Childhood Obesity: Are We All Speaking the Same Language?[1–3]

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ABSTRACT

Terminology and measures used in studies of weight and adiposity in children can be complex and confusing. Differences arise in metrics, terminology, reference values, and reference levels. Most studies depend on body mass index (BMI) calculated from weight and height, rather than on more direct measures of body fatness. Definitions of overweight and obesity are generally statistical rather than risk-based and use a variety of different reference data sets for BMI. As a result, different definitions often do not give the same results. A basic problem is the lack of strong evidence for any one particular definition. Rather than formulate the question as being one of how to define obesity, it might be useful to consider what BMI cut-points best predict future health risks and how efficiently to screen for such risks. The answers may be different for different populations. In addition, rather than depending solely on BMI to make screening decisions, it is likely to be useful to also consider other factors, including not only race-ethnicity, sex and age, but also factors such as family history. Despite their limitations, BMI-based definitions of overweight and obesity provide working practical definitions that are valuable for general public health surveillance and screening. *Adv. Nutr. 2: 159S–166S, 2011.*

Introduction

When we talk about childhood overweight and obesity, what are we talking about? Terminology and measures used in studies of weight and adiposity in children and in adults can be complex and confusing. Different reports may use the same term but define it quite differently, making comparisons difficult. For example, in a single recent issue of a journal, one article (1) defined overweight among children as a BMI at or above the 90th percentile of the French reference curves for BMI (2), and the following article (3) used the International Obesity Task Force (IOTF) standards (4) to define overweight.

We examine some of the definitions in use today and consider some of the underlying difficulties in arriving at consistent and coherent definitions. Differences arise in metrics, terminology, reference values, and reference levels. Finally, we discuss the uses of these definitions and some future avenues of research.

BMI

Although most discussions revolve around the effects of excess fat, the most common metric in use today is BMI, weight in kilograms divided by the square of height in meters. This index was originally devised by the Belgian statistician Adolphe Quetelet (1796–1874) (5), who applied it to adults, not to children. For adults, the index describes the relation of weight to height, in effect adjusting weight for height. It was subsequently shown for adults that if adiposity was independent of height, then BMI would be highly correlated with adiposity (6–8). For adults, BMI provides a way to translate weights at different heights into a common metric.

The use of BMI for children is a more recent development (9,10). For children, BMI varies with age, not only with weight. Because of this, for children, BMI values are compared with reference values that are generally age and usually also sex specific and need to be further transformed in order to be put on a common footing. This is most often done by

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translating BMI-for-age into a Z-score or a percentile relative to some specified distribution of BMI-for-age. Generally, some smoothing process is applied to an empirical BMI distribution to generate smooth percentiles. A normalizing transformation is also required to allow for flexible calculation of Z-scores. A Z-score or SD score represents the number of SD units above or below the mean, so that, e.g., a Z-score of 2 refers to a value that is 2 SD above the mean. Z-scores and percentiles have a 1 to 1 equivalence in a normal distribution; any percentile can be translated to a Z-score and vice versa. Thus, to create a Z-score value, a normal transformation of the distribution of BMI for that age and sex group is applied. The Z-score is a function of the SD of the BMI distribution after it has been transformed to a normal or approximately normal distribution. Thus, for a given age, a specified difference in Z-score represents the same difference in normalized BMI units at any Z-score level, unlike percentiles. However, if the BMI data have been normalized, a specified difference in Z-score does not necessarily represent the same difference in absolute BMI units at any Z-score level. In addition, because SD vary across ages, the same difference between 2 Z-scores may represent a difference in BMI units that is not constant across ages.

