Original Article

Percent body fat cutoff values for classifying overweight and obesity recommended by the International Obesity Task Force (IOTF) in Korean children

Kayoung Lee MD, PhD[1], Sangyeoup Lee MD, PhD[2], Su Yung Kim MD, PhD[3], Su Jin Kim MD[3] and Yun Jin Kim MD, PhD[2]

[1]*Department of Family Medicine, Pusan Paik Hospital, College of Medicine, Inje University, Republic of Korea*
[2]*Center for Obesity, Nutrition and Metabolism, Pusan National University Hospital and Medical Education Unit, College of Medicine, Pusan National University, Republic of Korea*
[3]*Department of Pediatrics, College of Medicine, Pusan National University, Republic of Korea*

Objective: To predict the percent body fat (%BF) cutoff values corresponding to overweight and obesity recommended by the International Obesity Task Force (IOTF) in Korean children and to compare those values with the published cutoff values in Caucasian children. **Research methods and procedures:** The sample consisted of 1083 Korean children and adolescents (555 boys and 528 girls) aged 7-18 years from 3 schools. Body mass index (BMI) and %BF using a bioelectrical impedance analyzer were measured. The classification of overweight and obesity was based on the age- and sex-specific BMI cutoff values of the IOTF guidelines. **Results:** The predicted %BF cutoff values for overweight and obesity varied by age and sex: overweight, 17-22% in boys and 24-37% in girls; obesity, 24-30% in boys and 30-53% in girls. Those %BF cutoff values in older Korean boys tended to be lower than the published %BF cutoff values in Caucasian boys. While %BF cutoff values for overweight in Korean girls were similar to the values in Caucasian girls, %BF cutoff values for obesity in Korean girls aged 13~18 years were higher compared to cutoff values in Caucasian girls. **Conclusion:** The %BF values associated with the IOTF-recommended BMI cutoff values for overweight and obesity may require age- and sex-specific cutoff values in Korean children aged 7-18 years.

Key Words: IOTF, Korean children, obesity, overweight, percent body fat

INTRODUCTION

Childhood obesity is an increasingly serious public health problem in Korea as well as in Western countries. According to the Korean National Health and Nutrition Examination Survey, the prevalence of overweight and obesity in children aged 10-19 years between 1998 and 2001 increased from 9 to 14% in boys and 9 to 10% in girls, based on the age-and sex-specific relative weight using local growth charts.[1, 2]

Despite concern about the epidemic of childhood obesity, the standard definition for screening obesity remains inconsistent. Because of their feasibility under clinical settings and in epidemiological studies, an anthropometric index such as body mass index (BMI) is used as a surrogate for assessing adiposity. The Pediatric Obesity Committee of the International Obesity Task Force (IOTF) recommends BMI values corresponding to 25 and 30 kg/m^2 as cutoff values (at age 18) for overweight and obesity, respectively, between the ages of 2 and 18 years.[3] Because the IOTF guideline was established for use as an international standard definition for childhood overweight and obesity, it is important to evaluate whether these BMI cutoff values accurately reflect excess adiposity in children of diverse ethnicity. Moreover, given the different muscle and fat distribution during the developmental status of children, it is essential to determine those relationships in the context of age and sex.[4]

Although several studies have explored the relationship of BMI to adiposity,[5-14] the adiposity cutoff values for classifying overweight and obesity based on the IOTF BMI guideline have been evaluated in only two studies.[13,14] Fu *et al*.[13] examined the appropriate definition of obesity in Chinese children by comparing the IOTF-recommended definition with the local population-specific definition using the age- and sex-specific 95th percentile of percent body fat (%BF) as a standard of obesity. Taylor *et al*.[14] examined the %BF values associated with the IOTF-recommended BMI cutoff values for overweight and

Corresponding Author: Kayoung Lee MD, PhD, Department of Family Medicine, Pusan Paik Hospital, 633-165 Kaegum-dong, Pusan Jin-Gu, Pusan, 614-735, Republic of Korea
Tel: 82-51-890-6229; Fax: 82-51-894-7554
Email: fmlky@inje.ac.kr
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obesity in Caucasian children aged 2-18 years. Although BMI is highly correlated with adiposity in children, the body composition of equivalent BMI may differ according to ethnicity, as is the case in adults.[15] Given the widespread use of the IOTF BMI cutoff values for classifying overweight and obesity, it is important to assess the adiposity cutoff values predicted from those BMI cutoff values in children of different ethnicity. However, to the best of our knowledge, there has been no previous study on adiposity values for classifying overweight and obesity based on the IOTF-recommended BMI cutoff values in Asian children.

