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Effective and appropriate use of Body Mass Index for children and adolescents

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ABSTRACT

Pediatric obesity is considered a major public health problem in the United States today. Because excess body fat is associated with various health risks, clinicians and researchers have been investigating effective ways to reduce the incidence of pediatric obesity. To identify at-risk individuals, the U.S. health care community encourages the use of Body Mass Index (BMI)—defined as weight/height² (kg/m²)—to classify children and adolescents into different health risk categories, including overweight and obese. However, the scientific validity of using BMI in pediatric population is questionable, even though BMI may be desirable as a means of tracking the growth patterns of individual children and adolescents in order to identify potential health problems. This review notes that BMI is not a reliable indicator of body fat for individual children and adolescents because it does not distinguish percent body fat from percent lean body mass. Neither does a single BMI value show the growth pattern of an individual child or adolescent. BMI does not account for distribution of body fat, ethnicity, and stages of maturation. Labeling children and adolescents as overweight or obese may lead to problems such as restrictive feeding by parents and unhealthy or unnecessary weight-control practices.

INTRODUCTION

Body Mass Index (BMI)—originally termed the Quetelet index—has been used extensively by researchers, the media, and a large proportion of people both in the United States and across the globe as a measure of fatness. The Quetelet index was originally developed by Belgian statistician Aldolphe Quetelet in the 19th century, and was renamed body mass index by Ancel Keys in 1972 (Quetelet, 1842; Keys *et al*., 1972).

BMI is a ratio of weight/height² (kg/m²). Currently, it is used to classify adults into different health risk categories worldwide (WHO, 2000; U.S. Department of Health and Human Services, 2000). In the United States, BMI is also used to classify children and adolescents (2-19 years of age) into different health risk categories (Barlow and the Expert Committee, 2007). Health risk categories are determined based on the age- and gender-specific BMI percentile on the 2000 Centers for Disease Control and Prevention (CDC) growth charts (Figures 1 and 2) as shown in Table 1 (Barlow and the Expert Committee, 2007).

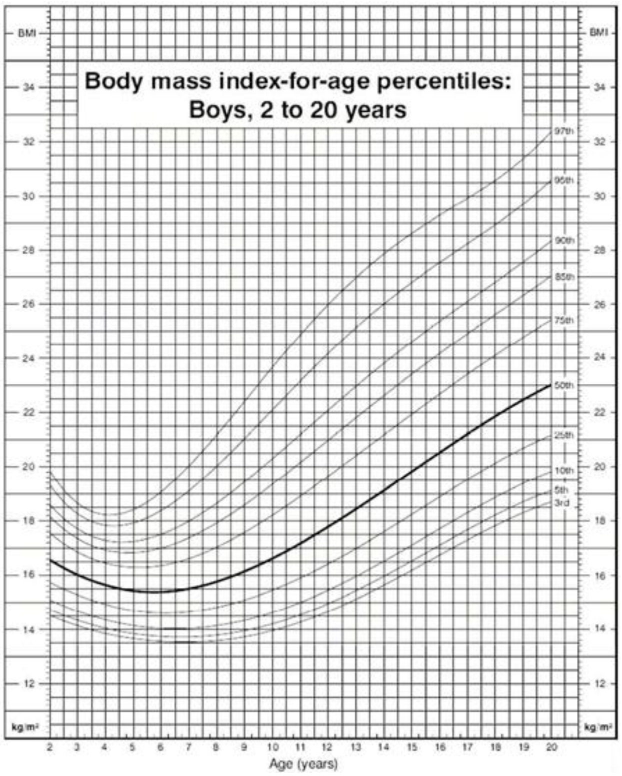

Figure 1. Male-specific BMI growth chart. Provided by the Centers for Disease Control and Prevention.

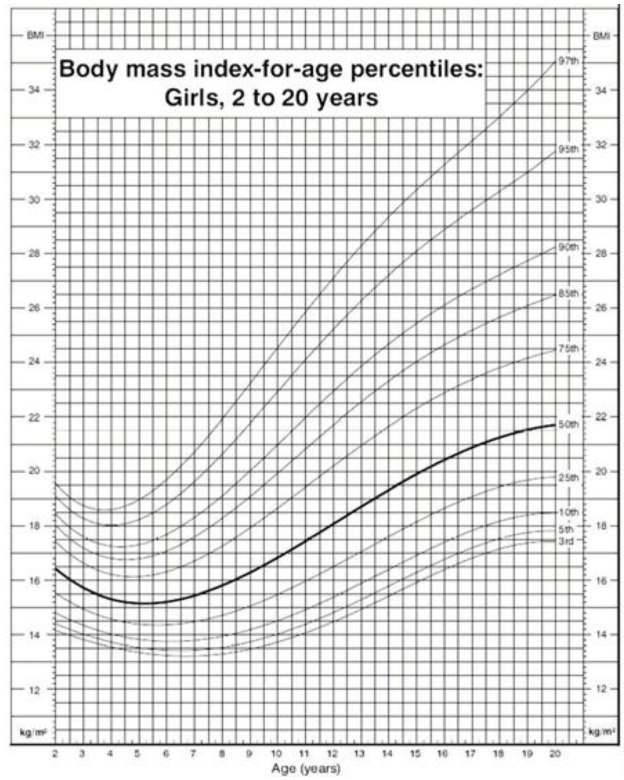

Figure 2. Female-specific BMI growth chart. Provided by the Centers for Disease Control and Prevention.

U.S. children and adolescents are getting heavier as a population (Kuczmarski *et al*., 2000). Currently, about 17% of children and adolescents are considered obese, and approximately 30% of children and adolescents have BMIs greater than the 85th percentile on the CDC BMI-for-age growth charts (i.e. are overweight or obese) (Ogden, *et al*., 2010). Some studies suggest that overweight children and adolescents are at increased risk of adverse health conditions later in adulthood (Srinivasan *et al*., 1996). Obese children and adolescents also tend to carry higher concurrent health risks in terms of blood pressure, serum cholesterol levels, and fasting insulin levels, compared with normal-weight counterparts (Freedman *et al*., 1999).

