International efforts to screen children have previously focused on the problem of malnutrition in the preschool years. The new World Health Organization–derived but US-based data for “optimum” growth in school-aged children may not be accepted in more than a few countries. Currently, an international perspective suggests that those school-aged children’s BMIs that, on a percentile-ranking basis, track to adult BMIs of \( \gtrless 25 \text{ kg/m}^2 \) are likely to be associated with an appreciable increased risk of the comorbidities associated with weight gain. There is limited evidence on the value of individually directed help for children with higher BMIs as a national policy, but national surveillance systems are badly needed to allow a better focus on the development of both public health and individual treatment policies. *Pediatrics* 2009; 124:S42–S49
The monitoring of childhood growth has, perhaps surprisingly, been a contentious issue for several decades. This global debate has reflected the disparate views of pediatricians who, when using the “reference” curves established by the World Health Organization (WHO) and based on the best data then available, observed that these data were classifying children in their own countries as well below the curves. Despite these reservations, immense efforts were made, particularly in Africa, to establish these growth charts as the legitimate vehicle for monitoring good health. Much of the effort was led originally by Jelliffe in Uganda1 and then by Morley and Cutting2 of the Institute of Child Health (London, United Kingdom).

In the early 1970s, epidemiologic analyses in the Caribbean island of Montserrat led us to recognize the dominant role of stunting in explaining the low weight for age of the majority of the world’s children. Malnutrition was specified when the height, weight, or weight-for-height values were <2 SDs of the reference means for boys and girls of the appropriate age.3 This approach was reaffirmed in the 1995 WHO analyses of the usefulness of anthropometric assessments of nutritional status.4

With the almost exclusive focus on the growth of preschool-aged children as the most vulnerable group, there has been relatively little information on the growth of school-aged children in most parts of the world. Thus, in the assessment of children’s malnutrition and obesity for the WHO’s first-ever analyses of the risk factors associated with the global basis of disease and disability, de Onis et al5 were able to provide extraordinarily comprehensive analyses of children’s growth from birth to 5 years. However, when considering obesity in children older than 5 years, we had little option but to use occasional national surveys, sometimes extrapolate from small-scale ad-hoc studies to national estimates, and (often in Africa in particular) give a crude estimate on the basis of neighboring country data.6

THE USE OF BMIs IN MONITORING CHILDREN’S GROWTH

When the International Obesity Taskforce (IOTF) produced its draft on obesity for the first WHO consultation on obesity just over 10 years ago, there was no robust international system for considering obesity in children. Dietz and Bellizzi7 in the IOTF children’s group therefore considered the issue in detail and agreed to use the BMI values, although the Benn index p in the measure weight/height to the power p chosen as 2.0 (ie, similar to the Quetelet index in adults [ie, BMI, weight (kg)/height (m)2]) should have been changed on a yearly basis if the objective was to have a height-independent measure of body size.8 Relating skinfold thickness to Benn values of ~2.0 in the weight/height8 index was reasonable except for children aged 12 to 16 years. For these children the optimal values for n were higher. Overall, the use of BMI as an indicator of adiposity seemed acceptable for children aged 6 to 7 and 17 to 18 years (see Fig 1). However, a Benn index of 2.0 means that taller children, particularly at 6 to 12 years of age, have higher prevalences of obesity9 (Fig 2). This has often been observed and led to the conclusion that children who grew tall earlier were those most likely to become overweight and obese. This is true if subsequent obesity is observed in adults but may be confounded by the fixed Benn index of 2.0 if assessed in earlier years.

The IOTF group then developed BMI reference values10 based on the data from nationally representative surveys of 6 countries: Brazil, United States, United Kingdom, Netherlands, Singapore, and Hong Kong. These derived IOTF values for the mean of the appropriate percentiles are now used almost universally for quantifying the prevalence of

![Figure 1](http://pediatrics.aappublications.org/)

**FIGURE 1**

Benn index values fitting skinfold measures best in 2 surveys of US white boys.4 The graph shows the optimum value of the power p in the equation weight (kg)/height (m)2 when the same average values for the weight/height index for children of different heights are obtained and applied to 2 US national cross-sectional surveys. NHES indicates National Household Education Surveys. (Reproduced with permission from Franklin MF. Comparison of weight and height relations in boys from 4 countries. Am J Clin Nutr. 1999;70(1):161S.)