Adiposity is measured by a variety of methods, which vary in their sophistication, accuracy, feasibility, cost, and availability. While the %BF derived from bioelectrical impedance analysis (BIA) is less accurate compared to that measured by dual-energy X-ray absorptiometry (DXA), it is suitable for assessing %BF in large numbers of children and adolescents with good feasibility, cost, and reasonable accuracy.[6] Therefore, we estimated %BF values (derived from BIA) corresponding to the IOTF-recommended BMI cutoff values for overweight and obesity in Korean children aged 7-18 years. Additionally, we compared the predicted %BF values with those of Caucasian children researched by Taylor *et al*.

MATERIALS AND METHODS

Subjects

The subjects in the study were 1083 school children and adolescents (555 boys and 528 girls) aged 7–18 years from one elementary, one middle, and one high school in Busan, South Korea. They were recruited through regular growth examinations conducted at each school from May to June 2003. The procedures were explained to the subjects. The study was approved by the school authorities and the institutional review board of Pusan National University Hospital.

Measures

Trained school nurses measured subjects' heights and weights according to standard procedures. Height was measured to the nearest 0.1 cm and weight to the nearest 0.1 kg using automated weight and height scales (Dongsan Jenix, Seoul, Korea). BMI was calculated as kg/m^2. Percent body fat was measured using a bioelectrical impedance analyzer (HTM-1000; BizMed, Seoul, South Korea) that used a multifrequency segmental bioelectrical method. All subjects were measured following a standard method. Subjects stood on a footplate, which had two electrodes per foot, and held a handgrip with two electrodes per hand. To validate %BF measured using BIA, 100 children (58 boys and 42 girls) underwent a DXA scan (whole body scanner, QDR 1000/W; Hologic, Waltham, MA, USA). The correlation between the two measures for %BF was >0.9 in boys and girls. The mean difference (±S.D.) between the estimated %BF measured by BIA and DXA was 1.37 (3.79)%. The bias was not significant ($p > 0.05$).

Statistical Analysis

Overweight and obesity were classified by the IOTF-recommended BMI values for each age and sex, which corresponds to the BMI cutoffs of 25 and 30 kg/m^2 at the age of 18 years.[3] Because cutoff values were provided for each half-year of age, and the age of current subjects was provided at 1-year intervals, we used the BMI cutoff value for each child at the midyear value recommended by Cole *et al*.[3] To assess the effect of age, data were analyzed in three age groups (7-10, 11-14, and 15-18 years old). A probability–probability plot was used, which showed that the distribution of BMI and %BF followed a normal distribution. Therefore, BMI and %BF were not transformed. To examine sex and age-group differences for anthropometric data, *t*-tests and one-way analysis of variance with Scheffe's test were conducted, respectively. Chi-square tests were performed to determine sex or age-group differences in prevalence of overweight and obesity. Because of a curvilinear relationship between BMI and %BF, multiple regression analyses were conducted to determine %BF from the model including age, sex, square BMI, and interaction between square BMI, sex, and age. Chi-square test was performed to compare the proportions of overweight or obesity estimated by the IOTF-recommended BMI cutoff values and those proportions estimated by the %BF cutoff values derived from the model. SPSS/PC version 12.0 for Windows (SPSS, Chicago, IL, USA) was used for all analyses.