BMI level	Health risk Category
Below 5th percentile	Underweight
5th – 85th percentile	Healthy weight
85th – 94th percentile	Overweight
95th percentile or above	Obese

Table 1. BMI percentiles and corresponding health risk categories for individuals 2-18 years of age (Barlow and the Expert Committee, 2007)

In 2005, the American Medical Association (AMA), the Health Resources and Service Administration, and the CDC formed a new expert committee to revise 1998 recommendations regarding the prevention, assessment, and treatment of childhood obesity (Barlow and the Expert Committee, 2007). The goal of obesity treatment in children and adolescents is the adoption of a healthful lifestyle, which is characterized by eating a variety of foods, including fruit and vegetables, limiting sugar-sweetened beverage intake, decreasing television and other forms of screen time, and exercising regularly for

the reduction of cardiovascular disease risk and long-term physical health (Barlow and the Expert Committee, 2007; Spear *et al.*, 2007). For most cases, the general weight goal is a BMI of less than the 85th percentile on the 2000 CDC BMI-for-age growth charts, which were created based on data taken from the five national health examination surveys in the U.S. completed between 1963 and 1994 (Kuczmarski *et al.*, 2000; Spear *et al.*, 2007). The weight goals and intervention stages were determined based on the BMI categories, ages, and the prevalence of health risks. Structured dietary and physical activity changes are included as part of the intervention methods. Weight loss is recommended for children and adolescents only in certain BMI categories and ages (Barlow and the Expert Committee, 2007).

Some health professionals oppose the emphasis of BMI in clinical settings today as such an approach could adversely affect the growth of children and adolescents. Many researchers question the scientific validity of BMI because BMI fails to distinguish body fat mass from lean body mass (Freedman *et al.*, 2005; Kline 2001; Ellis *et al.*, 1999). BMI percentiles do not take body fat distribution and the maturation stage of children and adolescents into consideration (Daniels *et al.*, 1997). Some argue that the BMI percentiles cannot be applied to the multiethnic U.S. population because different ethnic groups may carry different degrees of health risks associated with high BMI percentiles (Daniels *et al.*, 1997). Epidemiologists have argued that BMI should not be used for individuals as a measure of adiposity because the correlation between BMI and body fat was based on population statistics data (Kline 2001; Ellis *et al.*, 1999). Labeling children and adolescents as overweight or obese may place them at risk of restrictive feeding by parents and of being engaged in unhealthy weight control practices (Satter, 2005). Inadequate intake of essential nutrients could then disrupt the normal growth and development of children and adolescents (Satter, 1986; Tsang & Nichols, 1988).

This literature review intends to examine the scientific validity of BMI and to investigate the potential harms of labeling children and adolescents as overweight or obese. This review begins with a discussion on how BMI is currently used in the U.S., followed by a discussion on how reliable BMI is to measure body fat levels of individual children and adolescents. Then, the potential harms brought by labeling children and adolescents as overweight or obese are discussed. The main scientific questions raised in this review are the following: Is it ethical to label children and adolescents as overweight or obese? Is BMI used appropriately for them today? If not, where and how can BMI be used appropriately?

CURRENT USE OF BMI IN THE U.S. PEDIATRIC POPULATION

The 2007 Expert Committee report regarding the assessment, treatment and prevention of childhood and adolescent overweight and obesity, recommends that clinicians measure BMI at every child's pediatric visit (Barlow and the Expert Committee, 2007). BMI level is calculated from the height and weight of a child or adolescent. The BMI level is then plotted on the 2000 CDC BMI-for-age growth chart. Individuals 2-19 years of age are considered overweight or obese according to the 2000 CDC growth charts if age- and gender-specific BMI percentiles are $\geq 85^{th}$ and $<95^{th}$ percentile, or $\geq 95^{th}$ percentile,

respectively (Barlow and the Expert Committee, 2007). For older adolescents, however, even if their BMI level is below 95^{th} percentile, they are considered obese when their BMI level meets or exceeds 30 kg/m^2 (Barlow and the Expert Committee, 2007). The terms “overweight” and “obese” were changed from “at risk of overweight” and “overweight,” respectively, when the current recommendations were created, as health professionals believed these terms better reflected the gravity of the pediatric obesity problem.

BMI serves as an initial health risk screening tool. After plotting BMI, the medical and behavioral risks of the child or adolescent are assessed. Based on the child’s or adolescent’s age, BMI level, presence of health risks, and readiness to change her/his lifestyle, different interventions are recommended. The Expert Committee recommends four stages of interventions of differing intensity. The first three stages mainly focus on behavior modification, such as dietary habit change, regular physical activity, and reduction in television and other forms of screen time. The final stage consists of the most intensive interventions, such as a very-low calorie diet, medications, and bariatric surgery, in addition to behavior modification. The weight goals are determined mainly based on age, BMI percentile, and the presence of health risks (Table 2). Weight maintenance results in reduction in BMI

Age	BMI category	Weight to improve BMI percentile
<2	Weight for height	Not appreciable
2-5	5^{th} – 84^{th} percentile or 85^{th} – 94^{th} percentile with no health risks	Weight velocity maintenance
	85^{th} – 94^{th} percentile with health risks	Weight maintenance or slow weight gain
	≥ 95^{th} percentile	Weight maintenance (weight loss of up to 1 lb./mo. may be acceptable if BMI is >21 or 22 kg/m^2)
6-11	5^{th} – 84^{th} percentile or 85^{th} – 94^{th} percentile with no health risks	Weight velocity maintenance
	85^{th} – 94^{th} percentile with health risks	Weight maintenance
	95^{th} – 99^{th} percentile	Gradual weight loss (1 lb./mo. or 0.5 kg/mo.)
	> 99^{th} percentile	Weight loss (max. 2 lbs./wk.)
12-18	5^{th} – 84^{th} percentile or 85^{th} – 94^{th} percentile with no health risks	Weight velocity maintenance; after linear growth is complete, weight maintenance
	85^{th} – 94^{th} percentile with health risks	Weight maintenance or gradual weight loss
	95^{th} – 99^{th} percentile	Weight loss (max. 2 lbs./wk.)
	> 99^{th} percentile	Weight loss (max. 2 lbs./wk.)

Table 2. Weight goal for children and adolescents with or without health risks, at different ages and BMI levels (Barlow and the Expert Committee, 2007).

as children and adolescents increase in height.

In actual clinical settings, however, not all physicians use BMI charts at a child's visit (Woolford *et al.*, 2008). Woolford *et al.*, conducted a survey on the use of BMI among 600 pediatricians and family physicians in the state of Michigan and found that about one-third of the physicians reported that they generally did not use BMI charts for preschool children. Possible barriers that prevented the physicians from using BMI charts included time costs associated with calculating and plotting BMI as well as complexity in explaining BMI to parents who were more familiar with height and weight curves.

To address the issue of pediatric obesity, BMI screening has begun in schools in some states like Arkansas, whose legislature passed a law requiring schools to send "BMI report cards" to parents in 2003 (Nihiser *et al.*, 2007). After the initiation of the BMI measurement program, the number of participating schools increased. During the year 2005-2006, 98.6% of schools in the state of Arkansas had adopted the program (Nihiser *et al.*, 2007). Not all students' data were collected, however, as some parents refused their children's participation in the study.

