Prevalence of overweight in US children: comparison of US growth charts from the Centers for Disease Control and Prevention with other reference values for body mass index[1,2]

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ABSTRACT

Background: Several different sets of reference body mass index (BMI) values are available to define overweight in children.

Objective: The objective of this study was to compare the prevalence of overweight in US children calculated with 3 sets of reference BMI values: the revised growth charts of the Centers for Disease Control and Prevention (CDC-US growth charts), international standards proposed by Cole et al, and values developed by Must et al.

Design: Data for children and adolescents came from cross-sectional nationally representative US surveys: cycles II and III of the National Health Examination Survey (1963–1965 and 1966–1970) and the first, second, and third National Health and Nutrition Examination Surveys: NHANES I (1971–1974), II (1976–1980), and III (1988–1994). The reference values of Cole et al equivalent to a BMI of 25 were compared with the 85th percentiles from the other 2 methods; the values equivalent to a BMI of 30 were compared with the 95th percentiles.

Results: The 3 methods gave similar but not identical results. The reference values of Cole et al gave lower estimates than did the CDC-US growth charts for young children but higher estimates for older children. The reference values of Must et al gave much higher prevalences for younger girls than did the other 2 methods.

Conclusions: Differences between methods were related to differences in data sets, smoothing methods, and theoretical approaches. All 3 methods are based on statistical criteria and incorporate arbitrary assumptions. These methods should be used cautiously, with awareness of the possible limitations. *Am J Clin Nutr* 2001;73:1086–93.

KEY WORDS Adolescents, body weight, body mass index, children, health surveys, overweight, obesity, growth charts, National Health and Nutrition Examination Survey, NHANES

INTRODUCTION

Children and adolescents can be defined as overweight on the basis of a variety of reference percentiles based on body mass index (BMI) in various populations. Some issues surrounding the use of such reference values were discussed elsewhere (1, 2). A widely used set of reference BMI values is that developed by Must et al (3), which is based on the sample from the first National Health and Nutrition Examination Survey (NHANES I). In this reference set, smoothed values of BMI for selected percentiles are provided for single years of age from 6 to 19 y, separately for boys and girls. In the absence of widely accepted international reference values for defining overweight in children and adolescents, Must et al's values were recommended by a World Health Organization (WHO) Expert Committee in 1995 (4).

Two more recent sets of reference values were developed. The Centers for Disease Control and Prevention growth charts for the United States (CDC-US growth charts), which are the revised version of the 1977 National Center for Health Statistics (NCHS) growth charts, include values for BMI percentiles and other anthropometric data (5). These reference values are based on US national survey data and are intended to be used for US children and adolescents.

Cole et al (6) developed another set of reference BMI values intended for use in international comparisons. These proposed values are smoothed percentiles but were derived by using an approach different from that used for the other 2 methods. Percentiles were chosen to match the adult BMI cutoffs of 25 and 30 at age 18 y, without specifying the centile in advance. The centiles corresponding to BMI values of 25 and 30 were estimated separately for several large nationally representative data sets from different countries, including the United States, Brazil, Great Britain, Hong Kong, the Netherlands, and Singapore, and then combined. The objective was to propose cutoff values for defining childhood overweight and obesity that could be used to provide internationally comparable prevalence estimates, with the advantages of being less arbitrary (because they were based on adult reference values) and more internationally based (because they used data from several countries) than other sets of reference values.

The new CDC-US growth charts are intended to provide appropriate reference BMI values for US children and adolescents. The reference values provided by Must et al have been used widely in both the United States and internationally and are currently recommended by the WHO. The reference values of

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TABLE 1
Examples of BMI reference values for selected age categories for boys