The effect is that a BMI Z-score reflects an extensive series of transformations of the original weight and height data for a child. Weight and height are transformed into a BMI value and the BMI value in turn is transformed into an age and sex specific Z-score based on a normalizing transformation or a smoothed version of observed reference data. A BMI Z-score or percentile represents a measure of weight, adjusted for height, sex, and age, relative to a smoothed reference distribution, and not simply a measure of weight and height for a child. Not surprisingly, because body weight is correlated with fat mass and percent body fat, BMI also tends to be correlated with percent body fat. However, because body weight is also correlated with muscle and lean mass, BMI tends to be correlated with muscle and lean mass as well and may be correlated with height within age groupings. Thus, BMI is correlated with fatness but is not a precise measure of fatness. Additional complexities arise with children, where BMI is not the actual measurement, but rather a sex and age specific percentile of BMI (9,11). The same BMI percentile does not represent the same percentage body fatness at different ages, for boys and girls, or among different race-ethnic groups.

Terminology

The words "overweight" and "obesity" are widely used but can be ambiguous. Are these terms mutually exclusive? Does one include or preclude the other? Overweight and obesity are terms that may be distinguished in several different ways. Overweight may be defined as a weight over a weight standard and be contrasted with obesity, defined as body fat over a body fat standard. With these definitions, overweight and obesity are not synonymous but can overlap with each other. For example, according to Sjostrom (12), "Obesity is an increased amount of body fat or adipose tissue, while overweight is an increased body weight in relation to height. … Marked overweight is always associated with obesity but moderate overweight is occasionally due to other conditions." With this approach, an individual could be both overweight and obese or could be overweight but not obese.

Another approach is to consider overweight and obesity as mutually exclusive terms indicating 2 different levels of excess weight or fat. In this approach, overweight may be considered as a milder degree of adiposity or excess weight than is obesity. Yet a 3rd approach is to consider overweight and obesity as overlapping terms. For example, for adults, a WHO expert consultation defined overweight as a BMI $\geq$ 25 and obesity as a BMI $\geq$ 30 (13). With these definitions, individuals with a BMI > 30 are both obese and overweight and individuals with a BMI from 25 to <30 are overweight but not obese. Finally, these 2 terms are sometimes used more or less interchangeably without making a clear distinction between them.

An example of 2 different approaches can be seen by comparing the report of one expert committee in the United States to a later report of a different expert committee. According to the 1994 expert committee report (14), "The committee reserved the use of the term obesity for a condition characterized by excess body fat. ...the committee elected to define excess body mass as overweight and to rely on additional measures to distinguish those who are obese from those who are overweight but may not be obese." This committee defined overweight as a BMI at or above the 95th percentile of a suitable reference. Thus, in this formulation, overweight is defined as high BMI and obesity as excess body fat, and a child may be both overweight and obese. A different expert committee convened in 2007 by the American Medical Association took a different tack and elected to define overweight as a BMI between the 85th and 95th percentiles and obesity as a BMI at or above the 95th percentile (15). With these definitions, the 2 categories of overweight and obesity are mutually exclusive. As a result, the definition of overweight as a BMI-for-age at or above the 95th percentile by the 1994 committee and the definition of overweight by the 2007 committee as a BMI-for-age between the 85th and 95th percentiles have no overlap.

Reference data sets

There are a number of reference data sets for BMI in childhood. In many countries, BMI reference data are used or recommended as part of monitoring children's growth (2,16–21). Such reference data are often based on representative data from a given country. For example, data for weight, height, BMI, and head circumference from 37,000 children from surveys representative of England, Scotland, and Wales were used to develop the 1990 British growth reference (22).

In the United States, the CDC 2000 growth charts for the US were developed from 5 nationally representative survey data sets (the National Health Examination Surveys II and III in the 1960s, the NHANES I and II in the 1970s, and NHANES III, 1988–1994) (23). WHO subsequently used

much of the same NHANES data to develop growth standards for older children and adolescents (24). The 2000 CDC charts are revised versions of the 1977 National Center for Health Statistics growth charts (23).