Although BMI measurement programs have been incorporated in many schools, the efficacy of school BMI screening in preventing and decreasing pediatric obesity is unclear (Nihiser *et al.*, 2007). Some researchers raise concern over BMI screening in schools because such an approach has the potential to exacerbate social stigmatization of students labeled as obese by BMI, to make students more concerned and dissatisfied with their weight, and to promote unhealthy weight control practices (Nihiser *et al.*, 2007; Ikeda, *et al.*, 2006).

SCIENTIFIC VALIDITY OF BMI FOR CHILDREN AND ADOLESCENTS

BMI and adiposity of individual children and adolescents

Studies have shown that high BMI percentiles correlate with high body fatness (Ellis *et al.*, 1999; Freedman *et al.*, 2009). Ellis *et al.* (1999), conducted a study to assess how well high BMI percentiles identified children and adolescents with excess body fat, because the validity of BMI to measure body fat level of individual children was uncertain despite experts' recommendations to use BMI. The subjects were children and adolescents 3-18 years of age residing in Houston, Texas metropolitan area. Dual-energy x-ray absorptiometry (DXA)—which had been found to be a more reliable indicator of body fatness compared with hydrodensitometry estimates—was used in the study to measure percent body fatness. Percentage of body-fat-ranking, specific for age and gender, was used to decide if individuals had excess body fat. Results showed a statistically significant correlation between BMI and percentage body fat.

Percentage of body fat (DXA)	Body Mass Index (BMI)							
	Females				Males			
	Normal	At risk [b]	Overweight [c]	Total	Normal	At risk [b]	Overweight [c]	Total
Normal	402	67	18	487	288	42	15	345
Excess [d]	5	28	24	57	6	14	20	40
Obese [e]	0	3	26	29	0	6	15	21
Total	407	98	68	573	294	62	50	406

Table 3. Comparison of body mass index and percentage of body fat rankings, for the total population of 979 White, Black, and Hispanic children living in the Houston, Texas metropolitan area, 1994-1998 [a] (Ellis *et al.*, 1999). The definitions "at risk" and "overweight" in this study correspond to "overweight" and "obese," respectively, according to the current definitions (Barlow and the Expert Committee, 2007).

[a] The cutpoints for the percentage of body fat groups were obtained for each gender population, independent of ethnicity.
[b] 85^{th} percentile $\leq$ BMI < 95^{th} percentile for age and gender.
[c] BMI $\geq$ 95^{th} percentile for age and gender.
[d] 85^{th} percentile $\leq$ percentage of fat ranking < 95^{th} percentile for gender.
[e] Percentage of fat ranking $\geq$ 95^{th} percentile for gender.

Among individuals with typical body fat percentages, 83% of females and males were classified as normal by BMI (Table 3). Sensitivity was recorded as 94% and 90% for females and males, respectively, meaning that 6% of females and 10% of males classified as "excess" or "obese" by DXA were classified as normal by BMI. The specificity was 83% for each gender, meaning that 17% of females and males with normal body fat percentage were mislabeled as at risk or overweight by BMI.

The results in Table 3 can be interpreted in the following way as well. Among those labeled as overweight by BMI, 26% ($^{18}/_{68}$ * 100) of females and 30% ($^{15}/_{50}$* 100) of males had normal body fat percentages. Thus, more than one in four individuals in the overweight category were mislabeled as overweight. Among those labeled as at-risk based on BMI, 68% of females and males had normal body fat percentages. In other words, about two in three individuals in the at-risk category were mislabeled as at-risk. Thus, in this study, there were a significant number of children and adolescents mislabeled as at risk or overweight by BMI. The results also clearly demonstrated that individuals with the same BMI level can have different body fat levels.

Freedman *et al.* (2009) also assessed the validity of BMI percentiles in estimating body fatness in the Pediatric Rosetta Body Composition project. This study also demonstrated that a large number of children and adolescents with high BMI percentile values had an elevated level of body fat, since 75% of boys and 80% of girls labeled as obese by BMI had elevated body fatness. However, among those with BMI between the 85^{th}

BMI-for-Age percentile	Number (%) of participants by body fatness category [a]					
	Boys			Girls		
	Normal	Moderate	Elevated	Normal	Moderate	Elevated
< 85th	392 (92)	28 (7)	5 (1)	353 (92)	30 (8)	1 (< 1)
85th – 94th	31 (32)	46 (47)	21 (21)	30 (29)	56 (55)	16 (16)
≥ 95th	2 (2)	24 (23)	77 (75)	1 (1)	16 (19)	67 (80)
Total	425	98	103	384	102	84

Table 4. Classification of children by BMI-for-age and body fatness categories (Freedman, *et al.*, 2009).

[a] The body fatness categories were defined so that the number of children in each of the 3 categories would be equal to the number of children in the corresponding BMI-for-age category.

and 94th percentile, about one-third of boys and girls had normal levels of body fatness, indicating that a significant number of children and adolescents were mislabeled as overweight by BMI. The results are given in Table 4.

The degree of misclassification differed according to race/ethnicity (Freedman *et al.*, 2009). Half of black children and adolescents classified as overweight by BMI had normal levels of body fatness while about one in four Asian children and adolescents in the overweight category had a normal level of body fatness. The results are given in Table 5. The fact that race or ethnicity affects the correlation between BMI and body fatness has been shown in other studies as well (Ellis *et al.*, 1999; Daniels *et al.*, 1997; Freedman & Sherry, 2009). Given a similar level of BMI, black children and adolescents tend to have lower levels of body fatness than those of white children and adolescents (Freedman & Sherry, 2009). Although the study results may not be generalizable to the current general pediatric population, it clearly shows that labeling children and adolescents as overweight or obese based on BMI percentile values alone will result in the misclassification of a significant number of individuals as having excess body fat.

Table 6 shows the percentage of children and adolescents with high BMI percentiles in 2007-2008 according to race or ethnicity. There is a clear racial difference in the prevalence of high BMI. Minority populations (Hispanic, Mexican American, and non-Hispanic black) have higher percentages of individuals with high BMI percentiles compared to non-Hispanic white and the national U.S. average (Ogden *et al.*, 2010). These results must be interpreted with caution because a higher percentage of overweight and obese individuals in a certain racial group does not necessarily indicate that more children and adolescents of the racial group have higher adiposity than other racial groups do.