![Figure 2](http://pediatrics.aappublications.org/)

**FIGURE 2**

The prevalence of obesity in white US boys of different height: impact of a Benn index of 2.0.4 Note that the prevalence of obesity is based on the proportion of children at each age who exceeded the 85th percentile of BMI derived from US children in the National Health and Nutrition Examination Survey I as presented by Must et al.4 The 3 different groups relate to the 3 tertiles of height observed in the survey. If height had little or no effect on the prevalence of obesity as determined by a weight/height index to the power 2.0, then the proportions of boys exceeding the 85th percentile should be roughly equal for all height categories and age groups. (Reproduced with permission from Franklin MF. Comparison of weight and height relations in boys from 4 countries. Am J Clin Nutr. 1999;70(1):161S.)
overweight and obesity rates increased by one third when the new WHO standard curves were used rather than the old National Center for Health Statistics data; there were also far more infants and 1-year-olds classified as stunted.13

The new set of growth curves from the WHO is being considered as the ideal growth pattern for children up to 5 years from any ethnic group, but this is at variance with policies in many countries in which governments still assume that their children grow differently for genetic or other reasons particularly in their height trajectories. The Centers for Disease Control and Prevention (CDC) has produced its own growth curves. However, comparing the new WHO charts with the CDC charts for children younger than 5 years shows that the CDC curves show their “normal” children to be heavier and shorter than the WHO-measured children, particularly during the first year.14

**NEW STANDARD (THAT IS, “IDEAL” GROWTH CHARTS): COMPARISONS WITH THE CENTERS FOR DISEASE CONTROL AND PREVENTION CHARTS**

The 1990 WHO reference values were derived from the US National Center for Health Statistics set of reference charts of 1977, which reflected the growth of predominantly bottle-fed infants. The new WHO study involved breastfed infants and children from California, Norway, India, Oman, Ghana, and Brazil. They showed that, despite the different ethnic backgrounds, the children’s growth was almost identical and the variability in growth was far less than in the databases normally used for producing growth charts. If one takes the new WHO ± 2 SD values as the limits of normality, then the estimated prevalences of underweight and overweight will now be greater, particularly in terms of overweight, because in both children and adults there is an increasingly skewed distribution of weights as the average weight for age rises. Thus, overweight and obesity across the world.11 They have also been assessed in relation to estimates of impedance measurements of body fat in UK children. The IOTF values were found to be very satisfactory at the lower overweight cutoff point but not so robust at the obesity cutoff values (see Table 1).12

**THE IDEAL GROWTH OF SCHOOL-AGED CHILDREN**

In late 2007, the WHO set out their estimates of the growth of children from 5 to 20 years of age.15 Surprisingly, these are once more based exclusively on US data despite detailed examination of other growth curves from many international sources. Although specified as “reference” curves for those older than 5 years, the melding of the preschool- and school-aged curves implies that the world’s children, if optimally fed and nurtured, should in theory grow in line with a subset of the cohort of US children of old. What is already clear, however, is that far more children in population surveys will now be designated as overweight. In fact, the cutoff points chosen are very close to those percentiles chosen for the IOTF analyses at the age of 18 to 20 years, but there are appreciable differences in the actual BMI values between the different estimates at younger ages (see Fig 3).

Therefore, there are now 3 cutoff systems in widespread use:

- the 2000 CDC reference curves at the 85th and 95th percentiles;
- the IOTF BMI 25 and BMI 30 percentile-equivalent cutoffs; and
- the 2007 WHO growth curves with first and second SD limits.

