Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents[1,2]

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ABSTRACT The validity of the body mass index (BMI) as an indicator of the risk of becoming overweight and of the presence of overweight was evaluated in 6 groups of adolescents comprising several ethnic groups (*n* = 1570, aged 9–19 y). With use of triceps skinfold thickness and estimated percentage body fat as the criteria for adiposity, BMI had high specificities (86.1–98.8% for risk of overweight and 96.3–100% for presence of overweight) and lower but variable sensitivities (4.3–75.0% for risk of overweight and 14.3–60% for presence of overweight). Thus, almost all adolescents who were not at risk for overweight or who were not overweight were classified correctly. In contrast, many adolescents who were at risk of overweight or who were overweight were not correctly identified as measured by BMI. Partial correlations, controlling for age, between BMI and the triceps skinfold thickness and estimated percentage body fat were generally moderate to moderately high, whereas BMI and triceps skinfold thickness appeared to be equally related to estimated total body fatness and percentage body fat in Mexican American and Austrian white males. BMI was better correlated with trunk skinfold thicknesses, but when relative subcutaneous fat distribution was statistically controlled, the trunk-extremity contrast in the correlations was no longer apparent. *Am J Clin Nutr* 1999;70(suppl):131S–6S.

KEY WORDS Risk factors, body composition, overweight, puberty, obesity, anthropometry, body mass index, percentage body fat, adolescents

INTRODUCTION

Overweight is routinely described as a major problem in developed countries and in some segments of developing countries. Criteria for overweight, however, vary, and there is a need for an indicator that has applicability across a broad range of populations. Currently, the body mass index (BMI; in kg/m^2) is used widely because of the relative ease and accuracy of the basic measurements (1). However, the BMI has limitations; it tends to have high specificity, but variable sensitivity in children and adolescents (2, 3), although the validity of the BMI across diverse samples of youth has not been evaluated. The purpose of the present study is to evaluate the sensitivity and specificity of the BMI as an indicator of the risk of becoming overweight and of the presence of overweight in 6 groups of adolescents comprising several ethnic groups.

SUBJECTS AND METHODS

Characteristics of the 6 study groups used in the analysis are shown in **Table 1**. Genital development was evaluated in the Austrian boys (9) with the criteria of Tanner (11), in which stage 1 is the prepubertal stage, stage 2 is initial development of the genitalia, stages 3 and 4 are intermediate stages, and stage 5 is the mature stage. Stage of sexual maturation in the girls in New York was determined on the basis of a combination of menarcheal status and breast and pubic hair development (10) and was not equivalent to the stages of breast and pubic hair development described by Tanner (11). Young et al (10) described the stages of sexual maturation as follows: premenarcheal with no secondary sexual development (stage 1); premenarcheal with some secondary sexual development (stage 2); premenarcheal at the time of study but attained menarche within 6 mo (stage 3); postmenarcheal with secondary sexual development not yet mature (stage 4); and postmenarcheal with mature secondary sexual development (stage 5).

BMI was calculated for all subjects. Percentage of body weight as fat (%Fat) was estimated from densitometry and the equation of Siri (12) for the sample of Mexican American boys from Austin, Texas (7), and from total body water converted to fat-free mass (FFM) for the samples of boys and girls from Vienna (9) and New York (10). The age- and sex-specific constants of Lohman (13) for the water content of the FFM were used to adjust for the chemical immaturity of the developing FFM in the boys in Vienna and the girls in New York. The age-specific constants of Lohman (13) for the density of the FFM were applied to the densities of the Mexican American boys; however, several negative values for %Fat were obtained. The suggested constants may not be appropriate for boys of Mexican American ancestry. Hence, the values calculated originally were used in the analysis.