As shown above (Freedman *et al.*, 2009), a significant portion of black children and adolescents classified as overweight by BMI had normal amounts of body fatness. In addition, different growth patterns among different race or ethnicity categories should be taken into

Characteristic	Number (%) of participants by body fatness category		
	Normal	Moderate	Elevated
Age (yrs.)			
< 9	8 (22)	18 (50)	10 (28)
9 – 11	20 (28)	41 (57)	11 (15)
12 – 14	15 (31)	25 (52)	8 (17)
≥ 15	18 (41)	18 (41)	8 (18)
Race/ethnicity [a]			
White	12 (27)	24 (55)	8 (18)
Black	18 (50)	11 (31)	7 (19)
Hispanic	12 (33)	20 (56)	4 (11)
Asian	16 (23)	39 (57)	14 (20)

Table 5: Body fatness among children who had a BMI for age between the 85th and 94th percentiles by age and race/ethnicity (Freedman, *et al.*, 2009).

[a] Analyses excluded the 92 children who had grandparents of different racial/ethnic groups. *P*<.05 for difference in the prevalence of normal vs. moderate or high levels of body fatness, adjusted for sex, across race/ethnicity groups.

account (Tybor *et al.*, 2010). Tybor *et al.* (2010), analyzed longitudinal data from the National Heart, Lung, and Blood Institute's Growth and Health Study to determine whether racial differences existed in the growth of waist circumference, which reflects the deposition of central body fat. The study showed that black girls had a higher annual mean increase in waist circumference than white girls did. However, adjusting for BMI and age at menarche resulted in the opposite trend: white girls had a higher annual mean increase in waist circumference compared with black girls. Thus, a higher percentage of overweight and obesity among black girls compared with white girls may be partly due to the fact that black girls undergo sexual maturation and experience increase in BMI, earlier than white girls do. Since BMI-for-age growth charts are age-specific and not race-specific, the different timing of sexual maturation among different race or ethnicity groups should be taken into consideration.

As Tybor's study showed, other researchers also found that BMI percentiles do not take stages of sexual maturation into account (Daniels, *et al.*, 1997). Stages of maturation can affect the correlation between BMI and body fatness. Daniels, *et al.* (1997), conducted a cross-sectional study on boys and girls 7-17 years of age to determine whether age, gender, race, sexual maturation, and distribution of body fat affected the correlation between BMI and body fatness. Results showed that these factors do affect the correlation between BMI and body fatness. The stage of sexual maturation was found to correlate with body fatness more than age. For individuals with similar BMI levels, more sexually mature adolescents are likely to have a lower level of adiposity than less sexually mature children. Girls carry a higher level of body fatness than boys do if they have a similar BMI level and maturation stage. Since the timing of sexual maturation differs from child to child, children of the same age with similar BMI levels can have different levels of body fatness.

BMI percentiles do not account for distribution of body fat, either. The same study by Daniels *et al.* (1997), showed that the waist-to-hip ratio, an indicator of central obesity, affects the correlation between BMI and body fatness. Children

BMI-for-age	Both sexes	Boys	Girls
BMI for age ≥ 95th percentile			
All [c]	16.9	17.8	15.9
Hispanic [d]	20.9	24.4	17.2
Mexican American	20.8	24.9	16.5
Non-Hispanic White	15.3	15.7	14.9
Non-Hispanic Black	20.0	17.3	22.7
BMI for age ≥ 85th percentile			
All [c]	31.7	32.1	31.3
Hispanic [d]	38.2	39.9	36.4
Mexican American	38.9	41.7	36.1
Non-Hispanic White	29.3	29.5	29.2
Non-Hispanic Black	35.9	33.0	39.0

Table 6: Percentage of children and adolescents 2-19 years of age with BMI ≥95th percentile and ≥85th percentile in the U.S. from 2007 to 2008 by sex and race/ethnicity [ab] (Ogden, *et al.*, 2010)

[a] Based on the Centers for Disease Control and Prevention 2000 growth charts.
[b] Body mass index (calculated as weight in kilograms divided by height in meters squared) was rounded to 1 decimal place. Pregnant adolescents were excluded. Data come from the National Health and Nutrition Examination Survey (NHANES).
[c] Includes racial/ethnic groups not shown separately.
[d] Includes Mexican American individuals.

and adolescents with higher waist-to-hip ratios tend to have higher body fatness compared with those with lower waist-to-hip ratios and similar BMI levels. Thus, the level of body fatness may be underestimated if individuals have high waist-to-hip ratios. Therefore, taking both BMI and a waist-to-hip ratio values may give clinicians a more representative picture of potential health risks that a child or adolescent may carry.

BMI does not distinguish fat mass from fat-free mass (Freedman *et al.*, 2005). Body weight consists of both fat mass and fat-free mass, including bones and muscles. Because BMI depends on only weight and height measures, individuals with a higher proportion of lean body mass may have a high BMI due to large weight, but not due to a large amount of fat mass (Maynard, *et al.*, 2001). Freedman, *et al.* (2005), used the results obtained in the Pediatric Rosetta Project to find the degree to which fat-free mass and fat mass contributed to BMI. The study found that BMI of thinner children was strongly correlated with fat-free mass, indicating that variations in BMI among relatively thin children and adolescents were largely due to fat-free mass. Thus, BMI is a very poor indicator of body fat for relatively thinner children and adolescents.

Having analyzed different indices of body composition, Bray *et al.* (2002) wrote, "BMI was almost useless as an estimator of percentage of body fat" for normal-weight children and adolescents. Interestingly, overweight children (with high BMI) tend to have not only higher fat mass but also higher fat-free mass (Freedman, *et al.*, 2005). Maynard *et al.* (2001) caution clinicians to bear in mind that increases in BMI during childhood and adolescence do not necessarily indicate increase in adiposity. Their study showed that the mean increase in BMI during childhood and adolescence was

mainly due to the increase in the fat-free mass (kg) to the square of height (m^2) ratio (FFM/height^2). For boys, rapid mean increase in FFM/height^2 (kg/m^2) and mean decrease in Total Body Fat mass (kg) to the square of height (m^2) ratio (TBF/height^2) were observed during adolescence. Compared with boys, girls showed smaller mean increase in FFM/height^2 and also showed continuous increase in TBF/height^2. The annual increase of FFM/height^2 was much greater than the annual increase of TBF/height^2 for girls 10-14 years of age. This study clearly showed that for adolescents, the mean increase in FFM/height^2 makes a significant contribution to the mean increase in BMI. Also noted in this study, BMI was correlated with height in early adolescent boys; and for girls 8-13 years of age, FFM was correlated with BMI more than percentage of body fat. The authors suggested that clinicians should avoid estimating the level of adiposity of children and adolescents by BMI alone and recommend the use of other body measures in addition to BMI, but none specifically.

