The Use of BMI in the Clinical Setting

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KEY WORDS
anthropometric measure, regional adiposity, adiposity, comorbidities, obesity

ABBREVIATIONS
DEXA—dual-energy radiograph absorptiometry
USPSTF—US Preventive Services Task Force
EMR—electronic medical record

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abstract

BMI has been recommended for evaluating overweight and obesity in children and adolescents in the clinical setting. Definitions of overweight and obesity are based on percentile cutoff points. There are both strengths and limitations of BMI for this use. The strengths include the fact that BMI is cheap and relatively easy to use. The weaknesses include the fact that BMI percentiles are not widely used, and categorization of BMI percentiles may not adequately define risk of comorbid conditions. In addition, percentiles are not optimal for stratifying children and adolescents with very high BMI. Alternatives to the use of BMI and BMI percentiles include waist circumference to evaluate regional fat deposition and replacement of percentiles with z scores. Despite limitations, BMI and BMI percentiles have great utility in the clinical setting and the potential to be even more useful as BMI is used more frequently and more appropriately by primary care providers. Additional research on alternatives or adjuncts to BMI is needed. Pediatrics 2009;124:S35–S41
The most current recommendations for evaluation of obesity in the clinical setting support the use of BMI percentiles as the most useful method for assessing the presence of increased body fat. This was chosen because BMI levels correlate with body fat and also with cardiovascular risk factors. High BMI also is a useful predictor of future adiposity as well as future morbidity and mortality. These recommendations also promote the use of BMI for screening because it has reasonable sensitivity for identifying children with the highest accumulation of fat, is easy to use, and is inexpensive. It also provides continuity with the current clinical practice in adults, which also uses BMI as an important screening method.

The use of any anthropometric measure in children and adolescents is complicated, because they are constantly growing and developing. This makes the use of any 1 set of cut points difficult, if not impossible. This has led to the use of percentiles specific to age and gender on which to select cut points. The selection of cut points is also difficult, because BMI and BMI percentiles are continuous. Presumably, the risk associated with increasing BMI is also continuous. However, many clinicians find such cut points useful from a clinical decision-making standpoint.

The American Medical Association Expert Panel did not recommend more precise measures of body fat, such as dual-energy radiograph absorptiometry (DEXA), because they were considered impractical in the clinic setting. The panel also did not recommend measures of regional adiposity such as skinfold thickness or waist circumference. There was concern about patterns of fat distribution, but there was consensus that there were feasibility issues with skinfold-thickness measurements, and there was insufficient evidence at the time to recommend widespread clinical use for either.

With these issues in mind, the panel provided recommendations for categorization of BMI according to percentiles for children and adolescents (Table 1). They also included the 99th percentile as a cut point indicating more extreme obesity with a higher risk of obesity-related comorbidities. These recommendations are different from those of the US Preventive Services Task Force (USPSTF). After a thorough evidence review of screening for obesity, the USPSTF found insufficient evidence for or against using BMI (or other measures) to formally screen children and adolescents for overweight or obesity in the primary care setting. The USPSTF has a policy of making recommendations for or against delivery of preventive services only in the presence of sufficiently strong evidence of adequate quality. Thus, the lack of a USPSTF recommendation was largely a comment on this lack of sufficient evidence and the need for improved evidence regarding the elements of an effective childhood obesity-screening program. Because the USPSTF evaluates the entire screening program, ineffective treatment of obesity or lack of evidence of an intervention impact on childhood obesity would also affect their recommendations. The USPSTF also evaluated specific questions related to screening for obesity. In their analysis, questions 2b, “What clinical screening tests for overweight in childhood are reliable and valid in predicting obesity in adulthood?” and 2c, “What clinical screening tests for overweight in childhood are reliable and valid for poor health outcomes in adulthood?” focused on the optimum screening measures.

The USPSTF found that BMI tracks from childhood to adulthood, but the degree of tracking varies according to age, with better tracking for older children, for younger children who are more overweight, and for children with an obese parent. They found that there was a ≥50% probability of adult obesity for teenaged children with a BMI at ≥95th percentile.