Age (mo)	Age labels in the original reference: CDC-US growth charts	Cole et al	Must et al	Level 1[1]: CDC-US growth charts	Cole et al	Must et al	Level 2[2]: CDC-US growth charts	Cole et al	Must et al
	mo	*y*	*y*		*kg/m²*			*kg/m²*	
84.0–84.9	84.5	7.0	7	17.40	17.92	17.37	19.15	20.63	19.18
85.0–85.9	85.5	7.0	7	17.44	17.92	17.37	19.22	20.63	19.18
86.0–86.9	86.5	7.0	7	17.48	17.92	17.37	19.29	20.63	19.18
87.0–87.9	87.5	7.5	7	17.53	18.16	17.37	19.37	21.09	19.18
88.0–88.9	88.5	7.5	7	17.57	18.16	17.37	19.44	21.09	19.18
89.0–89.9	89.5	7.5	7	17.61	18.16	17.37	19.52	21.09	19.18
90.0–90.9	90.5	7.5	7	17.66	18.16	17.37	19.59	21.09	19.18
91.0–91.9	91.5	7.5	7	17.71	18.16	17.37	19.67	21.09	19.18
92.0–92.9	92.5	7.5	7	17.76	18.16	17.37	19.75	21.09	19.18
93.0–93.9	93.5	8.0	7	17.80	18.44	17.37	19.83	21.60	19.18
94.0–94.9	94.5	8.0	7	17.85	18.44	17.37	19.91	21.60	19.18
95.0–95.9	95.5	8.0	7	17.90	18.44	17.37	19.99	21.60	19.18

[1] Corresponds to the 85th percentile for the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts; 5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 25.

[2] Corresponds to the 95th percentile for the CDC-US growth charts (5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 30.

Cole et al are intended to provide cutoff BMI values useful for making international comparisons. The objective of this article was to compare prevalence estimates of overweight for US children and adolescents derived from these 3 sets of reference values and to discuss the differences and similarities between these reference values.

METHODS

Data sets

NHANES III was conducted from 1988 to 1994 by the NCHS of the CDC. A nationally representative sample of the US civilian noninstitutionalized population was selected by using a complex, stratified, multistage probability cluster-sampling design. A home interview was followed by a physical examination in a mobile examination center. A description of the plan and operation of the survey was previously published (7).

NHANES III is one of a series of cross-sectional surveys. Previous surveys include cycles II and III of the National Health Examination Survey (NHES II, 1963–1965; NHES III, 1966–1970) and NHANES I (1971–1974) and II (1976–1980). NHES II included children aged 6–11 y and NHES III included adolescents aged 12–17 y. NHANES I, II, and III included adults and children.

In all of these surveys, ages are in months at the time of examination, truncated to the last full month (eg, a child aged 73 mo and 2 wk was considered to be 73 mo of age); height was measured by using standardized techniques and equipment (8); and BMI was calculated as weight (kg) divided by the square of height (m).

Reference values

The revised version of the CDC-US growth charts includes BMI percentiles for ages 2–19 y. These values were based on data from the series of US health examination surveys, including NHES II and III and NHANES I, II, and III. However, NHANES III data for children aged ≥6 y were not included in the reference population because of the increasing trends in overweight for children in this survey (9). The revised CDC-US growth charts provide reference BMI percentiles for single months of age, expressed as the midpoint of the month (eg, reference values for children aged 73.0–73.9 mo would be given at 73.5 mo). Issues regarding age groupings for this and the other reference values below were discussed in more detail elsewhere (10).

Cole et al's reference values are presented in 0.5-y increments and do not represent groupings but rather the point values at that exact age. Thus, the value for 9 y is considered the appropriate reference value for children aged 8 y and 9.0 mo to 9 y and 2.9 mo because it represents the midpoint of that 6-mo interval. Similarly, the value for 9.5 y is considered the appropriate reference value for children aged 9 y and 3.0 mo to 9 y and 8.9 mo.

Must et al, when smoothing the NHANES I data, categorized children and adolescents into single-year age groupings based on age at the last birthday, calculated the percentile values for each year of age, and then smoothed those points. Thus, Must et al's values at age 9 y represent all 9-y-olds in the NHANES I sample, including children aged 9 y and 0 mo up to, but not including, children aged 10 y and 0 mo. Because the average age of children within year-of-age groupings is likely to represent approximately the midpoint of the range, these values are considered to represent the approximate value for a child aged 9.5 y. The appropriate procedure when using this reference is to group children by year of age based on age at the last birthday (eg, from 9 y and 0 mo to 9 y and 11 mo) and to evaluate all children in that group by using the reference value labeled age 9 y.