The correlation between BMI and adiposity is also affected by the cutoffs used to define excess body fatness. Due to the scarcity of longitudinal studies that assessed the association between body fat level during childhood and disease risk during adulthood, some researchers have conducted cross-sectional studies on cardiovascular risk factors and body fat levels to derive cut-off points (Williams *et al.*, 1992; Higgins *et al.*, 2001). Skinfold thickness measurements and DXA were used to estimate percent body fatness (Williams *et al.*, 1992; Higgins *et al.*, 2001). Williams *et al.* (1992) recommended percent body fat measurements of >25% for boys and >30% for girls as cut-offs based on their study's results. However, the cut-off point for excess body fatness is arbitrary. Researchers have not yet come to an agreement as to which cut-off points should be used for excess body fatness that confers health risks (Freedman & Sherry, 2009). The relationship between body fat and body weight may change during different stages of development. According to Freedman and Sherry (2009), the data of the Pediatric Rosetta Study showed that a 30% body fat measure corresponded to approximately 95th percentile of percent body fat in 7 year old girls in the study and 50th percentile of percent body fat in 15 years old girls in the study, respectively. Therefore, having 25% body fatness at different ages may have different meanings in terms of health risks (Freedman & Sherry, 2009).

BMI percentile cut-off points are imprecise because they are statistical estimates (Himes, 2009). The sample size used when creating the 2000 CDC growth charts affects the precision of percentile estimates. Larger sample size results in more precise estimates. Based on the sample size used in the 2000 CDC growth charts, for example, children (15~17 years old) ranked at 85th percentile on the growth charts have actual BMIs somewhere between 81st and 88th percentiles because values included in the 95% confidence intervals around 85th percentile fall into the range. Therefore, even if a child is ranked at 86th percentile on the CDC growth chart, the child's actual BMI percentile can be below 85th percentile. The statistical nature of percentile values makes it inappropriate to label an individual child or adolescent as overweight or obese. It is more preferable to use BMI for statistical purposes, such as to track the body size trends in a population.

In summary, BMI is not a good indicator of adiposity for a given child or adolescent. BMI does not distinguish body fat mass from lean body mass. A high BMI level can be due to high fat-free mass, high fat mass, or both. In addition, race, ethnicity and stages of sexual maturation each can affect the correlation between BMI and body fat, making it more inappropriate to determine if a child or adolescent is overweight or obese by a BMI percentile value only. Further studies on the relationship among BMI, body fatness, and these variables are required. For example, studies on how BMI and body fat percent values change over time among different ethnic groups of children and adolescents can be conducted. BMI may be a better indicator of body fatness than other indices, but this result alone should not justify its use as an alternative to body fat measurement, as discussed in the Maynard *et al.*, (2001) study. Studies have clearly shown that there are a large number of children and adolescents unnecessarily mislabeled as overweight or obese by a simple measurement of BMI. In addition, the cutoff points are imprecise. Therefore, a single BMI value alone should not be used to label children and adolescents as overweight or obese.

Correct use of growth charts

A single measurement of BMI does not provide an indication of the growth rate or pattern of a given child. Even with a high BMI percentile, a child may be growing normally as long as her/his growth pattern is consistent (Satter, 2005; Legler & Rose, 1998). The rate of growth allows clinicians to detect potentially abnormal growth. Growth rates are determined by measuring BMI two or more times and then connecting the two or more points on the growth charts.

Although growth charts may give the impression that a child's growth occurs in a smooth, continuous fashion, studies have shown that actual growth may be discontinuous (Legler & Rose, 1998). Therefore, to track the growth pattern of children and adolescents, the interval between two measurements should be determined carefully. If BMI is measured twice within a short period of time, it may not reflect the actual growth pattern. For adolescents, Legler & Rose (1998) suggest that at least three to four months are needed between measurements. Crossing of percentiles may indicate excessive weight gain or inadequate weight gain and need to be evaluated carefully.

A study by Flegal *et al.* (2002), compared weight-for-stature growth curves and BMI-for-age growth charts to determine how the charts would classify children and adolescents into overweight or obese categories. The study found that BMI-for-age charts classified more individuals into overweight categories.

In summary, BMI can be used to track the growth pattern of a given child or adolescent. However, BMI should be used with caution because children and adolescents may undergo growth spurts and because BMI does not take race, ethnicity, or stages of sexual maturation into account. It is preferable to plot anthropometric measurements on multiple growth charts to determine if a child or adolescent has a growth or development problem. Some anthropometric values that can be used with BMI include height-for-age, weight-for-age, and weight-for-height, as found in the World Health Organization (WHO) Child Growth Standards (WHO Multicentre Growth Reference Study Group, 2006).

POTENTIAL HARMS OF LABELING INDIVIDUAL CHILDREN AND ADOLESCENTS AS OVERWEIGHT OR OBSESE

Restrictive Feeding by Parents

Some parents restrict the amount of food that their child eats, out of fear that their child may become fat. Studies show that parental control over the amount of food that a child eats may yield various negative effects on the child (Birch *et al.*, 2003; Fisher & Birch, 2000; Davison & Birch, 2001; Johnson & Birch, 1994; Hood, *et al.*, 2000; Birch & Fisher, 1998). Labeling children and adolescents as overweight or obese may promote the problem of restrictive feeding by parents.

Birch *et al.* (2003) conducted a longitudinal study on how maternal restrictive feeding practices predicted the development of eating in the absence of hunger among white girls in central Pennsylvania. The study subjects were 197 five-year-old girls at the time of enrollment and were followed until they were 7 and 9 years old. The study divided the subjects into four groups based on the level of restriction by their mothers and overweight status. The results showed that for all four groups, girls ate more in the absence of hunger as they got older, indicating that they became more responsive to environmental cues such as the presence of palatable food. Importantly, girls with high maternal restriction ate more in the absence of hunger than did girls with low maternal restriction. Overweight girls with high restriction ate the most in the absence of hunger among the four groups, followed by nonoverweight girls with high restriction.

Restrictive feeding practices create a situation where girls are hungry but unable to eat foods, possibly leading to their preoccupation with food and overeating in the presence of a large amount of food (Satter, 2005). Related to this topic, Fisher and Birch (2000) conducted a cross-sectional study on how parents' restriction over certain palatable foods affected daughters' preference over the restricted food and evaluation of eating such foods. The subjects (197 girls 5 years of age) were instructed to play with toys or eat any of ten prepared palatable foods, such as popcorn, chocolate chip cookie, and ice cream, for 10 minutes shortly after lunch. The results showed that girls' negative self-evaluation of eating palatable foods and their perception of being restricted were both associated with parental restriction on the restricted foods. Reporting of eating too much was correlated with the girls' perception of being restricted on the foods by parents, and not with the amount the girls ate. Like the previous study conducted by Birch, *et al.* (2003), parental restriction on certain foods was associated with the consumption of those foods by girls in the absence of hunger. Thus, restrictive feeding can be counterproductive because such feeding practices may make girls want to eat more of the restricted foods.