There was insufficient evidence concerning whether childhood obesity determined by BMI was predictive of adverse health outcomes in adults independent of adult obesity. In the Bogalusa Heart Study, which did control for adult BMI, effects of childhood BMI on adult outcomes were lessened or eliminated after such statistical control. This would suggest that the adverse effects of childhood obesity operate primarily through the relationship with adult obesity. However, the question of whether early identification could be useful in either prevention of obesity or slowing the rate of abnormal weight gain remains.

**BENEFITS OF BMI**

An important element of any measure used as a screening test is that it should be relatively cheap, easy to use in practice, noninvasive, and associated with little or no harm. It must also have good test characteristics, such as sensitivity and specificity, so it can be used with minimal false-positive and false-negative results. It seems that BMI fulfills many of these criteria. Because BMI is derived from simple measurements of height and weight, it is clearly inexpensive. It is much less expensive than using DEXA, air-displacement plethysmography, or

<table>
<thead>
<tr>
<th>BMI Percentile</th>
<th>Category</th>
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<tbody>
<tr>
<td>&lt;5th</td>
<td>Underweight</td>
</tr>
<tr>
<td>5th–84th</td>
<td>Healthy weight</td>
</tr>
<tr>
<td>85th–94th</td>
<td>Overweight</td>
</tr>
<tr>
<td>≥95th</td>
<td>Obesity</td>
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**TABLE 1** Categorization of BMI According to Percentiles for Children and Adolescents

The USPSTF found that BMI tracks from childhood to adulthood, but the degree of tracking varies according to age, with better tracking for older children, for younger children who are more overweight, and for children with an obese parent. They found that there was a ≥50% probability of adult obesity for teenaged children with a BMI at ≥95th percentile. There was insufficient evidence concerning whether childhood obesity determined by BMI was predictive of adverse health outcomes in adults independent of adult obesity. In the Bogalusa Heart Study, which did control for adult BMI, effects of childhood BMI on adult outcomes were lessened or eliminated after such statistical control. This would suggest that the adverse effects of childhood obesity operate primarily through the relationship with adult obesity. However, the question of whether early identification could be useful in either prevention of obesity or slowing the rate of abnormal weight gain remains.
other techniques that require the purchase and maintenance of expensive equipment. BMI is also easy to use and requires only personnel who are trained to measure height and weight. The most challenging aspect of BMI is its calculation from height and weight measurements and determination of the BMI percentile. This can be made easier with the use of BMI wheels and by personal digital assistants, or with new electronic medical records (EMRs). Determination of skinfold thickness is substantially more complicated and requires staff that are trained, with subsequent retraining and quality control. Skinfold thickness also requires calibrated equipment that must be maintained. Measurement of BMI is noninvasive and safe. Other methods are also likely to be safe, but DEXA does include exposure to a low dose of radiation.

The test characteristics for use of BMI for screening for childhood obesity are generally adequate when viewed from the perspective of correlation with gold-standard methods for measuring body composition and tracking coefficients. The test characteristics are less good but probably still acceptable when the objective is to predict outcomes in adulthood.

**LIMITATIONS OF BMI**

Although BMI has many advantages in the clinical setting, it also has some limitations that must be recognized. These limitations occur when BMI is used as a screening tool and also when it is used in the clinical setting to follow patients during an intervention.

BMI does have limitations in its ability to assess adiposity. It has long been recognized that elevation of BMI does not always equate to increased adiposity. Because it is a weight-for-height measure, BMI does not distinguish between fat mass and lean body mass. Thus, individuals with increased muscle mass may also have increased BMI. A classic example is the football player who appears to be overweight but is not overfat. Individuals with decreased lean body mass and increased adiposity may also be misclassified by assessment with BMI. An example of this might be patients with Prader-Willi syndrome who have decreased muscle and lean body mass. Ultimately, if fat accumulation becomes extreme, this concern is overridden. It is also a concern that the limitation of BMI to characterize adiposity may differ across ethnicity and gender. This means that BMI may have nonuniform limitations that need to be understood by clinicians.