In 2006 WHO released a new set of growth charts for children from birth through 5 y of age based on data from the Multicentre Growth Reference Study conducted by WHO (25). The WHO charts are based on different principles than the aforementioned national growth charts. The WHO charts are intended to serve as growth standards, describing how children should grow. In contrast, many national charts are descriptive, describing how children in the reference population did grow. The WHO charts are based on a highly selective sample of children from 6 sites around the world, consisting of children who were not subjected to socioeconomic constraints on growth, who were healthy term singleton births, whose mothers did not smoke before, during, or after pregnancy, and who were fed according to Multicentre Growth Reference Study feeding recommendations for breast and complementary feeding. The growth of these children was considered to represent optimal growth. Although the children were selected in a different fashion than for other national and international references, the WHO charts are constructed along similar lines to other charts and consist of descriptive percentiles from this select population.

Reference sets of charts, such as the 1990 UK reference, the 2000 CDC Growth Charts, and the WHO charts, are intended for clinical use in monitoring children's growth. The use of selected percentiles of such charts to define overweight and obesity is a secondary purpose.

There are also several sets of BMI reference data that are intended specifically to define childhood overweight rather than to be used for clinical monitoring of growth patterns. These include only a few cutoff values. One reference set of BMI values that has been widely used consists of sex specific smoothed 85th and 95th percentiles for single year of age from 6 to 19 y based on data from NHANES I (1971–1974) in the United States, developed by Must et al. (26). In 1995, a WHO Expert Committee recommended the use of these reference values (27). Although the 1995 Must et al. (26) reference values were considered to represent the 85th and 95th percentiles of the distribution of BMI in NHANES I, in fact, because of some slight over-smoothing of the data for girls, the Must et al. (26) values for the 85th percentile are systematically lower than the empirical 85th percentile from the same data set and are more similar to the 80th percentile than to the 85th (28). As a result, when the Must et al. (26) values are used, the prevalence of BMI above the 85th percentile tends to be high for adolescent girls.

In 2000, Cole et al. (4) published a set of smoothed sex specific BMI cutoff values based on 6 representative data sets from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. The U.S. data used were the same as those from which the 2000 CDC growth charts were derived, excluding NHANES III data. The selection of data sets was based on specified criteria, including a large nationally representative sample, minimum age ranges of 6–18 y and appropriate quality control. These values, often referred to as the IOTF cutoff values, represent cutoff points chosen as the percentiles that matched the adult cutoffs of a BMI of 25 and 30 at age 18 y.

The Cole (4) (IOTF) reference grew out of a workshop held by the IOTF and was developed to provide a suggested common basis for prevalence estimates internationally. The goal was to develop BMI criteria that could be used for international comparisons of prevalence without depending on using solely U.S. reference data and without using a specified percentile, such as the 85th or 95th percentile, of a specific population. The IOTF cutoffs were not intended as clinical definitions or to replace national reference data, but rather to provide a common set of definitions that researchers and policy makers in different countries could use internationally for descriptive and comparative purposes. Several discussions on the use of national compared with international reference data have been published (29,30).

Choice of cut-points for children

In adults, the cutoffs to define obesity and overweight are based on fixed BMI values of 25 and 30, which are approximately related to health risk (31). In children, there are no risk based fixed values of BMI used to determine overweight, because it is unclear what risk related criteria to use. The long time span before adverse outcomes appear and the small samples identifying cardiovascular risks in youth make finding risk related cutoffs difficult. Consequently, a statistical definition of overweight based on the 85th and 95th percentiles of BMI-for-age in a specified reference population is often used in childhood (14,32). Despite their common use, the rationale for using the 85th and 95th percentiles has not been very clearly spelled out. In terms of Z-scores, WHO has defined obesity as a Z-score > 3 and overweight as a Z-score > 2, but not with an explicit justification for these cutoff values (33).

Cutoff values are not necessarily exact. For both adults and children, most cutoff values of percentiles or Z-scores for BMI end in 5 or zero. The propensity to choose values ending in 5 or zero has been repeatedly noted in studies of blood pressure measurements and has been demonstrated to occur in other situations, including clinic arrival times and even in pathology reports (34,35). This digit preference may also affect the choice of cutoff values for BMI.