Sensitivity, specificity, predictive value, and efficiency were calculated with the equations of Himes and Bouchard (2) as shown in **Figure 1**. The indicators of true obesity (overweight) were triceps skinfold thickness and %Fat. For BMI, cutoffs for the risk of becoming overweight and for the presence of overweight were

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TABLE 1
Characteristics of the 6 study groups used in analysis[1]

Location, study, sex, and ethnic group	Age[2]	Height	Weight	BMI	Triceps	%Fat
	y	*cm*	*kg*	*kg/m²*	*mm*	*%*
Ontario (white) (4)[3]						
Boys (*n* = 47)	13.0 ± 3.2 (9–19)	157.3 ± 19.6	51.3 ± 19.6	19.9 ± 3.8	12.2 ± 5.8	—
Girls (*n* = 39)	13.6 ± 3.1 (9–19)	154.9 ± 13.0	50.0 ± 18.9	20.2 ± 4.6	16.5 ± 7.1	—
California (girls) (5)[3]						
Mexican American (*n* = 331)	14.2 ± 1.6 (11–18)	156.1 ± 6.0	52.9 ± 9.8	21.7 ± 3.5	21.2 ± 5.6	—
White (*n* = 81)	14.1 ± 1.5 (12–17)	158.8 ± 6.9	53.7 ± 11.9	21.2 ± 3.9	21.6 ± 5.9	—
Black (*n* = 27)	13.4 ± 1.6 (12–17)	161.8 ± 6.1	56.1 ± 10.8	21.4 ± 3.6	20.5 ± 6.2	—
Asian (*n* = 63)	14.6 ± 1.5 (12–18)	152.9 ± 6.3	48.8 ± 8.3	20.8 ± 3.3	20.8 ± 5.9	—
Austin, Texas (6)[4]						
Mexican American boys (*n* = 95)	11.9 ± 1.8 (9–15)	141.0 ± 11.3	36.0 ± 9.0	17.8 ± 2.2	8.4 ± 3.3	14.1 ± 5.4
Brownsville, Texas (Mexican American) (7, 8)[5]						
Boys (*n* = 318)	13.6 ± 2.5 (9–18)	154.2 ± 13.5	49.0 ± 13.2	20.2 ± 3.0	11.2 ± 5.8	—
Girls (*n* = 357)	13.7 ± 2.5 (9–18)	150.3 ± 9.6	48.3 ± 11.2	21.1 ± 3.5	18.3 ± 7.4	—
Austria (9)[6]						
White boys (*n* = 108)	12.3 ± 1.4 (10–15)	152.1 ± 11.3	41.6 ± 8.8	17.8 ± 1.7	8.2 ± 2.2	14.8 ± 6.4
New York (10)[7]						
White girls (n = 104)	12.6 ± 2.0 (9–17)	153.9 ± 11.7	45.0 ± 10.2	18.7 ± 2.2	—	22.7 ± 10.3

[1] $\bar{x}$ ± SD. %Fat, percentage body fat; Triceps, triceps skinfold thickness.
[2] Range in parentheses.
[3] Weight, height, and 4 skinfold thicknesses were measured in all subjects.
[4] Height, weight, body density (by underwater weighing), and 4 skinfold thicknesses were measured in all subjects.
[5] Weight, height, and triceps skinfold thickness were measured in all subjects.
[6] Weight, height, total body water, 2 skinfold thicknesses, and genital development were reported for all subjects.
[7] Weight, height, total body water, and stage of sexual maturation were reported for all subjects.

those recommended by Himes and Dietz for adolescents (1). Risk of overweight was defined as a BMI at or above the 85th percentile and below the 95th percentile, whereas the presence of overweight was defined as a BMI at or above the 95th percentile of age- and sex-specific US reference data (1, 14). A third category was created in which the 2 groups (at risk and overweight) were combined. The percentile cutoffs for the triceps skinfold thickness were the same as for BMI using the same reference sample (14). The cutoffs for %Fat were from the charts of Lohman (15). For boys, risk of overweight was defined as ≥20%Fat and the presence of overweight was defined as ≥25%Fat. For girls, the cutoff for risk of overweight was ≥25%Fat and that for presence of overweight was ≥30%Fat. These percentages are higher than those used by Himes and Bouchard (2) on the basis of total body water predicted from weight and height (16).