Another concern about BMI relates to the cut points chosen to indicate the need for clinical action. Some investigators have suggested that certain ethnic groups, particularly Asians, may be at risk for comorbidities due to obesity at lower BMI thresholds than for other ethnic groups. This raises the concern that ethnicity-specific BMI cut points may be needed, a possibility that may be quite complex because the mechanisms of ethnicity differences associated with ethnicity are not well understood. In addition to limited understanding of the mechanisms of ethnic differences, in a global population, it is increasingly difficult to assign ethnicity to certain individuals. Still, because there is increasing focus on trying to develop true personalized and predictive medicine, the possibility of moving away from a “1-size-fits-all” approach has some attraction.

The use of categories based on BMI percentiles may be problematic. This is especially true of the overweight category (85th–94th percentile). Although children in this category are well into the upper half of the BMI distribution, it is not clear that they are truly overweight. Children and adolescents in that category have some increased risk of adiposity-related comorbid conditions but, especially at the lower end of this category, the increase is not great. The larger concern is that these children and adolescents may be on a longitudinal path to be in the obese category (≥95th percentile), with increasing risk of comorbidities as they get older.

Another limitation with BMI is the fact that its use in actual clinical practice is quite limited. Perrin et al surveyed physicians who were members of the North Carolina Pediatrics Society, with a response rate of 71% to their survey. Physicians were asked to describe what methods they used to evaluate obesity in children and were also provided a clinical scenario. For one group of pediatricians, only height and weight data were provided. For another group, BMI data and percentiles were provided. Perrin et al demonstrated that many pediatricians reported relying on visual inspection to make a diagnosis of obesity. Others used the height and weight charts, and only a small fraction of the pediatricians routinely used BMI percentiles. In the clinical scenario in which both height and weight were within normal limits but weight was elevated for height and the BMI was above the 95th percentile, those pediatricians who were given the BMI chart were more likely to be concerned about the patient and were more likely to take appropriate clinical action than those pediatricians who were only given the height and weight charts. Barlow et al also evaluated the identification of obesity in pediatric practices. They found that pediatricians correctly identified overweight or obesity in 27% of children with a BMI at the 85th to 94th percentile and 86% of children with a BMI at ≥95th percentile. Pediatricians were better at identifying obesity in adolescents than in children. In their medical record review,
the authors found that only 41% of growth charts were up-to-date, and only 6% had BMI plotted so that the percentile could be determined. Plotting of BMI was associated with improved identification of overweight when the BMI was at the 85th to 94th percentile. They also found that identification of overweight and obesity was important because it was associated with initiation of diet and exercise counseling.

Visual inspection is becoming an increasingly poor method for clinicians to use to recognize obesity. As the population of children and adolescents achieves a higher mean BMI, and a higher prevalence and severity of obesity, the perception of what appears normal or average changes. Increasingly, the norm is overweight and children and adolescents who are above the 95th percentile and obese do not appear to be very far from the norm. It seems that visual inspection is particularly problematic when patients are in the overweight range (BMI = 85th–94th percentile).

It is also important to recognize that BMI is not useful for children younger than 2 years. In this group, weight-for-length measures are used. However, the cut points that determine overweight and obesity for this measure are not well established. In the past, this was not seen as a major concern because most obesity developed later in childhood. In recent years, obesity has seemed to be occurring at younger and younger ages. Pediatricians should be concerned about children who are overweight, even in the first 2 years of life. It may also be true that the lack of use of a measure of adiposity during the first 2 years of life leads to pediatricians subsequently being less practiced and skilled at using and interpreting measures at later ages. If such measures were incorporated in all well-child visits, overall utilization might improve.