A sample of the cutoff BMI values for the 3 reference methods is shown in **Table 1** for boys aged 84.0–95.9 mo (7 y old). The revised CDC-US growth charts give values for each month. Cole et al's reference values include point values that are spaced at 6-mo age intervals. These point values were used as the reference values for 6-mo intervals centered on the age at the point value of Cole et al. Must et al's values are single values for children grouped by age at the last birthday.

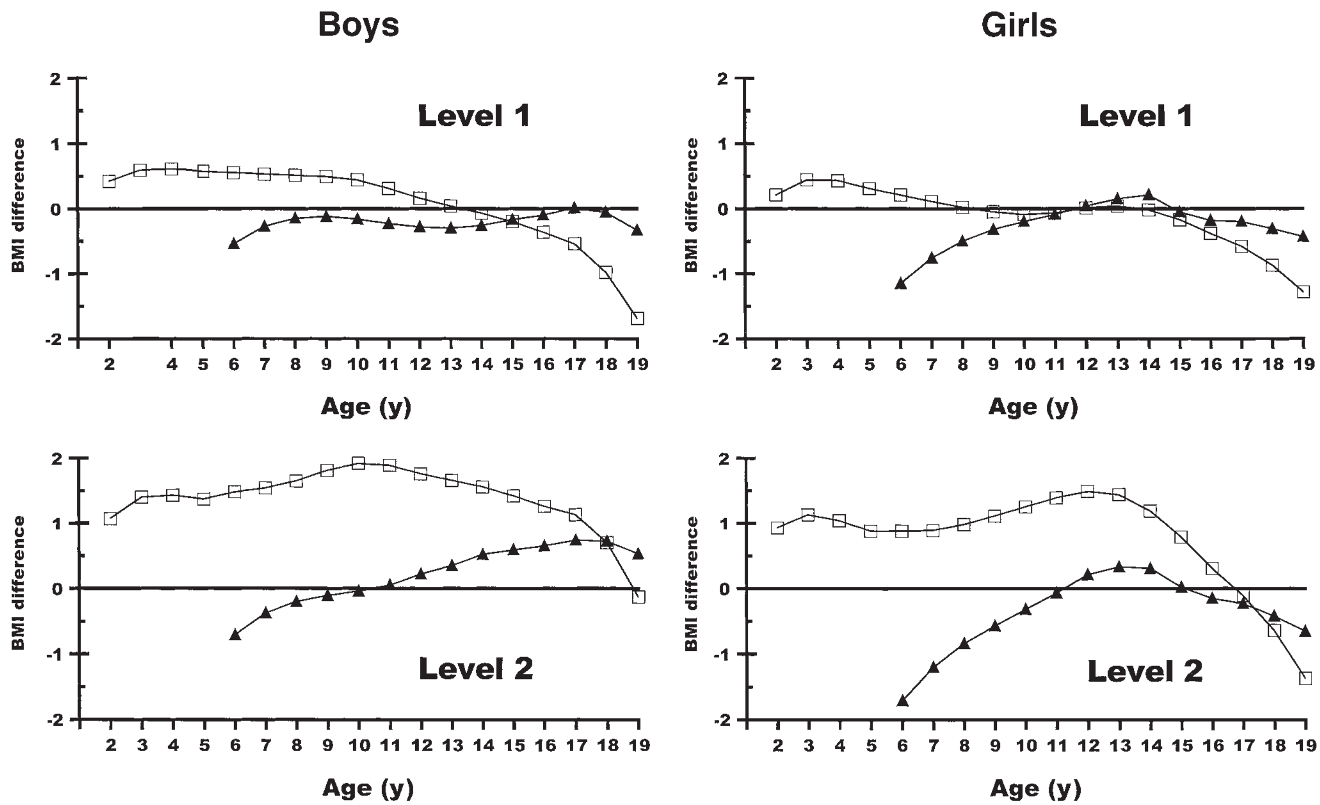

FIGURE 1. Differences in BMI units between reference values of the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts) and those of Cole et al (□; 6; calculated as Cole et al reference values minus CDC-US growth chart reference values) and those of Must et al (▲; 3; calculated as Must et al reference values minus CDC-US growth chart reference values) by age, sex, and reference level. Level 1 corresponds to the 85th percentile for the CDC-US growth charts and Must et al's reference values and to the reference values of Cole et al equivalent to an adult BMI of 25. Level 2 corresponds to the 95th percentile for the CDC-US growth charts and Must et al's reference values and to the reference values of Cole et al equivalent to an adult BMI of 30.

Definitions of overweight

Terminology in this field is not completely standardized. It has been recommended that children between the 85th and 95th percentiles of BMI or weight-for-height not be labeled as overweight but rather to be at possible risk of overweight and be evaluated further (11, 12). However, BMI values >85th percentile are sometimes considered to indicate overweight. In Cole et al's article, the 2 levels corresponding to a BMI of 25 and to a BMI of 30 are called *overweight* and *obesity*, respectively, to match the terminology used for adults.

In this paper, for convenience and to avoid terminologic confusion, we refer to 2 different levels of reference values that can be considered to define some degree of overweight simply as *level 1* and *level 2*. Level 1 corresponds to the 85th percentile for the CDC-US growth charts and Must et al's reference values and to the reference values of Cole et al equivalent to an adult BMI of 25. Level 2 corresponds to the 95th percentile for the CDC-US growth charts and Must et al's reference values and to the reference values of Cole et al equivalent to an adult BMI of 30.

Statistical methods