RESULTS

The number of subjects, the subjects' age, body size, and indicators of fatness are shown in Table 1; the estimated prevalence of the risk of overweight and presence of overweight in each sample is shown in **Table 2**. In the 3 samples for which %Fat was estimated, prevalence of the risk of overweight was greater when the criterion used was %Fat than when BMI or triceps skinfold thickness was used. In the sample of boys from Vienna, the prevalence of the risk of overweight using the triceps skinfold thickness as the criterion was zero, followed by a low prevalence with BMI as the criterion (1.9%). The corresponding prevalence with BMI as the criterion was 6.7% in the sample of New York girls. With %Fat as the criterion, 21.3% and 42.3% of the boys from Vienna and girls from New York, respectively, were classified as being at risk of overweight. In the sample of Mexican American boys, prevalences of the risk of overweight were 4.2%, 5.3%, and 13.7% with the triceps skinfold thickness, BMI, and %Fat used as the respective criterion. In contrast, no individuals in the 3 samples were classified as overweight.

In the other samples, with few exceptions, the prevalence of the risk of overweight with either BMI or triceps skinfold thickness as the criterion was reasonably similar. With BMI as the criterion (though numbers were small in some samples), fewer black and Asian girls were classified as being at risk of overweight, whereas prevalences for Mexican American and white girls were higher. The prevalence of overweight in all samples was low, ranging from 0.0% to 6.4% with BMI as the criterion, and from 0.0% to 12.8% with the triceps skinfold thickness as the criterion. The most recent sample of white boys from northern Ontario had the highest prevalence of overweight (12.8%) with the triceps skinfold thickness as the criterion.

Validity of the BMI as an indicator of the risk of overweight and of the presence of overweight is shown in **Table 3**. Specificities of the BMI relative to the triceps skinfold thickness and %Fat were high, indicating that almost all boys and girls not obese were classified correctly. In contrast, sensitivities (ie, proportions of subjects truly at risk of overweight or truly overweight) were variable, ranging from 20.0% to 75.0% for the risk of overweight with the triceps skinfold thickness as the criterion and from 4.3% to 30.8% for the risk of overweight with %Fat as the criterion (Table 3). In the samples from Europe and New York, the BMI was a poor predictor of the risk of overweight compared with %Fat. Perhaps the cutoff value for the risk of overweight based on %Fat was too low or, conversely, the cutoff values for the risk of overweight based on the BMI and subcutaneous fatness (triceps skinfold thickness) were too high such that the criteria did not appropriately reflect safe amounts of total body fatness. Sensitivities ranged from 14.3% to 60.0% for overweight (Table 3). Several samples had no or only few individuals classified as overweight by either the BMI, triceps skinfold thickness, or %Fat.

The predictive value of the BMI as an indicator of the risk of overweight relative to the triceps skinfold thickness varied among samples from 16.7% in Canadian girls to 80.0% in Asian girls (Table 3). Corresponding data for the BMI as an indicator of the risk of overweight relative to %Fat were limited and predictive values were 50.0%, 57.1%, and 80.0% in European white boys, American white girls, and Mexican American boys, respectively. The predictive value of the BMI as an indicator of overweight was generally high in all samples for which it could be calculated with the exception of Mexican American girls in California (16.7%). The predictive value for Mexican American girls from Texas was 76.9%. In contrast, efficiency of the BMI as an indicator of the risk of overweight and of overweight was reasonably high among samples.

Relations between indicators of overweight are of potential interest in the context of selecting a reasonable index with which to assess adiposity or obesity in adolescents. Partial correlations, controlling for age, between the BMI and the triceps skinfold thickness and estimated %Fat (indicators of overweight), though significant, varied among samples (Table 3). With few exceptions, the correlations were moderate to moderately high. The lowest correlations were those in the samples from Europe and New York. These were also the samples with the lowest specificities when %Fat was used as the criterion. Thus, the weaker relations between BMI and %Fat in these samples may explain the poor specificity.