While the prevalence of obesity has increased, so has its severity. Increasing numbers of adolescents are reaching levels of BMI that place them at risk for adverse outcomes. This is a major reason for the American Medical Association Expert Panel recommending the use of the 99th percentile to characterize more severe obesity. However, the guidelines for eligibility for bariatric surgery among adolescents use BMI cut points that are substantially above even the 99th percentile. The current guidelines suggest that bariatric surgery would be an acceptable therapeutic modality for adolescents who have a BMI of ≥40 kg/m² if they also have serious medical comorbid conditions such as type 2 diabetes mellitus or obstructive sleep apnea. Adolescents with a BMI of 50 kg/m² qualify even with more minor comorbidities such as hypertension or psychosocial difficulties.

These issues with severe and morbid obesity raise the question regarding whether percentiles are the most useful method for characterization of BMI. One problem with the 99th percentile for BMI is that it is currently based on a relatively small sample size, and the estimate of this percentile cut point is imprecise. Another problem with using percentiles is that there is substantial room, in terms of higher BMI, above the 99th percentile. Because we use percentiles based on populations before the epidemic of obesity to maintain a constant standard for determining obesity, percentile values do not reflect the current population status. Thus, there is an increasingly large population of children and adolescents who have BMIs above the 99th percentile, for whom no further risk stratification is possible when using percentiles.

A potential solution to this “accordion effect” in the upper percentiles is to use BMI z scores or SD scores. The z score reflects the number of SDs above or below the mean a patient is for BMI. A higher z score is associated with more severe obesity, and there is no ceiling at the 99th percentile where values are collapsed. Researchers have been using BMI z scores for some time. A difficulty is that these measures are not widely used in clinical practice, and z scores are more difficult for patients and families to understand without proper explanation. Another problem in using BMI z scores is that the meaning of various z-score values in clinical terms is not clear. Substantial new research needs to be performed to determine the utility of z scores in practice.

BMI and BMI percentiles also have limitations in following patients during treatment. Parents of children who are overweight learn to understand the concept of BMI. They also realize that as patients grow in height, if they maintain a steady weight, their BMI will improve. It is a bit harder for them to understand that if children maintain their BMI as they grow older, their BMI percentile will improve. The most difficult aspect of the use of BMI during treatment is its relative insensitivity to body-composition changes. For example, if a child with obesity embarks on an appropriate regimen of diet and increased physical activity, it is possible to lose fat mass and gain lean body mass. This is clearly an improvement in body composition and should lead to a more favorable health status, but it may not be reflected in the patient’s weight or BMI. The lack of a favorable change in BMI, the traditional measure, can be defeating to a patient who is working hard on his or her treatment regimen but apparently is not seeing the desired effect. This may be a reason for patients to become less adherent to their treatment plan.
The solution to the measurement problem is not simple. It probably requires a more sophisticated measure of body composition that can be followed longitudinally. DEXA and air-displacement plethysmography are probably the most useful methods, but they have limitations, as previously described. Bioelectric impedance analysis is an alternative, but it would need to be studied more in the clinical setting with longitudinal measurements before its use could be widely recommended.

A very important issue in the use of BMI and BMI percentiles as a method for obesity evaluation is whether they are as useful in special populations of children and adolescents. For example, children with developmental disabilities, including patients with Down syndrome, seem to be at risk of obesity development. Children and adolescents with myelomeningocele often have limited mobility and may have difficulty achieving appropriate energy balance in our current obesogenic environment. Because of potential high risk, earlier identification of overweight and obesity may be particularly important for this subset of patients. In addition, children with limitations in the ability to be physically active may have altered body composition, as has been demonstrated in studies of children with cerebral palsy and myelomeningocele. Few studies have evaluated the validity of BMI as a method for identifying obesity in children with physical disabilities. There are also technical issues with measuring BMI in some children with physical or developmental disabilities. For example, it is difficult for some children with myelomeningocele to stand in a way to obtain an accurate height or weight measurement. It may also be difficult to measure weight and height accurately in children who are reliant on a wheelchair or who have developmental and behavioral problems. It is clear that additional research is needed to overcome these obstacles. Unfortunately, children with various forms of disability are often excluded from research. For this reason, even the prevalence of obesity and related health concerns remains largely unknown for children with disabilities.