RESULTS

Relationship of %BF to BMI

The physical characteristics of our subjects are shown in Table 1 according to sex and age groups. Whereas %BF in girls increased with age ($p < 0.001$), it was significantly lower in boys aged 15–18 years compared to boys aged 7–14 years ($p < 0.001$). Although there was no sex difference in %BF in the 7–10 years age group, this difference became greater with age. For adolescents aged 15–18 years, whereas %BF was significantly greater ($p < 0.001$) in girls than in boys, the boys had significantly higher ($p < 0.001$) BMI and were more likely to be overweight and obese compared to girls. Ninety-one boys (16.4%) and 52

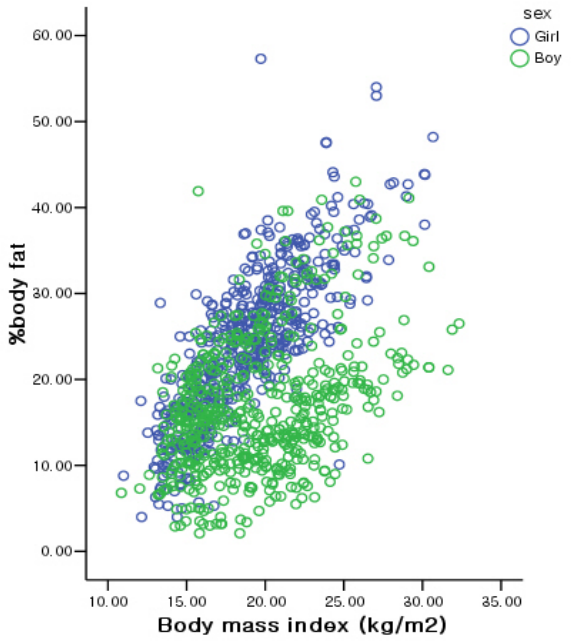

Figure 1. Percent body fat in relation to BMI according to sex in 555 Korean boys and 528 Korean girls aged 7-18 years.

girls (9.8%) were classified as overweight, and 24 boys (4.3%) and 10 girls (1.9%) met the criteria for obesity.

The curvilinear relationships between BMI and %BF according to sex presents that the same value of BMI predicted a lower %BF in boys than in girls (Fig 1). Using the multiple linear regression models, the equation determined was %BF = 7.596 + 0.060 × BMI^2 – 0.460 ×age+ 2.445 × sex -0.002 × BMI^2 × age × sex, with R^2 = 0.64 and 5.42 as the standard error of estimate. The coefficients of all independent variables in the model were significant and the variation inflation factors of all independent variables were <10. The difference between predicted and measured %BF was not significant: 0.27 ± 5.43 ($p > 0.05$, paired *t*-test).

Percent body fat cutoff values for overweight and obesity

The predicted %BF values corresponding to BMI cutoff values of overweight and obesity are presented for every year of age in Table 2. Those values were consistently greater in girls than in boys. Because the numbers of overweight and obese subjects were small, the 95% confidence intervals of the estimated %BF cutoffs were wide. The predicted %BF values at the BMI cutoffs defining overweight between 7 and 18 years ranged from 17 to 22% in boys, and from 24 to 37% in girls. Percent body

Table 1. Physical characteristics of subjects by sex and age.

	Boys	Girls	*p* -value
Age 7-10 y			
N	184	190	
Weight (kg), mean (SD)	27.4 (7.1)	27.0 (6.9)	0.59
Height (cm), mean (SD)	127 (8.0)	128 (8.4)	0.78
BMI (kg/m^2), mean (SD)	16.7 (2.8)	16.4 (2.6)	0.28
%body fat (%), mean (SD)	18.5 (8.1)	20.1 (8.4)	0.06
Prevalence, n (%)			0.16
Overweight	26 (14.1)	17 (8.9)	
Obesity	7 (3.8)	5 (2.6)	
Age 11-14 y			
N	182	149	
Weight (kg), mean (SD)	43.9 (12.4)	43.6 (11.1)	0.79
Height (cm), mean (SD)	150 (10.9)	150 (8.4)	0.76
BMI (kg/m^2), mean (SD)	19.3 (3.6)	19.3 (3.6)	0.99
%body fat (%), mean (SD)	17.9 (9.4)	23.6 (8.8)	<0.001
Prevalence, n (%)			0.22
Overweight	30 (16.5)	16 (10.7)	
Obesity	9 (4.9)	4 (2.7)	
Age 15-18 y			
n	189	189	
Weight (kg), mean (SD)	68.1 (9.9)	54.3 (7.4)	<0.001
Height (cm), mean (SD)	173 (6.1)	161 (4.6)	<0.003
BMI (kg/m^2), mean (SD)	22.7 (3.1)	21.1 (2.7)	<0.001
%body fat (%), mean (SD)	14.5 (4.9)	28.4 (7.2)	<0.001
Prevalence, n (%)			0.003
Overweight	35 (18.5)	19 (10.1)	
Obesity	8 (4.2)	1 (0.5)	