One feature of statistical definitions that has been little remarked on is that they include the assumption that in the reference population, the prevalence is exactly the same for every sex and age group. For example, if obesity is defined as a BMI-for-age at or above the 95th percentile, then in the reference population, 5% of 6-y olds are considered obese, 5% of 7-y olds are considered obese, and so forth up to 5% of 19-y olds. This is also the case with the definitions that are keyed to the adult BMI values of 25 and 30 at age 18 y. Those definitions are also percentiles that are constant

over age and sex in the reference distribution, even though the exact percentile level is not specified.

A BMI-for-age above a given value may be labeled obesity, but it is still a measure of excess weight, not necessarily of excess fat. In practice, measurement of body fat is difficult both in clinical applications and population studies. In addition, there are no well-accepted standards for body fatness for children. One issue is whether body fatness is best measured as fat mass, fat mass index, or percentage body fat. A more fundamental issue is that we do not have any well accepted standards for body fatness in children by any measure. If we had such standards, it would be easier to identify BMI cutoff values that corresponded to body fat standards.

Thus, there are a plethora of different references that can be used to define childhood overweight or obesity for calculating prevalence estimates. As a result, there are numerous analyses comparing the use of different definitions with the same population (29,36–48). As seen repeatedly, the various definitions do not give the same results. For example, in 1 analysis, 3 different sets of BMI reference values were used to estimate the prevalence of overweight among children in the United States (37). The 3 sets of BMI reference values resulted in similar but not identical estimates. For young girls, estimates based on the Must et al. (26) reference values were much higher than estimates based on the CDC (20) and Cole (IOTF) (4) references. The Cole (IOTF) reference gave rise to lower estimates for young children and higher estimates for older children than the Must et al. (26) and CDC (20) references.

Choice of terminology

Even for the same cut-point, the terminology can differ. The Institute of Medicine report on "Preventing Childhood Obesity" (49) retained the 95th percentile as a cutoff value, but changed the terminology, stating that, "The committee recognizes that it has been customary to use the term 'overweight' instead of "obese" to refer to children with BMI values above the age- and gender-specific 95th percentiles… However, the term "obese" more effectively conveys the seriousness, urgency, and medical nature of this concern than does the term "overweight," thereby reinforcing the importance of taking immediate action." Following along these lines, a subsequent AMA expert committee (15) retained the 2 cutoff values of the 85th and 95th percentile recommended by previous committees but used different terminology, referring to BMI-for-age from the 85th up to the 95th percentile as overweight and to BMI-for-age at or above the 95th percentile as obesity, stating that "The compelling reasons for this revision are clinical. The term obesity denotes excess body fat more accurately and reflects the associated serious health risks more clearly than does the term overweight, which is not recognized as a clinical term for high adiposity." Nonetheless, the committee also recommended the use of more neutral terms when discussing weight issues with families, stating that "Therefore, the expert committee recommends the use of the clinical terms overweight and obesity for documentation and risk assessment but the use of different terms in the clinician's office, to avoid an inference of judgment or repugnance." Concerns have been raised regarding the adverse effects of labeling and stigmatization (15), although the US Preventive Services Task Force found insufficient evidence to make conclusions about the potential harms from screening (50).

Barriers to consensus

The issue of different definitions is not new but has been discussed extensively in various previous publications [e.g. (10)]. Guillaume's summary from 1999 still applies today: "Available data allow neither a meaningful international estimation of the prevalence of obesity nor international comparisons. Although associated with considerable problems, this situation can be improved with an international consensus which, by necessity, will be riddled with uncertainties and compromises" (51).

Although there are many different proposals, guidelines, and recommendations, a basic problem is the lack of strong evidence for any precise definition. The Endocrine Society clinical practice guidelines (52) make a strong recommendation for classifying children as overweight if their BMI is between the 85th and 95th percentiles and as obese if their BMI is at or above the 95th, but in contrast to the strength of the recommendation, they describe the evidence for this recommendation as of "very low quality." A similar concern was described in a 2005 commentary by the Childhood Obesity Working Group of the US Preventive Services Task Force (53), which put the issue succinctly: "We do not know the best way to identify children who are at risk for future adverse health outcomes due to obesity or overweight. Although BMI is a convenient and widely agreed-on measure of obesity, it is not clear what BMI at any given age is associated with future good health." The US Preventive Services Task Force report (50) summarized the considerable gaps in knowledge of the links between childhood weight and future health outcomes. In terms of health outcomes, the task force found insufficient evidence to currently recommend screening for BMI among children and adolescents. This finding does not mean that screening is not valuable, but rather that additional evidence is needed (50).