Davison and Birch (2001) examined the relationship among weight status, parental concern about overweight, and self-evaluation in the same subjects. The results showed that satisfaction with physical appearance was lower among heavier girls. The perceived cognitive ability was also lower among overweight girls compared with normal-weight girls. Girls whose fathers were more concerned about the girls' weight were more likely to report lower body esteem, regardless of their weight status. Both overweight and nonoverweight girls with high maternal

concern were more likely to report lower perceived physical ability. Among those girls with high maternal restriction, the heavier girls were more likely to have lower perceived physical and cognitive ability compared with the less heavier girls. However, among those girls with low maternal restriction, only a small difference in perceived physical ability was seen between overweight girls and normal-weight girls. These results suggest that being overweight may increase the risk for negative self-evaluation in the presence of restrictive mothers. It is likely that girls of preschool age can recognize the parental expectation of their weight and already possess negative attitudes toward obesity. Labeling children as overweight or obese may make parents more concerned about their child's weight, which may negatively affect child's body esteem.

Johnson and Birch (1994) examined how children's anthropometric measures, parental adiposity and dieting practices, mothers' feeding style, and control over feeding imposed by mothers were related to children's ability to self-regulate their energy intake. The results demonstrated that the more control mothers imposed on how much their children ate, the less capable children were to compensate their energy intake in response to low-energy or high-energy density fluid intake. The fatter children were less capable to self-regulate their energy intake.

In summary, restrictive feeding by parents—which can be promoted by labeling children as overweight or obese—may make children more susceptible to overeating when they are not hungry. Parental restriction of food may also take away a child's ability to regulate energy intake and make the child feel guilty about eating certain foods that are forbidden. Also, labeling a child as overweight or obese may make parents more concerned about their child's weight. Restrictive feeding and parental concern of children's weight may negatively affect their psychological health.

Unhealthy weight control practices and eating disorders

Children and adolescents who are labeled overweight or obese may engage in restrictive dieting, including unhealthy weight control practices, and may develop eating disorders. High prevalence of dieting among adolescent girls has been documented by various studies (Centers for Disease Control and Prevention, 2010; Neumark-Sztainer *et al.*, 2006; Field *et al.*, 2003; Neumark-Sztainer *et al.*, 2007; Stice *et al.*, 1999). Some children and adolescents try to lose weight by exercising and reducing caloric intakes while others try to lose weight using unhealthy weight control practices (Centers for Disease Control and Prevention, 2010; Neumark-Sztainer, *et al.*, 2006; Stice, *et al.*, 1999).

The Youth Risk Behavior Surveillance in 2009 showed that about 15% of high school female students did not eat for 24 or more hours to lose weight or keep from gaining weight over the past 30 days of the survey (Centers for Disease Control and Prevention, 2010). Some high school students were engaged in unhealthy weight control practices, such as vomiting, taking laxatives or diet pills, powders or liquids. The percentage of U.S. high school students engaged in unhealthy weight control practices in 2009 are given in Tables 7, 8, and 9. These unhealthy weight control practices jeopardize the health of adolescents who are undergoing a critical growth period. A large number of adolescents are not

Category	Female		Male		Total	
	%	CI [b]	%	CI	%	CI
Race/Ethnicity						
White [c]	14.7	13.4 – 16.1	6.1	4.9 – 7.7	10.1	8.9 – 11.5
Black [c]	12.8	10.3 – 15.9	8.0	6.2 – 10.2	10.4	8.9 – 12.1
Hispanic	15.2	13.3 – 17.4	8.8	7.6 – 10.2	12.0	10.9 – 13.3
Grade level						
9	15.7	13.9 – 17.6	6.7	5.5 – 8.3	10.9	9.6 – 12.3
10	14.5	12.6 – 16.7	6.5	5.0 – 8.4	10.3	8.9 – 11.9
11	14.8	12.4 – 17.5	7.2	5.9 – 8.7	10.9	9.6 – 12.4
12	12.6	10.6 – 14.8	7.3	5.6 – 9.5	9.9	8.4 – 11.6
Total	14.5	13.4 – 15.7	6.9	6.0 – 7.9	10.6	9.7 – 11.5

Table 7: Percentage of high school students who did not eat for 24 or more hours[a], by sex, race/ethnicity, and grade—United States, Youth Risk Behavior Survey, 2009 (Centers for Disease Control and Prevention, 2010).

[a] To lose weight or to keep from gaining weight during the 30 days before the survey.
[b] 95% confidence interval.
[c] Non-Hispanic.

Category	Female		Male		Total	
	%	CI [c]	%	CI	%	CI
Race/Ethnicity						
White [d]	7.0	6.1 – 8.0	3.6	2.9 – 4.5	5.2	4.5 – 6.0
Black [d]	3.7	2.8 – 4.8	3.8	2.6 – 5.5	3.8	2.9 – 4.8
Hispanic	6.9	5.9 – 8.0	4.6	3.5 – 6.0	5.7	4.9 – 6.7
Grade level						
9	4.7	3.8 – 5.9	3.7	2.7 – 5.1	4.2	3.5 – 5.1
10	6.0	4.8 – 7.5	3.0	2.2 – 4.1	4.4	3.6 – 5.4
11	8.1	6.6 – 9.9	4.0	3.0 – 5.3	6.0	5.1 – 7.1
12	6.6	5.0 – 8.7	4.6	3.6 – 6.0	5.6	4.6 – 6.9
Total	6.3	5.7 – 7.0	3.8	3.2 – 4.5	5.0	4.5 – 5.5

Table 8: Percentage of high school students who took diet pills, powders, or liquids,[ab] by sex, race/ethnicity, and grade—United States, Youth Risk Behavior Survey, 2009 (Centers for Disease Control and Prevention, 2010).

[a] To lose weight or to keep from gaining weight during the 30 days before the survey.
[b] Without a doctor's advice.
[c] 95% confidence interval.
[d] Non-Hispanic.