p -value for difference in sex for all variables within age groups. All variables except % body fat in boys increased with age (by Scheffe's test p <0.001). The % body fat in boys was not significantly different between the 7-10 and 11-14 year-old groups, but both values were higher than that in the 15-18 year-old group (by Scheffe's test, p <0.001).

Table 2. Predicted percent body fat cutoff values for overweight and obesity according to age and sex in Korean children.

Age (y)	Overweight				Obesity			
	Boys		Girls		Boys		Girls	
	BMI†	% BF	BMI†	% BF	BMI‡	% BF	BMI‡	% BF
7	18.2	22.0	18.0	23.9	21.1	27.3	21.0	30.9
8	18.8	21.9	18.7	24.9	22.2	28.0	22.2	33.4
9	19.5	22.6	19.5	26.2	23.4	30.0	23.5	36.5
10	20.2	21.8	20.3	27.7	24.6	29.6	24.8	39.8
11	20.9	21.6	21.2	29.5	25.6	29.9	26.1	43.3
12	21.6	21.3	22.1	31.5	26.4	29.7	27.2	46.6
13	22.3	20.9	23.0	33.3	27.3	29.3	28.2	49.3
14	23.0	20.5	23.7	34.7	28.0	28.7	28.9	51.2
15	23.6	19.9	24.2	35.8	28.6	27.7	29.3	52.2
16	24.2	19.1	24.5	36.4	29.1	26.5	29.6	52.7
17	24.7	18.1	24.9	36.8	29.7	25.2	29.8	53.2
18	25.0	16.8	25.0	36.8	30.0	23.4	30.0	53.3

†The BMI at each age that is equivalent to a BMI of 25 kg/m^2 at the age of 18 years by Cole *et al* (3); ‡The BMI at each age that is equivalent to a BMI of 30 kg/m^2 at the age of 18 years by Cole *et al* (3)

Table 3. Prevalence of overweight and obesity classified by the IOTF-recommended BMI cutoff values and predicted %BF cutoff values in Korean children aged 7-18 years.

	Boys (N=555)		Girls (N=528)	
	BMI criteria	%BF criteria	BMI criteria	%BF criteria
Overweight*, N (%)	90 (16.2)	113 (20.4)	62 (11.8)	87 (16.5)
Obesity*, N (%)	33 (5.9)	46 (8.3)	12 (2.3)	9 (1.7)

$p < 0.05$ in boys and girls by chi-square tests.; IOTF, International Obesity Task Force; BMI, body mass index; %BF, percent body fat.; %BF values derived from the age-specific BMI cutoff values, which are equivalent to BMI of 25 (Overweight) and 30 (Obesity) kg/m^2 at the age of 18 years by *Cole et al.*(3)

fat values at the BMI cutoff values classified as obesity were 24–30% in boys and 30–53% in girls. However, the prevalence of overweight and obesity based on the predicted %BF cutoff values was significantly different from that prevalence based on the BMI cutoff values (Table 3).

The predicted %BF cutoff values for overweight and obesity in Korean children and in the Caucasian children studied by Taylor *et al*. (14) are shown in Fig. 2. In Korean boys, the predicted %BF cutoff values classifying overweight and obesity were stable up to the age of 9 years and then decreased with age. In contrast, %BF cutoff values for classifying Caucasian boys as obese increased up to the age of 13 years and the values for classifying them as overweight steadily increased up to age 17 years. In girls, the estimated %BF cutoff values for classifying Korean girls as overweight were similar to the values in Caucasian girls. However, the predicted %BF cutoff values for classifying obesity in Korean girls aged 13~18 years were steadily higher compared to the values in Caucasian girls.