Partial correlations controlled for age, of %Fat and total body fat with BMI and triceps skinfold thickness are shown in **Table 4**. BMI and triceps skinfold thickness appeared to be equally related to estimated total body fatness and %Fat in Mexican American and European white males. In the sample of American white females, the correlations were slightly lower (especially those for BMI and %Fat); comparisons between the indicators could not be made because of lack of data on the triceps skinfold thickness.

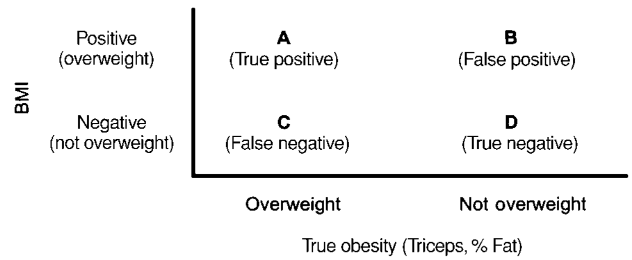

FIGURE 1. Sensitivity and specificity of anthropometric indicators of obesity. Triceps, measured by triceps skinfold thickness; %Fat, measured by percentage body fat. Calculations were as follows: prevalence (%) = (A + C)/(A + B + C + D) × 100; sensitivity (%) = A/(A + C) × 100; specificity (%) = D/(B + D) × 100; predictive value (%) = A/(A + B) × 100; and efficiency (%) = (A + D)/(A + B + C + D) × 100. Adapted from Himes and Bouchard (2).

The triceps skinfold thickness, though easily accessible for measurement cross-culturally, may have limitations as an indicator of overweight. Thus, partial correlations, controlled for age, between BMI and the sum of 4 skinfold thicknesses and individual skinfold thicknesses, were calculated. The correlations were moderate to moderately high and did not vary between ethnic groups (**Table 5**). It appeared that BMI was better correlated with trunk skinfold thicknesses. Given population variation in relative subcutaneous fat distribution, which generally indicates a trunk-extremity contrast, relative subcutaneous fat distribution may be a potential confounder of the relation between BMI and skinfold thicknesses. When relative fat distribution in the form of a trunk-to-extremity ratio was controlled (Table 5), partial correlations between BMI and the sum of 4 skinfold thicknesses and individual skinfold thicknesses did not appreciably differ from

TABLE 2
Prevalence of the risk of overweight and the presence of overweight based on BMI (in kg/m^2), triceps skinfold thickness (Triceps), and percentage body fat (%Fat)

Location, study, sex, and ethnic group	BMI		Triceps		%Fat	
	Risk	Presence	Risk	Presence	Risk	Presence
			%			
Ontario (white) (4)						
Boys	14.9	6.4	8.5	12.8	—	—
Girls	15.4	2.6	7.7	5.1	—	—
California (girls) (5)						
Mexican American	14.2	3.6	20.2	4.2	—	—
White	16.0	4.9	13.6	7.4	—	—
Black	7.4	3.7	18.5	0	—	—
Asian	7.9	3.2	22.2	1.6	—	—
Austin, Texas (6)						
Mexican American boys	5.3	0	4.2	0	13.7	0
Brownsville, Texas (Mexican American) (7, 8)						
Boys	14.5	3.1	6.6	6.0	—	—
Girls	14.8	3.6	11.8	7.6	—	—
Austria (9)						
White boys	1.9	0	0	0	21.3	0
New York (10)						
White girls	6.7	0	—	—	42.3	0

TABLE 3
Validity of BMI as an indicator of the risk of overweight and the presence of overweight compared to triceps skinfold thickness (Triceps) and percentage body fat (%Fat)[1]