Category	Female		Male		Total	
	%	CI [b]	%	CI	%	CI
Race/Ethnicity						
White [c]	5.2	4.4 – 6.1	1.8	1.3 – 2.6	3.4	2.8 – 4.0
Black [c]	3.6	2.4 – 5.3	4.6	3.0 – 6.9	4.1	3.1 – 5.4
Hispanic	6.9	5.7 – 8.2	4.0	3.0 – 5.2	5.4	4.7 – 6.3
Grade level						
9	5.6	4.6 – 6.9	2.8	1.9 – 4.0	4.1	3.5 – 4.8
10	5.3	4.2 – 5.7	2.2	1.5 – 3.3	3.7	3.1 – 4.5
11	6.3	5.0 – 7.8	2.7	2.0 – 3.8	4.5	3.7 – 5.4
12	4.2	3.2 – 5.5	2.6	1.8 – 3.6	3.4	2.7 – 4.3
Total	5.4	4.8 – 6.0	2.6	2.1 – 3.2	4.0	3.5 – 4.4

Table 9: Percentage of high school students who vomited or took laxatives[a], by sex, race/ethnicity, and grade—United States, Youth Risk Behavior Survey, 2009 (Centers for Disease Control and Prevention, 2010).

[a] To lose weight or to keep from gaining weight during the 30 days before the survey.
[b] 95% confidence interval.
[c] Non-Hispanic.

meeting the essential nutrient needs required for healthful growth.

Neumark-Sztainer *et al.* (2006) tracked the longitudinal and secular trends of weight status and various weight control practices of 2516 adolescents (1386 females and 1130 males) in two study cohorts in Project EAT-II (Eating Among Teens), which followed the study subjects of EAT-I, which investigated adolescents' diet and weight. The two cohort groups had mean ages of 12.8 years and 15.8 years, respectively, at the beginning of the study, and were followed five years later. Longitudinal analyses showed that the percentage of female adolescents who were engaged in unhealthy weight control practices and extreme weight control practices increased among the younger female cohort. In the older female cohort, the percentage for unhealthy weight control practices remained almost the same (62.1% in middle adolescence and 62.2% in late adolescence) while the percentage for extreme weight control practices increased from 14.9% in middle adolescence to 23.9% in late adolescence. Of particular concern is the great increase in the percentage of female adolescents who used diet pills in both younger and older cohorts. About one in five females in late adolescence were taking diet pills. Also, about a half of females in middle and late adolescence were eating very little and skipping meals. It is very likely that a large number of females are not meeting their essential nutrient needs required for healthful growth. Another concern is that the percentage of girls in the younger cohort who smoked cigarettes to lose weight more than doubled (from 5.4% to 12.0%) over the five-year period. The results for female adolescents are given in Table 10.

In younger male cohorts, the percentage of adolescents engaged in healthy weight control practices decreased considerably, from 75.9% in early adolescence to 57.7% in middle adolescence. The percentage for unhealthy behaviors decreased from 35.0% in early adolescence to 28.6% in middle adolescence. In the older male cohort, the percentage for unhealthy behaviors remained almost the same (30.5% in middle adolescence and 29.9% in late adolescence) while the percentage for extreme behaviors nearly doubled (3.4% in middle adolescence and 6.3% in late adolescence). Regrettably, the percentage of male adolescents who used diet pills increased by six-fold (0.9% in middle adolescence to 6.1% in late adolescence). Longitudinal increase in the percentage of male adolescents engaged in extreme weight control behaviors is of great concern because such practices can have serious adverse effects on health. The results for male adolescents are given in Table 11.

Ironically, studies have shown that dieting among adolescents predicts future weight gain (Field *et al.*, 2003; Neumark-Sztainer *et al.*, 2007; Stice *et al.*, 1999). Field *et al.* (2003) conducted a prospective study to assess whether dieting predicted future weight status. The study involved 8203 girls and 6769 boys 9-14 years of age in 1996, who completed two or more annual questionnaires during 1996-1999. This large sample size makes the study more significant than the previous study. The results demonstrated that the weight gain during the study period was larger among dieters compared with nondieters after adjusting for previous years' age-specific z score of BMI, age, and Tanner stage of development, which assessed sexual maturation stages of the subjects. Dieters were more likely to develop binge

	Younger cohort (n = 408)			Older cohort (n = 928)			Secular trend *P* value [d]
	Early adolescence 1999	Middle adolescence 2004	*P* value[b]	Middle adolescence 1999	Late adolescence 2004	*P* value[c]	
Healthy Behaviors							
Exercise	76.3	81.2	0.060	81.6	81.4	0.940	0.894
More fruits/vegetables	66.7	63.0	0.226	68.8	69.8	0.672	0.080
Fewer high fat foods	58.6	65.2	0.033	61.5	69.5	<0.001	0.269
Fewer sweets	54.2	63.4	0.003	63.0	69.4	0.007	0.906
Unhealthy Behaviors							
Smoking	5.4	12.0	0.002	12.2	14.7	0.123	0.916
Food substitutes	10.9	9.7	0.599	12.1	13.4	0.441	0.290
Fasting	10.9	19.2	0.002	21.2	20.3	0.655	0.478
Eating very little	36.2	44.7	0.006	49.7	46.1	0.138	0.160
Skipping meals	37.1	48.3	0.001	50.9	49.4	0.531	0.456
Extreme Behaviors							
Vomiting	7.3	4.9	0.154	8.2	6.5	0.177	0.062
Laxative use	1.1	2.6	0.143	1.8	2.9	0.155	0.431
Diet pills	3.5	14.2	<0.001	7.5	19.9	<0.001	0.004
Diuretics	1.3	1.3	0.941	2.1	2.0	0.807	0.373

Table 10: Specific weight control behaviors used by adolescent females from Minnesota who participated in Project EAT-I (1999) and EAT-II (2004) (%) [a] (Neumark-Sztainer, *et al.*, 2006).

[a] Analyses are adjusted for response propensity weights, age, ethnicity/race, and socioeconomic status.
[b] *P* value for longitudinal trend in younger cohort (early to middle adolescence).
[c] *P* value for longitudinal trend in older cohort (middle to late adolescence).
[d] *P* value for secular trend in middle adolescence (1999 to 2004) (e.g., exercise for weight control decreased from 81.6% in 1999 to 81.2% in 2004, *P* = 0.894).

eating habits, characterized by consuming a very large amount of food in a short amount of time and lacking a sense of control during eating. Dieters reported lower caloric intake, lower percentages of calories from fat, and lower servings of snacks per day, compared with nondieters. Although these practices seem healthful, dieting was found to be a predictor of weight gain. The authors suggested three mechanisms of how dieting leads to weight gain in the long-term. The mechanism supported by the results of the study is as follows. Dieters may repeat a cycle of calorie restriction and overeating because it is difficult to be on a calorie restricted diet continuously. The overeating may lead to the excessive weight gain. The results obtained in the study that dieters were more likely to report binge eating support the mechanism.