The data in Fig 3 show that the IOTF cutoff for obesity is much higher than that in the CDC and WHO curves, and these 2 latter curves almost overlap. However, the IOTF overweight curves almost match the 85th CDC percentile curves, but the new WHO curves for +1 SD present much lower cutoff points. The application of the WHO criteria would increase the prevalence of those classified as “overweight” in IOTF terms and those considered “at risk of overweight” in CDC and WHO terminology. Table 2 uses data from the latest National Health and Nutrition Examination Survey (NHANES) of children and presents the prevalence of overweight and obesity estimated by the 3 different criteria. The new WHO criteria give the highest prevalence of overweight (including obesity), with the IOTF system being the most conservative in the younger group of 6- to 11-year-old boys. In general, however, the CDC and IOTF give similar values, but the WHO system increases the prevalence by 10% to 15%. As in previous analyses, the prevalence of obesity by the IOTF cutoff scheme is substantially lower than that by the CDC method, but now the CDC and WHO figures for this extreme group are similar.

**INTERNATIONAL VALIDITY OF THE CDC AND WHO CURVES**

Given that the database for the WHO curves implies “near-perfect” growth, it is logical to consider those school-aged children and adolescents within the upper end of the BMI distribution as having healthy weights. However, the 15% of children above the 85th...
percentile would, on an IOTF basis, be considered as likely to be unhealthy. It is difficult to conclude, on the basis of current evidence, that the approach adopted by the WHO is wise from a public health point of view. There is substantial evidence from US adult data that BMIs of ≥25 are associated with marked morbidity. For decades we have also known that the earlier the excess weight is evident, the greater the long-term risk, and now new evidence has revealed that modest increases in the BMIs of 7- to 13-year-olds in Denmark (i.e., with genetic stock reasonably similar to that of US whites) predict early death and cardiovascular disease.16 Passing through the centiles to greater degrees of overweight is a powerful predictor of future morbidity. So, from a US point of view one has to recognize that if children in the higher percentiles of BMI with their known associated comorbidities maintain their higher BMIs into adulthood, then their health is likely to be compromised. On an individual basis there do not seem to be any illuminating analyses of the absolute risk for these children in terms of disability and premature death that can be used to inform pediatricians, but the public health dimension that relates to future health costs on a national basis and the implications for the economy of the country demands a different perspective.

ETHNIC ISSUES

With the Mexican government in their nationally representative survey in 2000, which compared with age- and gender-matched non-Hispanic US whites, we showed that Mexicans had a greater prevalence of type 2 diabetes and hypertension as BMI increased and a greater propensity for abdominal obesity. In our WHO global burden analyses6 we also found in nationally representative data that the Japanese were 2 to 5 times more prone to type 2 diabetes than Scandinavians, and we have now confirmed this with major data sets comparing Asian and white populations. White people are far less prone to hypertension and type 2 diabetes than Asian people for equivalent gains in BMI, and there seems to be an absolute increase in these morbid conditions even at low BMIs.18 It is little

![Figure 3](http://www.pediatrics.org/content/suppl/2009/09/04/PEDS.124006.Data.S1/Figure3.large.jpg)

**FIGURE 3**
Different criteria for overweight and obesity. A, Boys; B, girls.

![Table 2](http://www.pediatrics.org/content/suppl/2009/09/04/PEDS.124006.Data.S1/Table2.large.jpg)

**TABLE 2**
Prevalence of Overweight (Including Obesity) and Obesity in School-aged US Children (NHANES 2003 and 2004 Combined)

<table>
<thead>
<tr>
<th></th>
<th>&gt;85th CDC Percentile</th>
<th>Higher Than WHO SD 1</th>
<th>&gt;25 IOTF Percentile</th>
<th>Higher Than WHO SD 2</th>
<th>&gt;30 IOTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys 6–11 y</td>
<td>35</td>
<td>39</td>
<td>31</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Boys 12–17 y</td>
<td>38</td>
<td>42</td>
<td>38</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Boys 6–17 y</td>
<td>37</td>
<td>41</td>
<td>35</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Girls 6–11 y</td>
<td>39</td>
<td>40</td>
<td>39</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Girls 12–17 y</td>
<td>33</td>
<td>38</td>
<td>34</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Girls 6–17 y</td>
<td>35</td>
<td>39</td>
<td>36</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Obese</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Note that, on average, diabetes accounted for 29% of those diagnosed in glucose tolerance tests as having either glucose intolerance or diabetes.