Uses of these classifications

Definitions of overweight and obesity are used for several quite different purposes. For international comparisons of prevalence, the same definition should be used across countries. However, it is not yet clear that any one definition is better than another for this purpose. A given definition may be more suitable for one country than for another country. Furthermore, given the limitations of BMI as a measure of body fatness and the likely variation by not only age and sex but also by race-ethnic groupings, any international comparisons should be interpreted cautiously, particularly those between dissimilar countries. The WHO charts are based on a sample selected to represent normal growth in healthy children but nonetheless suffer from some of the same issues that affect

other definitions, including the use of BMI as an imperfect measure of adiposity and the difficulty in choosing an appropriate cutoff value. The IOTF definitions resolve the issue of choosing a cutoff value by linking to the adult levels, but this linkage serves only to choose the percentiles used as cutoff values and does not really substitute for a functional definition. In general, although "overweight" and "obesity" are useful descriptive terms, they have to be defined carefully, and it might be useful to consider ways of making more comprehensive comparisons of BMI distributions across countries without or in addition to these descriptive terms.

For use within a single country for public health purposes such as surveillance, often a national reference will be more suitable, allowing for comparison of children to a reference group of children from the same country. Children are defined as overweight or obese for population surveillance and screening purposes, using a variety of BMI cut-points. However, these children do not necessarily have any clinical complications or health risks related to over-fatness. According to the CDC (54), "In-depth assessments are required to determine whether children and adolescents with BMI-for-age $\geq$ 95th percentile are truly overfat and at increased risk for health complications." In the UK, different cutoff values are used for clinical use than for surveillance. The clinical guideline published by the National Institute for Health and Clinical Excellence defined overweight and obesity for clinicians as the 91st and 98th percentiles, respectively (55). For purposes of surveillance, however, the 85th and 95th percentiles are used for government statistics (56).

Higher BMI among children is associated with higher levels of blood pressure, serum lipids, and other factors (57) that in adults are associated with higher cardiovascular risk. The implications of a given level of BMI for children's future health, however, are unclear. This was noted in the expert committee report (14) published in 1994: "Unfortunately, little published information exists regarding specific degrees of overweight in adolescence and current or subsequent health-related outcomes. … Further, because of the low prevalence of the sequelae of obesity among adolescents, specific cutoff values for BMI or other measures of overweight in adolescence associated with health risks have not been established." The Childhood Obesity Working Group of the US Preventive Services Task Force noted similar concerns in a 2005 report (53).

For specific conditions, BMI is an important part of a screening algorithm. For example, the American Diabetes Association (58) recommends screening for diabetes in children with BMI at or above the 85th percentile and have in addition 2 of the following factors: *1*) family history of type 2 diabetes; *2*) membership in specified race-ethnic groups (American Indian, African American, Hispanic American, Asian/South Pacific Islander); or *3*) signs of insulin resistance. For dyslipidemia, current recommendations are that all children with BMI-for-age at or above the 85th percentile should be screened (59).

Despite recommendations that BMI be considered as a screening rather than as a diagnostic tool (60), BMI based categories may be considered as diagnoses [e.g. (61)], perhaps encouraged to some extent by recommendations for the use of clinical terminology. The use of BMI as part of a screening algorithm does not in fact require a particular definition or a particular label and can be separate from any definitions used for prevalence estimates. Considerable research efforts have been devoted to how to choose cut-points for screening, which is generally done taking into account the expected yield and a balance of costs and benefits. Interventions are designed to reduce the risk of future events and it might be decided to intervene in a given way for a given BMI level again without the need for a label.