Location, study, characteristics, and indicator	Risk (≥85 and <95th percentile)				Presence ≥95th percentile				Risk (≥85th percentile)				
	Se	Sp	PV	E	Se	Sp	PV	E	Se	Sp	PV	E	r^2
Ontario (white) (4)													
Boys (Triceps)	75.0	90.7	42.9	89.4	50.0	100.0	100.0	93.6	70.0	91.9	70.0	87.2	0.81
Girls (Triceps)	66.7	86.1	16.7	84.2	50.0	100.0	100.0	97.4	60.0	88.2	42.9	84.6	0.81
California (girls) (5)													
Mexican American (Triceps)	32.8	89.8	46.8	78.9	14.3	96.8	16.7	93.3	97.6	92.4	67.8	81.9	0.59
White (Triceps)	54.5	90.0	46.2	85.2	60.0	98.7	75.0	95.1	70.6	92.2	70.6	87.7	0.68
Black (Triceps)	20.0	95.5	50.0	81.5	—	96.3	—	96.3	60.0	95.5	66.7	85.2	0.64
Asian (Triceps)	28.6	98.0	80.0	82.5	—	96.8	—	95.2	33.3	95.8	71.4	81.0	0.53
Austin, TX (6)													
Mexican American boys													
Triceps	75.0	97.8	60.0	96.8	—	100.0	—	100.0	75.0	97.8	60.0	96.8	0.74
%Fat	30.8	98.8	80.0	89.5	—	100.0	—	100.0	30.8	98.8	80.0	89.5	0.58
Brownsville, TX (Mexican American) (7,8)													
Boys (Triceps)	61.9	88.9	28.3	87.1	36.8	99.0	70.0	95.3	77.5	91.0	55.4	89.3	0.65
Girls (Triceps)	47.6	89.5	37.7	84.6	37.0	99.1	76.9	94.4	72.5	94.4	75.8	90.2	0.83
Austria (9)													
White boys													
Triceps	—	98.1	—	98.1	—	100.0	—	100.0	—	98.1	—	98.1	0.36
%Fat	4.3	98.8	50.0	78.7	—	100.0	—	100.0	4.3	98.8	50.0	78.7	0.49
New York (10)													
White girls (%Fat)	9.0	95.0	57.1	57.7	—	100.0	—	100.0	9.0	95.0	57.1	57.7	0.28

[1] Se, sensitivity; Sp, specificity; PV, predictive value; E, efficiency.
[2] Partial correlations, controlled for age, between the BMI and the indicator of obesity. All correlations were significant at $P < 0.01$.

the correlations indicated previously. Further, the trunk-extremity contrast in the correlations between BMI and individual skinfold thicknesses was no longer apparent.

DISCUSSION

With use of the triceps skinfold thickness and estimated %Fat as the criteria for the risk of overweight or for the presence of overweight, BMI as an indicator of each condition had high specificity and lower but variable sensitivity. Thus, almost all adolescents who were not at risk of overweight or who were not overweight were classified correctly. In contrast, many adolescents who were at risk of overweight or who were overweight were not identified correctly with the BMI. These results are consistent with estimates for Canadian youth of French Canadian (2) and European (3) ancestry. There may have been ethnic variation in sensitivities. With the triceps skinfold thickness as the criterion, sensitivities for BMI as an indicator of the risk of overweight may have been somewhat higher in Mexican Americans and whites than in the small samples of blacks and Asians. Corresponding sensitivities for BMI as an indicator of overweight were lower in Mexican American than in white adolescents.

Ethnic variation in relative subcutaneous fat distribution and in the relative proportions of the trunk and lower extremities to height are potentially confounding factors in the use of the BMI as an index of adiposity (17, 18). Individual and population differences in the timing and tempo of the adolescent growth spurt and sexual maturation may be additional concerns in the interpretation of BMI. For example, the lower extremities experience maximum growth, on average, before maximum growth in the trunk, whereas maximum growth in body mass occurs, on average, more coincident with growth of the trunk (19). Population variation is evident in the timing of peak height velocity during the adolescent spurt and sexual maturation (age at menarche). These events occur earlier in American blacks than in American whites; they also occur earlier in southern Chinese and Japanese people than in Europeans (20, 21).

