Introduction: the use of body mass index to assess obesity in children[1,2]

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ABSTRACT The International Obesity Task Force (IOTF) was established in 1994 to address the increase in the worldwide prevalence of obesity. The goals of the IOTF are to *1*) raise awareness in the population and among governments that obesity is a serious medical condition, *2*) develop policy recommendations for a coherent and effective global approach to the management and prevention of obesity, and *3*) implement appropriate strategies to manage and prevent obesity on a population basis worldwide. To assess the global prevalence of obesity in children and adolescents, the IOTF convened a workshop on childhood obesity to determine the most appropriate measurement to assess obesity in populations of children and adolescents around the world. At the workshop, a variety of issues related to this problem were considered—including the best measure of fatness, the effect of application of a variety of existing standards on the prevalence of obesity in the same population, and the role of factors such as visceral adiposity and natural history in the definition of obesity. This article and those that follow represent the information presented at the workshop. The workshop concluded that the body mass index (BMI; in kg/m^2) offered a reasonable measure with which to assess fatness in children and adolescents and that the standards used to identify overweight and obesity in children and adolescents should agree with the standards used to identify grade 1 and grade 2 overweight (BMI of 25 and 30, respectively) in adults. *Am J Clin Nutr* 1999;70(suppl):123S–5S.

KEY WORDS BMI, body mass index, obesity, children, adolescents, underwater weighing, DXA, dual-energy X-ray absorptiometry, undernutrition, International Obesity Task Force

INTRODUCTION

A preliminary review of the prevalence of childhood obesity (1) indicated that the criteria used to assess obesity in children and adolescents varied widely. Therefore, it appeared essential to determine the most appropriate measurement with which to define obesity in children and adolescents for global use before the worldwide prevalence of childhood and adolescent obesity could be explored. As a result, the International Obesity Task Force (IOTF) convened a workshop on childhood obesity to explore the strengths and limitations of existing approaches to the measurement of childhood obesity. The workshop was held in Dublin on 16 June 1997 immediately before the European Congress on Obesity.

The workshop began with a review of the validity of the body mass index (BMI; in kg/m^2) as a measure of body fat and as an index of morbidity. Several factors were also considered that either contribute to the validity of the cutoff point used to define obesity or could modify or augment the definition of obesity. These factors included the effect of curve smoothing and transformations on the cutoff point, the likelihood that obesity will persist at various BMI cutpoints in childhood, and the contribution of visceral fat. The effect of obesity cutpoints, based on populations in the United States and United Kingdom, on prevalence was examined in several different populations to illustrate the importance of an international reference population to assess the prevalence of obesity. Because almost all the data considered at the workshop were derived from Europe or North America, validation studies in other populations are needed. Nonetheless, the articles included here and the consensus that emerged from the workshop provide a research agenda that will *1*) significantly improve our understanding of the strengths and limitations of the measures used to define obesity, *2*) define the characteristics of the populations required to develop an international reference population, and *3*) help specify the research agenda necessary to validate the definition of obesity that we have proposed.

USE OF BMI TO ASSESS OBESITY IN CHILDREN

The BMI now appears to be a widely accepted index for classifying adiposity in adults. Furthermore, a consensus conference proposed the use of a BMI above the 85th percentile as a screening index for overweight, and a BMI above the 95th percentile as an index of excess adiposity in adolescents (2–4). However, the validity of the BMI as an index of fatness has not been carefully examined or extensively studied in younger children or adolescents. Therefore, the conference began with a brief review of the

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TABLE 1
Correlations of percentage body fat with body mass index in boys and girls of different ages and ethnic groups[1]

Method, study, and subject characteristics	*r*
DXA	
Goran et al (6) (4–10 y)[2]	
Boys	
White (*n* = 86)	0.71
Black (*n* = 39)	0.82
Girls	
White (*n* = 89)	0.82
Black (*n* = 55)	0.82
Gutin et al (7) (9–11 y)[2]	
Boys (*n* = 21)	0.71
Girls (*n* = 22)	0.87
Daniels et al (8) (7–17 y)	
Boys	
White (*n* = 51)	0.50
Black (*n* = 49)	0.54
Girls	
White (*n* = 52)	0.83
Black (*n* = 40)	0.83
Underwater weighing	
Roche et al (9)	
Age 6–12 y	
Boys (*n* = 68)	0.68
Girls (*n* = 49)	0.55
Age 13–18 y	
Boys (*n* = 63)	0.68
Girls (*n* = 81)	0.77
Deurenberg et al (10)	
Age 7–10 y	
Boys (*n* = 56)	0.59
Girls (*n* = 83)	0.63
Age 11–15 y	
Boys (*n* = 177)	0.44
Girls (*n* = 164)	0.65

[1]DXA, dual-energy X-ray absorptiometry.
[2]Includes unpublished data from the same author.

validity of the BMI as a measure of adiposity in children and adolescents and an examination of the strengths and limitations of its use in populations.

MEASURES OF BODY FAT

Ideal measurements of body fat in populations should be reliable and correlate well with body fat in both sexes and across all ages and ethnic groups. Furthermore, because individuals of different heights or body builds may have similar fat masses yet substantially different proportions of total body fat, and because obesity connotes a condition of excess body fat, body fat expressed as a percentage of body weight (percentage body fat) is the most relevant measure against which anthropometric measurements should be correlated. Although other measures, such as triceps skinfold thickness, offer direct measurements of subcutaneous fat and are reasonably well correlated with percentage body fat, measurements by different observers and measurements of fatter subjects are difficult to reproduce. In contrast, the high reliability of measurements of height and weight suggests that a variant of weight-for-height provides a more reliable measure of adiposity that can be used to compare adiposity within and between populations.

