 ± 2.1 and 19.4 ± 3 kg/m^2, respectively [Table 1]. As shown in Table 1, means and standard deviations of body fat percent in 8- to 10-year-old children were 28 ± 5.8, 28.6 ± 5.3, and 29 ± 5.4, respectively, in which body fat percent increased with age. Similarly, mean of FMI in the participating children increased with age; in the ages of 8- to 10-year old, it was calculated as 5.7, 5.9, and 6.2 kg/m^2, respectively. The ROC curves of BMI for predicting obesity on the basis of FMI are shown in Figure 1. The AUC for prediction of obesity on the basis of FMI was 0.75 (SE = 0.0056). The cut-off point, sensitivity, and specificity of BMI to classify children as obese compared to FMI were 21.2 kg/m^2, 79%, and 73%, respectively. In this cut-off point of BMI (21.2 kg/m^2), the agreement rate between BMI and FMI for determining obesity status was 0.5 ($P < 0.001$).

Table 1: Mean and standard deviation of anthropometric measurements of subjects across age groups

Anthropometric measurements	Age (year)			
	8 (*n*=213)	9 (*n*=144)	10 (*n*=53)	Total (*n*=410)
Height (cm)	130.5 (5.3)	136.6 (6.5)	142.2 (6.1)	134 (7.1)
Weight (kg)	33.2 (6.6)	36.4 (7.7)	40.4 (8.2)	35.3 (7.6)
Fat mass (kg)	10.7 (4)	11.1 (4.1)	11.7 (4.2)	10.9 (4.1)
Fat mass (%)	28 (5.8)	28.6 (5.3)	29 (5.4)	28.8 (5.4)
Body mass index (kg/m^2)	19.4 (3.1)	19.4 (3)	19.8 (3.1)	19.4 (3)
Fat mass index (kg/m^2)	5.7 (1.9)	5.9 (2)	6.2 (2.1)	6 (2.1)

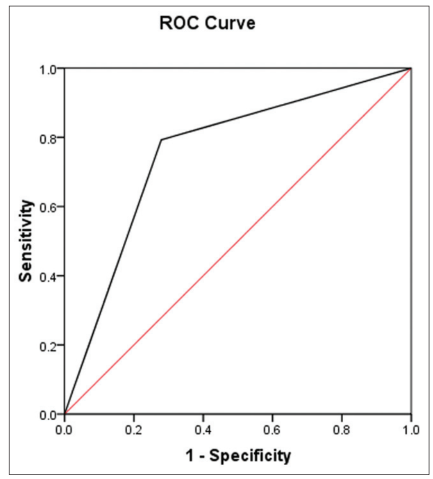

Figure 1: The receiver operating characteristic curves of body mass index for prediction of obesity on the basis of fat mass index in a sample of 8- to 10-year-old girls (*n* = 410)

DISCUSSION

Many health-related problems can be attributed to the increase of body fat mass and obesity. Obesity in childhood endangers health in adulthood.[9] Although it is common to use BMI for determining obesity, where only height and weight are needed to be measured, it is not an accurate criterion for obesity evaluation. The first step toward preventing and treating the problems related to obesity is to estimate body fat mass.[9]