Stage of sexual maturation may be a confounder when interpreting BMI as an indicator of the risk of overweight and of the

TABLE 4
Partial correlations, controlled for age, between percentage body fat (%Fat) and total body fat (TBF), and the BMI and triceps skinfold thickness (Triceps)[1]

Location, study, sex, and ethnic group	%Fat		TBF	
	BMI	Triceps	BMI	Triceps
Austin, TX (Mexican American boys) (6)	0.58	0.65	0.75	0.75
Austria (white boys) (9)	0.49	0.56	0.56	0.57
New York (white girls) (10)	0.28	—	0.46	—

[1] All correlations significant at $P < 0.01$.

TABLE 5
Partial correlations between the BMI and individual skinfold thicknesses, first controlled for age and then controlled for age and relative subcutaneous fat distribution[1]

Location, study, sex, and ethnic group	Controlled for age					Controlled for age and TER				
	SUM4	Triceps	Medial calf	Subscapular	Suprailiac	SUM4	Triceps	Medial calf	Subscapular	Suprailiac
Ontario (white) (4)										
Boys	0.89	0.81	0.80	0.84	0.89	0.88	0.87	0.85	0.79	0.84
Girls	0.92	0.81	0.77	0.90	0.89	0.89	0.80	0.86	0.89	0.86
California (girls) (5)										
Mexican American	0.70	0.59	0.49	0.67	0.63	0.64	0.61	0.54	0.58	0.53
White	0.88	0.68	0.77	0.84	0.83	0.85	0.72	0.82	0.79	0.79
Black	0.80	0.64	0.60	0.82	0.81	0.79	0.81	0.71	0.78	0.77
Asian	0.67	0.53	0.50	0.63	0.66	0.64	0.60	0.52	0.57	0.60
Austin (6)										
Mexican American boys	0.78	0.74	0.66	0.79	0.73	0.78	0.77	0.73	0.78	0.72

[1] SUM4, triceps + medial calf + subscapular + suprailiac skinfold thicknesses; TER, trunk-to-extremity ratio [(subscapular + suprailiac) / (triceps + medial calf)]. All correlations were significant at $P < 0.01$.

presence of overweight (**Table 6**). On average, BMI increases with stage of genital maturation in boys (though not significantly), whereas the triceps skinfold thickness does not; relative fatness, in contrast, decreases in the later stages of maturation (reflecting the rapid growth of FFM at this time). BMI also increases with stage of sexual maturation in girls, but estimates of relative fatness are variable, especially in girls who recently attained menarche (stage 3). Partial correlations, controlled for age, between BMI and %Fat, total body fat, and triceps skinfold thickness within each stage of sexual maturation are shown in Table 6. With the exception of boys in genital stage 2, correlations between BMI and estimated relative and absolute fatness were highest in prepubertal boys and somewhat lower later in puberty. Corresponding correlations for the triceps skinfold thickness were lower. Among girls, correlations between BMI and estimated relative and absolute fatness decreased with advancing maturation and were negative in the small sample of girls who recently attained menarche. The correlations varied in magnitude, emphasizing the need to control statistically for chronologic age within stages of sexual maturation when making comparisons. Chronologic age by itself may influence the indexes under consideration.

The partial correlations of estimated %Fat and total body fat with BMI and triceps skinfold thickness (Table 4) were generally lower than those reported by Roche et al (22) for youth aged 6.0–12.9 y and 13.0–17.9 y. The differences might reflect methodologic variation in estimating body composition. In addition, the reported correlations were zero order values without control for chronologic age. Because absolute and relative fatness, BMI, and triceps skinfold thickness vary with age during childhood and adolescence, this is expected.