Summary

Most definitions of childhood overweight and obesity are similar in the sense that they are based on BMI relative to a reference distribution of BMI for sex and age. Despite this underlying similarity, they display considerable variation. The terminology used is not standard and the terms overweight and obesity may be used interchangeably or contrasted with each other. There is a wide variety of national and international reference data sets used to establish criteria. The selection of cutoff values is generally based on statistical considerations rather than on clear relations to health risks or the degree of body fatness. BMI is a screening tool, however, not a diagnostic tool. Children with a BMI over these cut-points do not necessarily have clinical complications or health risks related to over-fatness. More in-depth assessment of individual children is required to ascertain health status. The definitions of overweight and obesity generally used are working definitions that are valuable for general public health surveillance, screening, and similar purposes.

Some future directions

Current and future research efforts continue to address the relationship between BMI and body fat in the general population and in different race/ethnic groups. These efforts may clarify the use of BMI as an indicator of body fatness in children as well as of the value of indicators other than BMI, such as waist circumference. Research continues on the development of risk based cut points. The percentile or Z-score cut-points have digit preference, are statistically based, and are not based on health risk. In addition, because the relationship between BMI and adiposity varies by sex, age, and race/ethnicity, risk based cut-points may also vary. Rather than formulate the question as being one of how to define obesity, it might be useful to consider what BMI cut-points best predict future health risks and how efficiently to screen for such risks. The answers may be different for different populations. In addition, rather than depending solely on BMI to make screening decisions, it is likely to be useful to also consider other factors, including not only race-ethnicity, sex, and age, but also those such as family history. Further examination of the relation between various health measures and BMI measured on a continuous basis may provide additional valuable information (62).

Recent concern about excess weight during infancy (63) warrants attention to the issues of reference distributions for weight during infancy. Should BMI or weight-for-length or some other measure be used during infancy? Does BMI based on recumbent length represent the same thing as BMI based on stature among older children? Are the reference populations for infancy adequate? A review of reference populations used to evaluate weight in infancy would be useful. The 2000 CDC infant weight growth charts were created using nationally representative data at birth and starting at age 2 mo. No national data were available between birth and 2 mo of age. U.S. national data from 1999–2006 are now available for infants from birth. These data could be smoothed with the original national growth charts data and the resulting curves can be evaluated (64).

There has also been recent interest in extremely obese children, in part in the context of possible bariatric surgery for adolescents (65). The current reference distributions for BMI are generally not very suitable for use in classifying or tracking very heavy children. Most reference data sets use data from several decades ago and have few very heavy children. In addition, several charts deliberately excluded the heaviest children. For example, in the construction of the WHO charts, the data were trimmed before constructing the charts specifically in order to exclude heavier children (25). Similarly, in the construction of the CDC charts, it was decided not to use the most recent data, because the children in that survey were heavier on average than children in earlier surveys (23). In general, data are sparse at the extremes of the BMI distributions and modeling data in the extreme tails is difficult. Z-scores as high as 3, sometimes suggested as cutoff points, represent the 99.8th percentile, which is difficult to estimate with any precision. The current reference populations for BMI may not provide reasonable cut-points for extremely obese children. One suggestion is to use percentages of the existing smoothed percentiles. Expressing high BMI values as a percentage of the 95th percentile can provide a flexible approach to describing and tracking heavier children (66).

Continued efforts to evaluate existing references in terms of growth over the whole range of body sizes are valuable and should not be limited just to evaluation of overweight and obesity (67). The continued use of BMI based references has many practical advantages, including familiarity and relative ease of obtaining weight and height measurements. However, some of the limitations of such references should also be recognized, including the statistical rather than clinical definition of cutoff values and the approximate nature of BMI as a measure of body fatness. Despite their limitations, BMI based definitions of overweight and obesity provide working practical definitions that are valuable for general public health surveillance and screening.

Notes

This is a revised and updated version of Flegal KM, Tabak CJ, and Ogden CL (68). Some parts of this article also appear in a chapter entitled "High body mass index, overweight and obesity in children: Definitions, terminology and interpretation" in the book Childhood Obesity Prevention—International Research, Controversies and Interventions (69).

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