In the present study, means of FMI and BMI in all participating children using a BCA device were calculated as 6 and 19.4 kg/m^2, respectively. The studies conducted in other countries have reported the FMI mean of 4.45 for 11-year-old girls,[19] 4.79 and 3.21 for 6- to 8-year-old girls and boys, respectively,[20] and 6.2 for 12-year-old girls.[21] In the study of Wells *et al*., FMI means of 4.5 and 3.2 (kg/m^2) were reported for 8-year-old girls and boys while their BMI means were 17.1 and 16.5 (kg/m^2), respectively.[22] In the study of Nakao *et al*., FMI values at the 90th percentile of the data obtained from 6- to 8-year-old boys and girls were 4.8 and 5.3 (kg/m^2), respectively. In the same study, these values were 6.4 and 7.2 (kg/m^2) in 9- to 11-year-old boys and girls, respectively.[1] In the present study, the 90th percentile of the calculated FMI was equal to 7.4 (kg/m^2), in which 0.2 (kg/m^2) difference was observed from the reference value which was calculated at the same age group by Nakao *et al*. The differences in FMI values in different studies could be attributed to the variations in the methods used for measuring body fat, application of different criteria for categorizing obesity, and also sample size. Considering that no reference values have been specified for FMI yet and it was not possible for the present study to have large samples and determine the 90th percentile rank of FMI due to sampling limitations, the present study used the reference values of the Nakao *et al*.'s study. In that study, FMI values were calculated age-wise among 522 boys and 649 girls for defining obesity in children within the age range of 3- to 11-year-old.

In the present study, the area under the ROC curve was 0.75 which means 75% of the time a randomly selected obese girl, based on FMI, has a BMI greater than that of a randomly selected girl with normal adiposity. In our study, the cut-off point for BMI was 21.2 kg/m^2 which meant subjects with BMI less than 21.2 kg/m^2 were non-obese and subjects with BMI equal to or more than 21.2 kg/m^2 were obese. Also, BMI had moderate sensitivity and specificity for detecting obesity, and it was observed that 79% of the obese children based on FMI were recognized to be obese based on BMI as well and 73% of the children with normal adiposity based on FMI showed the same status with BMI; in other words, sensitivity and specificity of BMI in comparison with those of FMI as the real criterion of obesity were 79% and 73%, respectively. Other studies have mentioned low sensitivity of BMI in determining obesity among children. In this cut-off point of BMI (21.2 kg/m^2), the agreement rate between BMI and FMI for determining obesity status was 0.5 which indicates there is moderate agreement between FMI and BMI.

In the study by Haeri-Behbahani, the 90^{th} percentile values of FMI for 6-11 years children were reported as 5.2, 5.9, and 5.6 (kg/m^2) for boys, girls, and total children, respectively. When FMI as the real criterion of obesity was applied, BMI sensitivity and specificity at equal to or more than the 95^{th} percentile of the CDC 2000 standard for determining obesity were reported to be 43.3% and 99.4%, respectively, and the difference observed at the obesity level based on these two criteria was significant. Based on the results of that study, BMI had lower performance in obesity diagnosis in children and FMI was a better criterion than BMI for obesity evaluation in children. The mentioned study used caliper to measure body fat, which has lower accuracy than BCA.[14] In the study of Eto *et al*., the validity of BMI and FMI was evaluated by considering body fat mass of more than 20% and 25% in boys and girls, respectively, as the real criterion of obesity in children and also determining the 90^{th} percentile of the data obtained from calculating BMI and FMI for defining obesity.[23] Thus, sensitivities of BMI and FMI were calculated as 37.5% and 68.8% in boys and 30.4% and 42.9% in girls, respectively. In their research, FMI showed higher sensitivity than BMI but both indicators demonstrated lower capability than body fat percent for diagnosing obese children. In addition, specificities of BMI and FMI were calculated as 95.5% and 99.5% in girls and 96.4% and 100% in boys, respectively, both of which showed high specificity. Due to observing a correlation between BMI and FMI on the one hand and body fat percent on the other, this study suggested both BMI and FMI as indicators of fat mass.[23] Nevertheless, with regard to the correlation between BMI and body fat percent in children, the study of Wells *et al*. stated that neither BMI nor body fat percent were independent of body fat free mass.[22]

Sidhu *et al*. analyzed sensitivity, specificity, and accuracy of BMI in determining high body fat mass by conducting a study on 500 girls within the age range of 6- to 11-year old. In this study, the BMI of equal to and more than the 95^{th} percentile of CDC standards was regarded as obesity and the fat mass (measured by caliper) of equal to or more than the 90^{th} percentile was regarded as having high fat mass. This study reported sensitivity, specificity, and accuracy as 42%, 85%, and 87%, respectively. Also, it concluded that using BMI by itself was not appropriate for determining high fat mass and suggested using another indicator along with BMI for determining obesity and high body fat mass.[24]