The variable sensitivities (ie, proportions of subjects truly at risk of overweight or truly overweight) of the BMI relative to the triceps skinfold thickness as an indicator of the risk of overweight

TABLE 6
Descriptive statistics for age and fatness indicators by stage of sexual maturation and correlations between BMI and other indicators of fatness within each stage[1]

Location, study, sex, and stage of sexual maturation	Age	BMI	Triceps	%Fat	r[2]		
					%Fat	TBF	Triceps
	y	*kg/m²*	*mm*	*%*			
Austria, white males (9)							
Stage 1 (n = 35)	10.8 ± 0.6	16.6 ± 1.4	7.7 ± 2.6	15.4 ± 5.7	0.75	0.81	0.48
Stage 2 (n = 28)	11.9 ± 0.6	17.8 ± 1.2	8.5 ± 1.9	16.1 ± 6.4	—	—	—
Stage 3 (n = 18)	13.2 ± 0.8	18.2 ± 2.2	8.7 ± 2.0	15.0 ± 5.8	0.53	0.67	—
Stage 4 (n = 19)	13.9 ± 0.6	18.6 ± 1.0	8.2 ± 2.4	12.7 ± 7.4	0.57	0.61	0.49
Stage 5 (n = 8)	14.6 ± 0.4	19.8 ± 1.3	8.3 ± 1.7	12.2 ± 7.4	—	—	—
New York, white females (10)							
Stage 1 (n = 20)	10.2 ± 0.7	16.8 ± 1.7	—	18.2 ± 8.6	0.47	0.59	—
Stage 2 (n = 25)	11.4 ± 1.0	17.9 ± 2.3	—	24.0 ± 11.6	0.55	0.72	—
Stage 3 (n = 12)	12.9 ± 1.2	18.7 ± 2.0	—	15.9 ± 10.3	—	—	—
Stage 4 (n = 14)	13.6 ± 1.4	18.8 ± 1.4	—	27.1 ± 6.7	—	—	—
Stage 5 (n = 33)	14.6 ± 1.4	20.4 ± 1.7	—	25.2 ± 9.7	—	0.35	—

[1] $\bar{x}$ ± SD. Stages of sexual maturation are defined in the text. Based on ANCOVA, with age as the covariate, BMI and percentage body fat (%Fat) were not significantly different among maturity stages in boys, but were significantly different among maturity stages in girls ($P < 0.05$). Among girls, BMI in stage 1 was significantly lower than in stages 4 and 5, and BMI in stage 2 was significantly lower than in stage 5. %Fat was significantly lower in stage 3 than in stage 4. Triceps, triceps skinfold thickness.

[2] Partial correlations, controlled for age, between BMI and %Fat, total body fat (TBF), and Triceps within stage of sexual maturation. All correlations are significant at $P < 0.05$.

and of overweight may be related to the different classifications of overweight and obesity. Van Itallie and Abraham (23) attempt to identify 3 types: 1) overweight, not obese (high BMI, low skinfold thicknesses), 2) obese, not overweight (high skinfold thicknesses, low BMI), and 3) overweight and obese (high BMI and high skinfold thicknesses). Growth characteristics of black, white, and Mexican American children classified as obese by the triceps skinfold thickness alone, by BMI alone, and by both BMI and triceps skinfold thickness were reported previously (24). Children of both sexes classified as obese by BMI alone were heavy and had large estimated midarm muscle circumferences. Children classified as obese by both BMI and triceps skinfold thickness were especially heavy (heavier than the BMI obese) and had larger estimated midarm muscle circumferences (but not as large as the BMI obese). Children classified as obese by the triceps skinfold thickness only were generally heavier than average, but were variable in stature and estimated midarm muscle circumference. Although there was some variation among the 3 ethnic groups, it appears that different types of overweight and obesity were identified by different criteria (24). These observations were in children 6–12 y of age and should be replicated in adolescents, given the considerable growth of arm musculature, especially in males, during adolescence (18).

In summary, application of the reference and cutoff values recommended by an expert committee (1) to several ethnically diverse samples showed BMI to have high specificity, but low and variable sensitivity, as an indicator of the risk of overweight and of the presence of overweight in adolescents. On the other hand, the efficiency of the BMI as an indicator of the risk of overweight and of overweight was relatively high. Allowing for the ease of measuring height and weight in the field setting, the BMI is an acceptable and valid indicator of the risk of overweight and the presence of overweight in adolescents. The BMI, however, is only a screening tool; adolescents identified as being at risk of overweight or as overweight should be referred for appropriate counseling.