Weight concern and dieting are risk factors for developing eating disorders (Killen *et al.*, 1996; Patton *et al.*, 1999; Tanofsky-Kraff *et al.*, 2007). A 4-year prospective study conducted by Killen *et al.* (1996), examined the potential factors that predicted the development of eating disorders in adolescent girls. The results showed that weight concern was a strong predictor of the onset of a "partial syndrome eating disorder," which was characterized by binge eating episodes, compensatory behavior to prevent weight gain, such as vomiting, using laxatives, and exercise as well as excessive concern and preoccupation with body weight and shape, or a sense of lack of control during a binge episode.

In summary, dieting behaviors are very prevalent among children and adolescents. Dieting puts them at increased risk of developing eating disorders such as binge eating. Childhood and adolescence are the critical periods of growth and sexual maturation. Without adequate nutrients for optimal growth, long-term health would be compromised. Labeling children and adolescents as overweight or obese may make them more concerned about their weight and exacerbate the problem of unhealthy weight control practices that would disrupt the normal growth and development. It is important for clinicians to be aware of potential problems arising from labeling individual children and adolescents as overweight or obese as well as of possibility that many children and adolescents engage in unhealthy weight control practices regardless of being labeled as overweight or obese.

CONCLUSION

This review was conducted to answer the following questions: (1) is it ethical to label children and adolescents as overweight or obese? (2) Is BMI used appropriately for them today? If not, where and how can BMI be used appropriately? Findings from various studies suggest that BMI can be used in only certain situations. BMI is a useful statistical tool to track the body size trends in a population. However, BMI is not a reliable measure of body fatness of *individual* children and adolescents. Having a high BMI does not indicate whether a child or adolescent has an

Table 11: Specific weight control behaviors used by adolescent males from Minnesota who participated in Project EAT-I (1999) and EAT-II (2004) (%) [a] (Neumark-Sztainer, *et al.*, 2006).

[a] Analyses are adjusted for response propensity weights, age, ethnicity/race, and socioeconomic status.
[b] *P* value for longitudinal trend in younger cohort (early to middle adolescence).
[c] *P* value for longitudinal trend in older cohort (middle to late adolescence).
[d] *P* value for secular trend in middle adolescence (1999 to 2004) (e.g., exercise for weight control decreased from 63.4% in 1999 to 56.7% in 2004, *P* = 0.072).

	Younger cohort (n = 408)			**Older cohort (n = 928)**			**Secular trend *P* value[d]**
	Early adolescence 1999	Middle adolescence 2004	*P* value[b]	Middle adolescence 1999	Late adolescence 2004	*P* value[c]	
Healthy Behaviors							
Exercise	72.2	56.7	<0.001	63.4	60.2	0.219	0.072
More fruits/vegetables	51.5	30.0	<0.001	40.2	36.8	0.203	0.007
Fewer high fat foods	40.2	31.8	0.010	33.6	36.6	0.245	0.621
Fewer sweets	39.9	29.6	0.001	35.0	38.6	0.171	0.147
Unhealthy Behaviors							
Smoking	3.0	4.7	0.323	6.2	5.3	0.475	0.382
Food substitutes	6.6	5.8	0.657	6.2	7.5	0.379	0.832
Fasting	12.1	9.8	0.296	10.1	6.8	0.052	0.909
Eating very little	20.4	18.2	0.414	18.2	17.5	0.720	0.995
Skipping meals	20.5	18.4	0.453	19.0	17.3	0.444	0.855
Extreme Behaviors							
Vomiting	3.2	2.0	0.252	2.1	0.2	0.009	0.905
Laxative use	0.9	2.1	0.113	0.6	0.7	0.821	0.038
Diet pills	2.5	3.6	0.450	0.9	6.1	<0.001	0.059
Diuretics	0.8	2.9	0.007	0.5	0.6	0.885	0.002

actual problem with growth. Each child's or adolescent's growth pattern must be evaluated in order to determine whether s/he is experiencing problems that require further evaluation. Clinicians should also note that rapid weight gain shown on the BMI growth charts may not necessarily indicate excessive or abnormal weight gain. Therefore, it is preferable to plot the height and weight data on other growth charts as well in order to detect problems with growth. For the above reasons, labeling children and adolescents as overweight and obese based on a single BMI value and arbitrary cut-offs is inappropriate.

Labeling children and adolescents as overweight or obese can cause various problems. Labeling may make parents concerned about their child's weight and cause them to restrict the amount and type of food that their child eats. Labeling may make children and adolescents concerned about their weight and make them engage in dieting and unhealthy weight control practices, both of which can disrupt normal growth and development of children and adolescents. Because potential harm outweighs benefits, labeling children and adolescents as overweight or obese in this manner may be ethically questionable.

In conclusion, BMI can be used to track body size trends in a population for a statistical purpose. However, BMI should not be used to label individual children and adolescents as overweight or obese at any one-time point during their growth because the cutoff points were arbitrarily determined and BMI does not account for race, ethnicity, and stages of sexual maturation. Further investigation into the relationship between children's and adolescents' adiposity levels and these variables are needed and should focus on the level of adiposity in different racial or ethnic pediatric populations that is associated with future disease risks. Studies on adults have shown that, at a given BMI, individuals in different race or ethnic groups carry different body fat levels and/or cardiovascular disease risks (Deurenberg-Yap *et al.*, 2002; Palaniappan *et al.*, 2002).

BMI can be used in conjunction with some other calculated anthropometric values, such as weight-for-age, height-for-age, and weight-for-height, to track the growth pattern of an individual child or adolescent. Other anthropometric measurements and calculated anthropometric values, such as waist circumference, abdominal skinfold, and waist-to-hip ratio, can be used with BMI as well, to detect problems with growth, because some studies have demonstrated positive correlations between the level of abdominal adiposity and these measurements (Goran *et al.*, 1998; Taylor *et al.*, 2000; Daniels *et al.*, 1997). However, these anthropometric values do not take race, ethnicity, and stages of sexual maturation into account, either. Thus, clinicians should be careful of the interpretation of the results of these measurements. Further investigation into how race, ethnicity, and stages of sexual maturation of children and adolescents affect the relationship among the level of adiposity, these anthropometric values, and future disease risks, is needed. Some studies related to this topic have been conducted on certain ethnic groups of adults (Hayashi *et al.*, 2007; Ko *et al.*, 1997; Mau *et al.*, 2009).

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