In Zimmerman's study, BMI sensitivity and specificity compared to body fat percentage (BF) from multisite skinfold thicknesses (using caliper device) were determined. Overweight and obesity were defined as values above the 85^{th} and 95^{th} percentiles, respectively, for %BF-for-age. It was shown that BMI had high sensitivity and specificity in determining obesity among 6-to 12-year-old children. This research concluded that BMI could be an appropriate sign of body fat mass in 6-to 12-year-old children.[25] However, the effect of height is not considered in this study which may produce some error in categorization of the subjects. Also, BIA has higher accuracy than caliper and provides more proper evaluation of body fat mass. The study by Demarath *et al*. which was conducted on 494 girls and boys within the age range of 8-to18-year-old showed that FMI significantly increased only at high percentiles of BMI. Although means for BMI were similar in girls and boys, FMI was significantly different in the two genders. In this study, with the equal increase in BMI percentile, body fat increase with age in heavier girls was higher than lighter ones. This research concluded that changes in BMI percentiles in children might not properly show changes in body fat mass in the course of time, especially in boys with low BMI.[19] Based on the results of his study on 5-to18-year-old individuals, Freedman stated that BMI accuracy as the estimation of body fat mass greatly depended on obesity intensity so that it had high correlation with FMI in children with the BMI more than the 85^{th} percentile and high correlation with fat free mass in children with the BMI less than the 50^{th} percentile. As a result, BMI difference in thin and normal children could arise more from body fat free mass.[26] In Colombo, study agreement between measured BMI and determined FMI based on DXA method was evaluated. The result showed 75% of the underweight subjects had normal FMI. Thirty percent of the subjects who were normal weight based on BMI had high body fat. In overweight subjects, 6.7% had normal FMI and 40% had very high fat mass. This research concluded that there was good agreement between BMI and FMI and moderate agreement between BMI and the body fat percentage and metabolic syndrome risk. These findings suggest that a certain proportion of subjects that were classified as having normal BMI may have excess body fat which could have clinical and metabolic consequences and indeed FMI can provide precise clinical assessment of subjects.[27] In general, BMI should be used with great caution as an indicator of body fat mass and obesity.[19]

Body weight is composed of fat mass and fat free mass, both of which can be different among individuals. Based on the results of the present study, BMI compared with FMI as the real criterion of obesity had relatively lower sensitivity and higher specificity, i.e., BMI had less capability in recognition of obese individuals correctly and higher capability in recognition of individuals with normal weight as compared with FMI. Considering that the differences in fat free mass are in most cases the main reason for BMI difference in children, there is no certainty that higher BMI equals higher body fat mass in children.[22] Therefore, it is necessary to verify BMI efficiency in determining obesity in children. In addition, it is beneficial to use FMI as an indicator of body fat mass in proportion to height and independent of body fat free mass for correct evaluation of the prevalence of obesity in children.[22] Nevertheless, it is recommended to conduct more researches in this field.

In the present study, body fat mass of children was measured by BCA, which had much higher accuracy compared to caliper. Previous studies in Iran have used caliper for measuring body fat mass in children. There were limitations in this study. This study was confined to girls only. There was no possibility to conduct this study on a larger sample and to determine the 90th percentile of FMI in the studied population; consequently, the reference values of previous studies were used.

CONCLUSION

Considering the increase in the prevalence of obesity in children and its outcomes in adulthood, it seems necessary to use a precise method for determining obesity. The results of the present study points that FMI could present more precise diagnosis in determining obesity in children since it considers body fat mass in determining obesity on the one hand and is not affected by body fat free mass on the other.

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