REFERENCES

1. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 1994;59:307–16.
2. Himes JH, Bouchard C. Validity of anthropometry in classifying youths as obese. Int J Obes 1989;13:183–93.
3. Marshall JD, Hazlett CB, Spady DW, Conger PR, Quinney HA. Validity of convenient indicators of obesity. Hum Biol 1991;63:137–53.
4. Katzmarzyk PT. A familial study of growth and health-related fitness among Canadians of Aboriginal and European ancestry. PhD dissertation. Michigan State University, East Lansing, 1997.
5. Malina RM, Huang Y-C, Brown KH. Subcutaneous adipose tissue distribution in adolescent girls of four ethnic groups. Int J Obes Relat Metab Disord 1995;19:793–7.
6. Zavaleta AN, Malina RM. Growth and body composition of Mexican American boys 9 through 14 years of age. Am J Phys Anthropol 1982;57:261–71.
7. Malina RM, Zavaleta AN, Little BB. Estimated overweight and obesity in Mexican American school children. Int J Obes 1986;10:483–91.
8. Malina RM, Zavaleta AN, Little BB. Body size, fatness and leanness of Mexican American children in Brownsville, Texas: changes between 1972 and 1983. Am J Public Health 1987;77:573–77.
9. Haschke F. Body composition of adolescent males. Acta Paediatr Scand Suppl 1983;307:1–23.
10. Young CM, Bogan AD, Roe DA, Lutwak L. Body composition of preadolescent and adolescent girls. IV. Total body water and creatinine excretion. J Am Diet Assoc 1968;53:579–87.
11. Tanner JM. Growth at adolescence. 2nd ed. Oxford, United Kingdom: Blackwell, 1962.
12. Siri WE. Gross composition of the body. In: Tobias CA, Lawrence JH, eds, Advances in biological and medical physics. Vol 4. New York: Academic Press, 1956:239–80.
13. Lohman TG. Applicability of body composition techniques and constants for children and youth. Exerc Sport Sci Rev 1986;14:325–57.
14. Must A, Dallal GE, Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht^2) and triceps skinfold thickness. Am J Clin Nutr 1991;53:839–46, 54:773.
15. Lohman TG. Advances in body composition assessment. Champaign, IL: Human Kinetics, 1992.
16. Rauh JL, Schumsky DA. Lean and non-lean body mass estimates in urban school children. In: Cheek DB, ed. Human growth, body composition, cell growth, energy, and intelligence. Philadelphia: Lea and Febiger, 1968:242–52.
17. Malina RM, Brown KH, Zavaleta AN. Relative lower extremity length in Mexican American and in American black and white youth. Am J Phys Anthropol 1987;72:89–94.
18. Malina RM. Regional body composition: age, sex and ethnic variation. In: Roche AF, Heymsfield SB, Lohman TG, eds. Human body composition. Champaign, IL: Human Kinetics, 1996:217–55.
19. Malina RM, Bouchard C. Growth, maturation, and physical activity. Champaign, IL: Human Kinetics, 1991.
20. Berkey CA, Dockery DW, Wang X, Wypij D, Ferris B. Longitudinal height velocity standards for U.S. adolescents. Stat Med 1993;12:403–14.
21. Eveleth PB, Tanner JM. Worldwide variation in human growth. 2nd ed. Cambridge, United Kingdom: Cambridge University Press, 1990.
22. Roche AF, Siervogel RM, Chumlea WC, Webb P. Grading body fatness from limited anthropometric data. Am J Clin Nutr 1981;34:2831–8.
23. Van Itallie TB, Abraham S. Some hazards of obesity and its treatment. In: Hirsch J, Van Itallie TB, eds. Recent advances in obesity research. IV. London: John Libbey, 1985:1–19.
24. Malina RM, Skrabanek MF, Little BB. Growth and maturity status of black and white children classified as obese by different criteria. Am J Hum Biol 1989;1:193–9.