Data analyses were carried out by using SAS (13). For each survey, sampling weights were calculated taking into account the unequal probabilities of selection resulting from the sample design and from planned oversampling of certain subgroups. These sample weights were used for all prevalence estimates. Here and elsewhere, no statistical tests are provided because these estimates were derived by applying different cutoffs to the same data sets. Because the data sets are the same and only the cutoff values vary, the differences can be in only one direction. For example, if cutoff values of 25 and 30 are applied to the same data set, it is not possible for the prevalence calculated on the basis of the cutoff of 30 to be less than the prevalence estimate calculated on the basis of the cutoff of 25. Statistical tests and CIs for the differences between estimates calculated by using standard methods would not be meaningful or applicable in this case.

RESULTS

The mean differences between the CDC-US growth chart percentiles and Cole et al's and Must et al's reference values are shown in **Figure 1** by sex, age (in y), and reference-value level (level 1 or 2). Ages were grouped by single year of age as in age at the last birthday (in other words, age 2 y represents 24 mo through 35 mo) and differences were averaged over all months within the year. At level 1 for both boys and girls, Cole et al's values were higher than those of the CDC-US in the youngest group. At older ages, Cole et al's values first approached the CDC-US values and then became progressively lower than the CDC-US values, with a difference of −1.69 BMI units for 19-y-olds. At level 2, Cole et al's values were almost uniformly higher

TABLE 2
Prevalence of BMIs ≥level 1 reference values for boys, by age group and survey[1]

Age group and reference values	NHES II (1963–1965) and III (1966–1970)	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)
		%		
2–5 y				
CDC-US growth charts	—	17.2	12.7	16.7
Cole et al	—	8.2	7.1	9.2
Must et al	—	—	—	—
6–8 y				
CDC-US growth charts	11.2	12.1	15.8	23.3
Cole et al	7.6	9.1	12.5	18.3
Must et al	14.4	14.6	19.3	25.2
9–11 y				
CDC-US growth charts	13.6	17.6	17.4	27.8
Cole et al	11.8	14.5	15.6	25.2
Must et al	14.3	18.3	19.4	29.1
12-14 y				
CDC-US growth charts	14.8	14.1	15.6	29.4
Cole et al	14.5	14.4	15.4	29.1
Must et al	16.2	15.3	16.9	30.0
15–17 y				
CDC-US growth charts	12.8	14.7	14.4	23.2
Cole et al	15.5	17.4	16.5	27.1
Must et al	13.5	14.4	14.9	23.5
18–19 y				
CDC-US growth charts	—	18.6	12.2	16.0
Cole et al	—	22.8	22.0	23.6
Must et al	—	20.0	13.7	16.2