DISCUSSION

Studies on the relationship between %BF and BMI can be divided into three categories. Several studies have examined the interrelationships of two measures[5-7] or evaluated the validity of BMI compared to the criterion of overfatness.[8-13] However, only one previous study estimated %BF values corresponding to overweight or obesity based on the BMI-derived classification.[14] These studies supported the postulate that BMI is closely associated with adiposity even though adiposity is measured using different methods. However, the strength of association was a little different according to the age and sex of the subjects.[5,7,14] In Korean children aged 7–18 years, BMI was highly

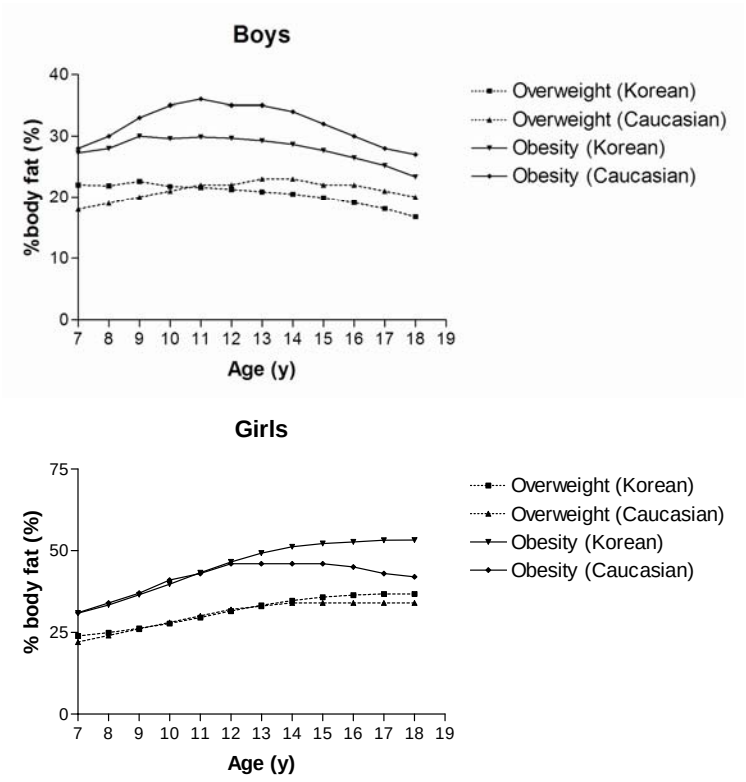

Figure 2. Percent body fat in relation to age in Korean children and Caucasian children by Taylor et al (14) in each sex. The lines represent the estimated percent body fat values corresponding to the age-specific BMI cutoff values, which are equivalent to BMI of 25 (Overweight) and 30 (Obesity) kg/m^2 at the age of 18 years by *Cole et al.*(3)

correlated with %BF and the relationship of %BF to BMI was influenced by age and sex. Although boys and girls had equivalent BMI, on average, %BF in girls was higher and the difference between the sexes increased with age. These findings are in agreement with previously reported results using different measures of adiposity.

%BF cutoff values for overweight and obesity in Caucasian boys tended to be greater than those cutoff values in Korean boys with age increase. In contrast, %BF cutoff values for obesity in Korean girls were higher than those values in Caucasian girls as they grew older. The age and sex difference for change in %BF cutoff values between our results and those of Taylor *et al.* may have been due to ethnicity or sexual development. The differences in adiposity between Korean and Caucasian boys may have been attributable to different measuring methods.

In the absence of widely accepted definitions of excess adiposity, two definitions of over-fatness were used; one based on health-related criteria and the other based on population distribution[10]. Ideally, the best choice for classifying obesity using adiposity should be based on health-related criteria. However, there is no defined amount of adiposity for designating obesity in relation to long-term health status across every age in children and adolescents. Williams *et al.*[16] showed that a %BF of ≥25% in boys and ≥30% in girls increased the risks of cardiovascular disease in Caucasian and African American children aged 7–18 years. Dwyer and Blizzard[17] also presented the standards of over-fatness associated with health outcome as a %BF of ≥20% for boys and ≥30% for girls aged 9-15 years. These two studies showed that a single, sex-specific criterion could be applied throughout adolescence. The approach based on a population distribution uses age- and sex-specific percentile cutoffs of %BF.[8,13] With this approach, the %BF corresponding to a given percentile varies considerably by age and sex. This standard may not be suitable for making international comparisons on the prevalence of over-fatness because of the differences posed by age and sex.