**UNRESOLVED ISSUES: POTENTIAL SOLUTIONS**

A number of unresolved issues have been presented. Despite some limitations, BMI still seems to be the most useful method for assessing adiposity in the clinical setting. The largest concern is the fact that BMI is not widely used in practice. It is clear that education is warranted both for health care professionals and laypersons, which could lead to more widespread use of BMI and more appropriate interpretation. It also seems that the availability of EMRs should make BMI use and interpretation easier and more a regular part of standard routine care for children. There is evidence that improved recognition of overweight and obesity using BMI by primary care physicians is associated with greater efforts to identify potential comorbid conditions. Dilley et al administered an in-office survey to parents at 13 diverse pediatric practices to identify health habits and also evaluated medical records. The investigators limited their analysis to children 2 years of age or older for whom a BMI percentile could be calculated. They found that 28% of the children who were obese were identified as such in the medical record. When those identified as obese were compared with those who were not identified, there was a significant difference in screening for comorbidities (54% in those identified versus 17% in those not identified). For children who were overweight (BMI between the 85th and 94th percentiles), only 5% had been identified in the medical record. Children who were identified as overweight or obese had a 6-times greater odds of receiving an evaluation of comorbidities and management of overweight compared with those children who were not identified. These results suggest that use of BMI and BMI percentiles is part of an overall focus on obesity as an important health problem and identification of comorbidities. Additional research to evaluate whether pediatricians and family physicians who adopt the use of BMI and BMI percentiles will become better at evaluation of obesity and institution of appropriate management strategies needs to be conducted.

Research is also needed to determine the best methods for encouraging the implementation of BMI use in pediatric practice and appropriate action based on the information obtained. The EMR may facilitate the use of BMI and BMI percentile, but it needs additional study. Research must also focus on how to improve the understanding of BMI and BMI percentiles among pediatric patients and their families. Unfortunately, the evaluation of overweight and obesity is often occurring in environments that discourage it as a clinical focus. McDonald et al evaluated the extent to which children's hospitals in the United States and Canada provide optimum health environments for their patients, families, health care providers, and staff. They found a very high prevalence of fast-food outlets and snack/beverage vending machines in children’s hospitals. They also found that the revenue generated from these activities may be viewed as a more important issue than establishing a healthy environment.

The issue of whether measures of regional deposition of fat, such as the waist circumference, will be a useful adjunct to BMI in the pediatric population remains to be determined. Waist circumference is being increasingly used in adult medicine and may also...
need to be part of the approach of the pediatrician and family physician in the future. Before routine waist-circumference measurement can be recommended, appropriate standards based on age, gender, and possibly other factors such as sexual matura-
tion will need to be developed. In addition, a deeper base of evidence will need to be developed to demonstrate that the addition of a waist-circumference measure will lead to improved risk stratification and clinical decision-making over the use of BMI alone. One possibility in the standardization of waist measurements in children is the use of the waist/height ratio. Additional research will be needed to evaluate the utility of this measure.

The question of how to best evaluate patients from birth to 2 years of age remains. Clearly, assessment of adiposity early in life is becoming increasingly important, and establishing a baseline on which to judge changes as the patient grows older will be useful. Additional research will be needed to establish the optimum approach for young patients.

The question of whether to use BMI percentiles or z scores also remains unanswered. One possible solution is to reserve the use of z scores for the population of children and adolescents with very severe obesity. Addi-
tional research is needed to evaluate whether additional risk stratification above the 99th percentile of BMI is possible and has clinical utility.

Finally, the optimum methods for following children and adolescents who are being treated for obesity need to be established. BMI percentiles have both advantages and potential disadvantages for this purpose.

**CONCLUSIONS**

It is clear that BMI has great utility and potential for even more as its use is adopted more widely. Nevertheless, numerous questions remain about the use of BMI and BMI percentiles that deserve additional investigation.

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