[1] Level 1 corresponds to the 85th percentile for the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts; 5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 25. NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

than those of the CDC-US, particularly for boys, for whom most of the differences were greater by ≥1 BMI unit. The exception was at the oldest ages, for which Cole et al's values were lower than those of the CDC-US for both boys and girls.

At level 1, Must et al's reference values tended to be lower (generally by <0.5 BMI units) than those of the CDC-US for boys and girls, with a few exceptions. At level 2, the differences for girls were similar to those seen at level 1; Must et al's values were lower than those of the CDC-US, except in one age group. The differences tended to be larger at level 2; Must et al's values were lower than those of the CDC-US by 1.7 BMI units for girls aged 6 y. For boys, the pattern was different. Must et al's values were lower than those of the CDC-US at younger ages but were higher than those of the CDC-US at older ages.

The differences between Cole et al's and Must et al's reference values were equivalent to the difference between the 2 curved lines in Figure 1. For example, at level 1 for boys aged 7 y, Cole et al's value was 0.53 BMI units higher than the CDC-US value and Must et al's value was 0.27 units lower than the CDC-US value. The difference between these 2 numbers, 0.80, is the difference between Cole et al's and Must et al's values. At level 1, Cole et al's values tended to be greater than those of Must et al at the younger ages and then became progressively lower than Must et al's values at lower ages. At level 2, Cole et al's values were considerably greater than those of Must et al at the younger ages, then approached the values of Must et al, becoming lower than the values of Must et al only in the oldest age group. The differences at age 6 y were quite large: Cole et al's values were 2.2 and 2.6 BMI units higher than Must et al's values for boys and girls, respectively.

Estimated prevalence of BMIs ≥level 1 reference values

The prevalence of a BMI ≥level 1 reference values for boys is shown in **Table 2** by survey, age group, and source of reference values. All 3 sets of reference values showed a marked increase in prevalence between NHANES II and NHANES III. For the age range 12–14 y, there was close agreement between all 3 sets of values, with differences generally <1.5 percentage points.

Relative to the CDC-US growth charts, Cole et al's method gave lower prevalence estimates for boys aged 2–5 and 6–8 y, slightly lower prevalence estimates for boys aged 9–11 and 12–14 y, and higher prevalence estimates for boys aged 15–17 and 18–19 y. Some of the differences were large, up to 10 percentage points. For all age groups, Must et al's reference values tended to produce slightly higher prevalences than did the CDC-US growth charts, with only a few exceptions. Cole et al's prevalence estimates were lower than those of Must et al at ages 6–8, 9–11, and 12–14 y. These differences were most striking in the age group 6–8 y, in which the prevalence estimates based on Cole et al's reference values were 5–7 percentage points lower than the estimates based on Must et al's reference value. At ages 15–17 and 18–19 y, Must et al's estimates were lower than those of Cole et al, especially in the age group 18–19 y (a difference >8 percentage points in one instance).