Our results show that a single %BF value may not be suitable for classifying overweight and obesity across a wide age range. If the cutoff values of over-fatness are defined as ≥30% for girls and ≥25% for boys in the current study, the prevalence of over-fatness increases to 23.3% in girls and decreases to 14.2% in boys. The proportion of over-fatness varies with age in each sex: for girls, 12.6% at age 7-11 years and 33.3% at 15-18 years; for boys, 23.1% at 12-14 years and 2.6% at 15-18 years. The choice of whether to use age- and sex-specific percentile cutoff values of %BF, single %BF, or %BF cutoffs corresponding to the BMI-derived cutoff values will depend on the purpose of the study. If one is conducting an international epidemiological comparison of adiposity levels in children and adolescents at the cutoff values corresponding to overweight or obesity on the basis of BMI, the latter approach would be appropriate.

There are some limitations. Earlier studies have reported a bias in %BF between BIA and DXA. The estimated %BF between the two measures was highly correlated, but there was a systemic tendency toward under- or overestimation according to child age and adiposity.[6,18,19] Although the %BF estimated using BIA and DXA were strongly correlated in our subjects, we should consider reliability of %BF measurement using BIA may be influenced by subject's physiologic status like water content in body and operational factors. The sample size also should be considered when interpreting %BF. Using the IOTF guideline, only 24 boys and 10 girls were classified as obese. The small sample size would contribute to the wide standard error of regression coefficients and different prevalence of overweight and obesity estimated by BMI cutoff values and by %BF cutoff values. Because of non-random sample, the results are not representative and limit to apply to all Korean children. Therefore, the estimated %BF cutoffs for the IOTF definition of overweight and obesity in our subjects may need further refinement by studying a greater number of representative subjects.

In conclusion, our results indicate that the %BF values for overweight and obesity based on the BMI definition in Korean children aged 7–18 years may require age- and sex-specific cutoffs. Furthermore, there will be ethnic differences in those %BF cutoffs according to children's age range and sex.

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AUTHOR DISCLOSURES

Kayoung Lee, Sangyeoup Lee, Su Yung Kim, Su Jin Kim and Yun Jin Kim, no conflicts of interest.

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[1]*Department of Family Medicine, Pusan Paik Hospital, College of Medicine, Inje University, Republic of Korea*
[2]*Center for Obesity, Nutrition and Metabolism, Pusan National University Hospital and Medical Education Unit, College of Medicine, Pusan National University, Republic of Korea*
[3]*Department of Pediatrics, College of Medicine, Pusan National University, Republic of Korea*

韓國國際肥胖專案小組建議兒童體重過重與肥胖分類之體脂肪率切點

目的：預測以國際肥胖專案小組(IOTF)建議的體重過重與肥胖分類之韓國兒童體脂肪率(%BF)切點值與的一致性，並與那些已發表之高加索兒童數值比較。**研究方法與程序**：樣本由來自三個學校之 1083 名 7-18 歲韓國兒童以及青少年（555 名男孩及 528 名女孩）組構。身體質量指數(BMI)以及%BF 使用生物電阻分析儀測量。體重過重與肥胖的分類是依據 IOTF 指南之年齡別及性別的 BMI 切點。**結果**：預測體重過重與肥胖的%BF 切點因年齡及性別而有所不同。17-22%男童及 24-37%女童為過重，24-30%男童 30-53%女童為肥胖。年齡較大的韓國男童%BF 切點比起已發表的高加索男童%BF 切點為低；而體重過重的韓國女童%BF 切點與高加索女童則相似；韓國 13-18 歲肥胖女童的%BF 切點比高加索女童的切點高。**結論**：韓國 7-18 歲的兒童之 IOTF-對體重過重及肥胖建議 BMI 切點值與相關的%BF 值，其切點可能需要針對年齡及性別分別訂定。

關鍵字：國際肥胖專案小組、韓國兒童、肥胖、過重、體脂肪率。