Measurements of body composition in children and adolescents with which anthropometric measures can be correlated have generally been based on measurements of body density, determined either by underwater weighing or dual-energy X-ray absorptiometry (DXA). In the former, the weight of the subject is divided by the volume of water displaced by the subject, corrected for residual air in the lungs. Based on assumed densities of fat mass and fat-free mass, body composition can be estimated (5). More recently, use of DXA has provided an alternative measure of density. DXA offers several advantages over underwater weighing. First, because immersion is not required, a broader age range of subjects can be analyzed. Second, bone density can be measured directly and the composition of fat-free mass adjusted accordingly. Therefore, DXA appears to be less dependent on assumptions about the density of fat-free mass than is underwater weighing. Finally, no correction is required for residual air in the lungs.

CORRELATION OF BMI WITH MEASURES OF TOTAL BODY FAT

The correlation coefficients of percentage body fat measured with underwater weighing and BMI are generally lower than those measured with DXA and BMI (**Table 1**). The difference in strength of the correlations may indicate that underwater weighing provides a less reliable or valid measure of total body fat in children and adolescents than does DXA or that the assumptions that underlie the calculations of total body fat from underwater weighing are incorrect. On the basis of the DXA measurements, correlation coefficients between percentage body fat and BMI appear comparable among young boys and girls and lower among older boys than among older girls. The only study that examined subjects by stage of puberty (8) suggested that, at similar BMIs, mature boys had less body fat than girls.

Two studies have examined children and adolescents in nonwhite racial or ethnic groups (6, 8). As shown in Table 1, correlation coefficients between percentage body fat and BMI for white and black children appear comparable. However, race and ethnicity add significantly to the regression coefficient when included in multiple regression models to predict percentage body fat (8). Black children had lower percentages body fat than did white children with the same BMI. In a separate study, black girls matched with white girls for BMI had significantly lower total, visceral, and subcutaneous adipose tissue (11).

POTENTIAL PROBLEMS WITH THE USE OF THE BMI AS AN INDEX OF ADIPOSITY

At least 3 problems potentially confound the use of the BMI as an index of adiposity in different populations. First, until more studies include ethnic groups other than whites, BMI should be used cautiously in assessing fatness across populations. Second, because the studies cited in Table 1 apply only to nonobese children and adolescents, these data do not exclude the possibility that a BMI above the 95th percentile may provide a more specific measure with which to identify children and adolescents with increased body fat. Calculation of the sensitivity and specificity of a BMI above the 85th and 95th percentiles for an increase in percentage body fat would provide critical insight into the validity of these BMI cutpoints to assess obesity. Lastly, prior undernutrition may affect the validity of the BMI. Several studies of populations with a significant prevalence of undernutrition have shown that among short children, factors other than increased body fat may be responsible for the increased weight-for-height (12). Additional studies of body composition in stunted populations with a high weight-for-height are essential to determine whether the higher weight-for-height is attributable to increased body fat.

In summary, the BMI offers a reasonable measure of fatness in children and adolescents. To provide a consistent assessment of obesity across the life span, the cutpoint selected to identify obesity in children should agree with that used to identify obesity in adults.

REFERENCES

1. Guillaume M. Defining obesity in childhood: current practice. Am J Clin Nutr 1999;70(suppl):126S–30S.
2. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 1994;59:307–16.
3. 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.
4. Must A, Dallal GE, Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht^2)—a correction. Am J Clin Nutr 1991;54:773.
5. Forbes GB. Human body composition. New York: Springer Verlag, 1987.
6. Goran MI, Driscoll P, Johnson R, Nagy TR, Hunter G. Cross-calibration of body-composition techniques against dual-energy X-ray absorptiometry in young children. Am J Clin Nutr 1996;63:299–305.
7. Gutin B, Litaker M, Islam S, Manos T, Smith C, Treiber F. Body-composition measurement in 9–11-year-old children by dual-energy X-ray absorptiometry, skinfold thickness measurements, and bioimpedance analysis. Am J Clin Nutr 1996;63:287–92.
8. 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;99:804–7.
9. Roche AF, Siervogel RM, Chumlea WC, Webb P. Grading body fatness from limited anthropometric data. Am J Clin Nutr 1981;34:2831–8.
10. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. Br J Nutr 1991;65:105–14.
11. Yanovski JA, Yanovski SZ, Filmer KM, Hubbard VS, Avila N, Lewis B, Reynolds JC, Flood M. Differences in body composition of black and white girls. Am J Clin Nutr 1996;64:833–9.
12. Trowbridge FL, Marks JS, Lopez de Romana G, Madrid S, Boutton TW, Klein PD. Body composition of Peruvian children with short stature and high weight-for-height. II. Implications for the interpretation for weight-for-height as an indicator of nutritional status. Am J Clin Nutr 1987;46:411–8.
13. Sawaya AL, Dallal G, Solymos G, et al. Obesity and malnutrition in a shantytown in the city of Sao Paulo, Brazil. Obesity Res 1995;3(suppl):107S–15S.
14. Popkin BM, Richards MK, Monteiro CA. Stunting is associated with overweight in children of four nations that are undergoing the nutrition transition. J Nutr 1996;126:3009–16.