The trends with age differed between methods. There were no consistent trends with age with the methods of the CDC-US and

TABLE 3
Prevalence of BMIs ≥level 1 reference values for girls, by age group and survey[1]

Age group and reference values	NHES II (1963–1965) and III (1966–1970)	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)
		%		
2–5 y				
CDC-US growth charts	—	13.9	15.6	19.1
Cole et al	—	10.4	11.2	14.8
Must et al	—	—	—	—
6–8 y				
CDC-US growth charts	12.4	11.0	12.5	23.3
Cole et al	11.5	10.2	11.8	22.7
Must et al	20.5	20.9	19.9	31.1
9–11 y				
CDC-US growth charts	15.4	14.5	16.1	25.6
Cole et al	15.5	15.0	17.1	26.4
Must et al	16.7	14.6	17.4	27.8
12–14 y				
CDC-US growth charts	16.2	22.3	17.1	30.9
Cole et al	15.9	21.5	17.3	31.2
Must et al	15.6	20.6	16.2	29.7
15–17 y				
CDC-US growth charts	13.2	17.3	13.3	23.0
Cole et al	15.0	18.7	15.3	25.0
Must et al	14.2	17.7	14.0	24.0
18–19 y				
CDC-US growth charts	—	10.1	12.6	18.5
Cole et al	—	14.4	17.8	23.8
Must et al	—	10.8	14.4	21.1

[1] Level 1 corresponds to the 85th percentile for the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts; 5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 25. NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

Must et al, although there was some variability. With Cole et al's method, however, there were striking differences with age. For instance, in NHES II and III the prevalence of overweight doubled from 7.6% in 6–8-y-olds to 15.5% in 15–17-y-olds.

The corresponding data for the prevalence of BMIs ≥level 1 reference values for girls are shown in **Table 3**. The relation among methods was somewhat different for girls than for boys, but the general patterns were similar. For girls, Cole et al's estimates were lower than those of the CDC-US by ~4 or 5 percentage points for ages 2–5 y; similar to those of the CDC-US for ages 6–8, 9–11, and 12–14 y; and higher than those of the CDC-US for ages 15–17 and 18–19 y. There were differences of ~2 percentage points in the age group 15–17 y and of ~4–5 percentage points in the age group 18–19 y.

For girls, the method of Must et al gave strikingly higher prevalences in the age group 6–8 y than did either of the other 2 methods. Must et al's reference values yielded prevalence estimates 8–10 percentage points higher than either of the other 2 methods in this age group. In other age groups, Must et al's and the CDC-US estimates agreed fairly well, with differences generally of <2 percentage points.

The results of the comparison between boys and girls differed somewhat by method. Use of the CDC-US growth charts gave similar results for both boys and girls. Use of Cole et al's and Must et al's methods both resulted in higher prevalence estimates for girls than for boys in the younger groups (2–5 and 6–8 y). In the age group 6–8 y, the most striking differences were those obtained with the use of Must et al's method; the prevalence estimate for girls was 6 percentage points higher than that for boys in 3 of the 4 surveys.

Estimated prevalence of BMIs ≥level 2 reference values

Corresponding data for the prevalence of BMIs ≥level 2 reference values for boys and girls by survey and age group are shown in **Tables 4** and **5**, respectively. Results are similar to those for the level 1 cutoffs. For boys, Cole et al's method gave lower prevalence estimates than did either the CDC-US growth charts or Must et al's method; the differences were larger in the younger age groups. The estimates obtained with Must et al's method were generally close to those obtained with the CDC-US growth charts; estimates tended to be somewhat higher in the younger age groups.

For girls, Cole et al's method gave lower prevalence estimates than did the CDC-US growth charts up to age 17 y, but higher estimates in the 18–19-y age group. Must et al's method gave estimates similar to those obtained with the CDC-US growth charts for ages >9 y. For the age group 6–8 y, the estimates obtained with Must et al's method were distinctly greater than those obtained with the other 2 methods.