These differences may have a genetic origin, although on the basis of extensive new data from the developing world and Scandinavia it is more likely that we are dealing with marked epigenetic and programming phenomena relating to the population’s adverse fetal and infant environment.

PREDICTING THE RISK ASSOCIATED WITH DIFFERENT RATES OF CHILDHOOD GROWTH

The classic Barker et al analyses of English adults with hypertension, diabetes, and abdominal obesity (characteristics of what was then called syndrome X and is now called metabolic syndrome) showed that the birth weight of these individuals was an important predictor of their ill health.

Similar results are now evident in many countries including the United States, Guatemala, Finland, China, and India. If the children are of low birth weight (LBW), then as shown in our Millennium analyses for the United Nations, their likelihood of being underweight for age in the first few years of life is exceptionally high, because children would have to show accelerated growth from birth to be classified otherwise. Table 3 shows in young Finnish adults that, as in the British subjects of Barker et al, the children’s risk of adult-onset diabetes was most evident when small newborn infants gained more weight than usual and were heavy at 12 years of age. Detailed Indian data provide roughly similar data in relation to both glucose intolerance and diabetes. The optimum prediction was evident if children were of lower weight at 2 years but subsequently gained excess weight so that they were heavy by the age of 12 years (Table 4). These data suggest that it is the disjunction between the early setting of growth rates and later accelerated weight gain that is particularly harmful.

It is noteworthy that, originally, small Indian children who had a BMI at >16 when 12 years of age already had about double the risk of developing diabetes (about one third of the numbers with both diabetes and glucose

### TABLE 3 Cumulative Incidence of Diabetes in Finnish Adults Aged 27 to 37 Years According to Their Birth Weight and BMI at the Age of 12 Years

<table>
<thead>
<tr>
<th>Birth Weight, kg</th>
<th>BMI at 12 y of Age, kg/m²</th>
<th>16–17</th>
<th>17–18</th>
<th>&gt;18</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3.0</td>
<td>3.9</td>
<td>3.5</td>
<td>4.4</td>
<td>4.9</td>
</tr>
<tr>
<td>3.0–3.5</td>
<td>1.5</td>
<td>3.3</td>
<td>3.8</td>
<td>5.9</td>
</tr>
<tr>
<td>&gt;3.5</td>
<td>1.8</td>
<td>1.0</td>
<td>2.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>

### TABLE 4 Prevalence of Adult Glucose Intolerance and Diabetes in Indians Aged 26 to 32 Years in Relation to Their BMIs When 2 and 12 Years and Then Taking Account of Their Adult BMI Status

<table>
<thead>
<tr>
<th>BMI at 2 y</th>
<th>Prevalence of Impaired Glucose Tolerance or Diabetes, % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI &lt; 14.7 at Age 12 y</td>
<td>BMI = 14.7–16.2 at Age 12 y</td>
</tr>
<tr>
<td>&lt;15.0</td>
<td>16.1 (217)</td>
</tr>
<tr>
<td>15.0–16.1</td>
<td>14.2 (148)</td>
</tr>
<tr>
<td>&gt;16.1</td>
<td>8.2 (61)</td>
</tr>
<tr>
<td>All subjects</td>
<td>14.3 (426)</td>
</tr>
<tr>
<td>Current BMI &lt; 22.7</td>
<td>Current BMI = 22.7–26.5</td>
</tr>
<tr>
<td>&lt;15.0</td>
<td>16.1 (188)</td>
</tr>
<tr>
<td>15.0–16.1</td>
<td>9.9 (152)</td>
</tr>
<tr>
<td>&gt;16.1</td>
<td>7.2 (97)</td>
</tr>
<tr>
<td>All subjects</td>
<td>9.4 (437)</td>
</tr>
</tbody>
</table>

Note that, on average, diabetes accounted for 29% of those diagnosed in glucose tolerance tests as having either glucose intolerance or diabetes.
is increasingly linked to vitamin B12 deficiency in the mother during pregnancy. Vitamin B12 deficiency is also evident in infants of mothers who were vitamin B12 deficient during pregnancy. Vitamin B12 deficiency is associated with low birth weight and birth defects. The prevalence of vitamin B12 deficiency in the general population is low, but it is relatively high in areas where there is a high prevalence of pernicious anemia, such as rural areas in northern Europe.