DISCUSSION

The revised US growth charts from the CDC provide a set of reference values for children and adolescents in the United States (5). For the first time, these charts also include charts of BMI-for-age. The use of these 85th and 95th percentiles to

TABLE 4
Prevalence of BMIs ≥level 2 reference values for boys, by age group and survey[1]

Age group and reference values	NHES II (1963–1965) and III (1966–1970)	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)
		%		
2–5 y				
CDC-US growth charts	—	5.0	4.7	6.2
Cole et al	—	1.8	1.9	2.5
Must et al	—	—	—	—
6–8 y				
CDC-US growth charts	3.4	2.5	5.5	10.8
Cole et al	1.9	1.1	3.4	7.7
Must et al	4.6	5.6	8.0	12.7
9–11 y				
CDC-US growth charts	4.6	5.9	7.8	12.8
Cole et al	2.7	2.8	4.0	6.5
Must et al	5.0	5.6	8.4	12.4
12–14 y				
CDC-US growth charts	4.7	5.9	4.7	11.9
Cole et al	3.0	3.5	2.6	6.9
Must et al	4.5	5.7	4.4	11.7
15–17 y				
CDC-US growth charts	4.2	4.9	4.4	12.0
Cole et al	3.1	3.4	3.4	8.9
Must et al	3.6	4.1	3.4	11.1
18–19 y				
CDC-US growth charts	—	8.3	5.8	9.2
Cole et al	—	7.8	5.1	9.3
Must et al	—	6.7	5.0	7.2

[1] Level 2 corresponds to the 95th percentile for the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts; 5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 30. NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

define overweight was recommended by an Expert Committee convened by the Maternal and Child Health Bureau (12). The reference BMI values published by Must et al (3), derived from NHANES I, were recommended for international use by a WHO Expert Committee in a 1995 publication (4). Must et al derived their values by using the same general approach used for the CDC-US growth charts and even from one of the same data sets, NHANES I, that was used to develop the CDC-US growth charts. The CDC-US growth charts are more comprehensive and include more of the available US data.

The method proposed by Cole et al represents a different approach to finding reference values and is based on a combination of data from several different countries. For both of these reasons, this method would not be expected to provide the same estimates as either the CDC-US growth charts or Must et al's reference values. Cole et al's reference values have been proposed for comparisons between countries to avoid the use of data from a single country for an international standard. In addition, Cole et al's reference values are linked to adult BMIs of 25 and 30, which indicate overweight and obesity, respectively, in adults (6).

The 3 methods discussed for providing reference values to define overweight in children did not give the same prevalence estimates; however, there were some similarities between all 3 methods. For example, regardless of the method used, we observed a similar trend over time for the children represented in NHANES III to have a considerably higher prevalence of overweight.

The differences between methods were sometimes large and tended to occur either in the youngest or the oldest age group. For example, for girls aged 6–8 y, Must et al's method gave level 1 prevalence estimates 8–10 percentage points higher than did either of the other 2 methods. For boys aged 18–19 y, use of the adult cutoff of a BMI of 25 gave prevalence estimates 8–10 percentage points higher than either of the other 2 methods.

The differences between methods were not systematic. For example, Cole et al's method gave lower prevalence estimates than did the other 2 methods at younger ages and higher prevalence estimates at older ages. The differences between the methods were different for boys and girls and between level 1 and level 2 reference values.

Differences between the methods may have arisen because of differences in the data sets used, in smoothing methods, and in approach. All 3 methods used some US data; however, Must et al's reference values are based only on a subset of US data and Cole et al's reference values are based on several data sets from other countries and on US data. The smoothing methods used differed between the data sets. In addition, Cole et al's method uses an approach different from that of the other 2 methods to define cutoffs. With Cole et al's method, cutoffs are defined by the percentiles that correspond to adult BMI values of 25 and 30 rather than by fixed percentiles, such as the 85th or 95th percentile, that are specified in advance.

The differences between the results of Cole et al's method and those of the CDC-US growth charts or Must et al's method

TABLE 5
Prevalence of BMIs ≥level 2 reference values for girls, by age group and survey[1]