Fund29 showed that the LBW prevalence was 28% in Asia (India, Bangladesh, Nepal, Sri Lanka, and the Philippines), 15% in sub-Saharan Africa, 15% in the Middle East and North Africa, and 9% in the Asia-Pacific and Latin American-Caribbean regions. However, the current adult morbidity rates relate to much higher prevalences of LBW and stunting when these adults were children 40 to 70 years ago.

Given these findings, one can surmise that when school-aged US children are found to have a high BMI (e.g., >85th percentile), they are at an increased risk of premature morbidity and mortality whatever their racial origin. If, however, the child was also born small or had a low BMI in their first 2 years of life, then their likelihood of having diabetes is increased approximately two-fold. If the child is of Asian, Hispanic, or Caribbean origin, then there is another twofold to fivefold increased risk of adult disease, with the most vulnerable group probably being those of Indian descent whose family still follows a vegetarian diet. These propositions need to be supported by new analyses undertaken in a standardized format so that the risks of overweight and obese children from different ethnic groups can be set out in a more coherent manner.

**INTERNATIONAL SCREENING AND SURVEILLANCE**

The UK government and the London Royal College of Child Health originally opposed the introduction of BMI screening of children at school because there seemed to be no good case to show that there were valid and cost-effective remedial measures that would justify the effort and expense. The policy was to only introduce a measure for medical screening if there was substantial and clear evidence of effective remedial action to justify the effort involved. At that time there were also remarkably few pediatricians in the United Kingdom who had any experience with helping overweight children effectively.

The routine surveillance of children, however, was considered a different issue in the United Kingdom, and the government opted for a national randomly sampled annual survey with measurements of children and adults. This is now routinely undertaken.

More recently, considerable political pressure to reintroduce BMI screening of children has led to a system in which parents give permission for their children to be monitored. Recent analyses have shown that parents of obese children opt out of the measurement system. The details of what will be involved in the government initiative are still unclear.

In Singapore, a very different approach was introduced in 1993, with a legal requirement for all children to be screened annually. Those in the upper range of BMI were required to stay after school and to eat separately in a different canteen for lunch, and the parents were alerted and required to change the eating patterns of their children. The schools themselves were disadvantaged financially if they sent children for the compulsory conscription medical examination who were found to be obese. The initiative, organized by the Ministry of Education led by the prime minister with all ministers and head teachers, involved extensive training of every teacher in the country to reinforce the message. The initiative initially had a dramatic effect on the prevalence rates of obesity (Fig 4) but was stopped in early 2007 after political lobbying by parents who felt that their children were being disadvantaged by, for example, the stigma of having to stay after school to exercise and eating in a separate canteen. International evidence on the importance of genetics in explaining a substantial part of the interindividual variation in BMI within a community reinforces the need for care in
selectively targeting overweight children. A more holistic approach for the whole school is now being developed in Singapore, but what this means in practice is still unclear.

CONCLUSIONS

International efforts to screen children previously focused on the problem of malnutrition in the preschool years. The new WHO data for those younger than 5 years, based on data from breastfed children, are now considered optimum for all ethnic groups. US-based data for the growth in school-aged children may not be accepted easily even as reference data; an international perspective suggests that those school-aged children whose BMIs on a percentile-ranking basis track to adult BMIs of ≥21 are likely to have a progressive increased risk of the comorbidities associated with weight gain in adolescence/early adult life and with premature death. The 15% whose ≥85th percentiles track to adult BMIs of ≥25 are clearly at greater risk. There is limited evidence on the value of individually directed help for children with higher BMIs as a national policy except in Singapore, where this very interventionist approach has now been changed to avoid overweight children and their families being classified as failing to respond to the government’s initiatives.

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