Age group and reference values	NHES II (1963–1965) and III (1966–1974)	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)
		%		
2–5 y				
CDC-US growth charts	—	4.9	5.3	8.2
Cole et al	—	1.7	3.0	4.2
Must et al	—	—	—	—
6–8 y				
CDC-US growth charts	4.1	2.8	4.5	11.0
Cole et al	2.6	2.4	2.9	7.8
Must et al	7.9	5.5	9.1	17.2
9–11 y				
CDC-US growth charts	4.9	4.3	8.0	11.0
Cole et al	3.1	2.5	5.6	8.8
Must et al	5.8	5.0	8.3	12.0
12–14 y				
CDC-US growth charts	4.4	7.6	6.2	11.7
Cole et al	2.6	5.9	5.0	10.1
Must et al	3.8	7.3	6.1	11.6
15–17 y				
CDC-US growth charts	5.1	6.0	4.6	8.7
Cole et al	4.5	5.9	3.8	6.6
Must et al	5.2	6.1	4.7	8.3
18–19 y				
CDC-US growth charts	—	4.2	5.0	8.1
Cole et al	—	6.0	5.7	11.7
Must et al	—	5.0	5.4	10.4

[1] Level 2 corresponds to the 95th percentile for the Centers for Disease Control and Prevention growth charts for US children (CDC-US growth charts; 5) and Must et al's (3) reference values and to the reference values of Cole et al (6) equivalent to an adult BMI of 30. NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

suggest some systematic differences in age trends or in the distribution of BMIs between the US and the other countries (Brazil, Great Britain, Hong Kong, the Netherlands, and Singapore) included in the reference data set used in Cole et al's method. Although the differences between countries appear minor when the data corresponding to a BMI of 25 or 30 are plotted, at the youngest ages the percentile curve for the United States is generally the lowest or next to the lowest percentile curve (6). The US data set used by Cole et al included the same data used to develop the CDC-US growth charts, with the one difference that Cole et al excluded all NHANES III data. The CDC-US growth charts excluded NHANES III data for ages ≥6 y, but included NHANES III data for younger children because the inclusion of these data had little effect on the smoothed percentiles.

All 3 sets of reference values were derived from statistical definitions and incorporate arbitrary assumptions (1, 2). For instance, use of the age- and sex-specific 95th percentile to define overweight is equivalent to making the assumption that, in the reference population, exactly 5% of children within each age-sex group are overweight. Although Cole et al's method does not depend on choosing a fixed percentile in advance, it does in effect make a similar assumption that the proportion of overweight children is fixed within each age-sex group of the reference population. In general, for any method based on statistical criteria, caution should be exercised when comparisons are made across age or sex groups because, generally, the reference values will have been constrained to give similar results in each group. There is little evidence linking precise cutoffs to health outcomes.

The terminology for different childhood BMIs is not well established and should be used cautiously because of issues of stigmatization and labeling and because little is known for certain about the health implications of, for example, BMIs above the 85th percentile of a reference population (11, 12). Cole et al's method assumes that overweight and obesity are identified by BMIs of 25 and 30, respectively, at age 18 y and presumably thereafter. The use of these adult values produces a higher prevalence of overweight in 18–19-y-olds than does use of the 85th or 95th percentile cutoffs from the CDC-US growth charts or from Must et al. On the basis of the adult definition, more than one-fifth (22%) of 18–19-y-old male adolescents are defined as overweight, even in NHANES I, which was conducted almost 30 y ago. This surprisingly high percentage suggests the possibility that a BMI of 25 may be too stringent a definition of overweight for adolescent boys.

For use in the United States, the CDC-US growth charts are generally preferable to Must et al's reference values for several reasons. Must et al's reference values were previously recommended as interim values (11). The CDC-US growth charts are based on a larger reference population, use improved smoothing methods, provide reference values for each month of age, and provide the ability to estimate exact percentiles and *z* scores rather than being limited to selected percentiles. Note that although in many cases results will be similar with both methods, there may be a large difference in prevalence estimates for young girls. This difference may arise from possible oversmoothing of Must et al's percentiles in this age group

(14). The reference values provided by Cole et al may be useful for international comparisons. These values will produce results different from those produced with use of the CDC-US growth charts.

Researchers should be aware of the differences between these 3 methods. No single method is necessarily the correct method. Each method has its advantages and limitations and each should be used cautiously, with awareness of its possible limitations.

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