A comparison of the National Center for Health Statistics and new World Health Organization growth references for school-age children and adolescents with the use of data from 11 low-income countries1,2

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ABSTRACT

Background: In 2007 new World Health Organization (WHO) growth references for children aged 5–19 y were introduced to replace the National Center for Health Statistics (NCHS) references. Objective: This study aimed to compare the prevalence of stunting, wasting, and thinness estimated by the NCHS and WHO growth references.

Design: NCHS and WHO height-for-age z scores were calculated with the use of cross-sectional data from 20,605 schoolchildren aged 5–17 y in 11 low-income countries. The differences in the percentage of stunted children were estimated for each year of age and sex. The z scores of body mass index–for-age and weight-for-height were calculated with the use of the WHO and NCHS references, respectively, to compare differences in the prevalence of thinness and wasting.

Results: No systematic differences in mean z scores of height-for-age were observed between the WHO and NCHS growth references. However, z scores of height-for-age varied by sex and age, particularly during early adolescence. In children for whom weight-for-height could be calculated, the estimated prevalence of thinness (WHO reference) was consistently higher than the prevalence of wasting (NCHS reference) by as much as 9% in girls and 18% in boys.

Conclusions: In undernourished populations, the application of the WHO (2007) references may result in differences in the prevalence of stunting for each sex compared with results shown when the NCHS references are used as well as a higher estimated prevalence of thinness than of wasting. An awareness of these differences is important for comparative studies or the evaluation of programs. For school-age children and adolescents across all ranges of anthropometric status, the same growth references should be applied when such studies are undertaken.

INTRODUCTION

In 2007 the World Health Organization (WHO) published revised anthropometric reference data for children aged 5–19 y to fill the gap between the new WHO growth standards for children from birth to 5 y of age and adult body mass index (BMI; in kg/m²) thresholds (1). The new growth references for children aged 5–19 y were created from the original National Center for Health Statistics (NCHS) data (2). The same statistical method used to construct the WHO growth standards for age 0–5 y was applied (1): the Box-Cox power exponential distribution with a cubic spline smoothing function (3). The differences in the construction of the NCHS and WHO growth references were that the latter included data for younger (18–71 mo) and older (≥24 y) age groups, and applied improved statistical techniques to fit the curves (1). The 2007 references were also modeled to ensure a smooth transition at 5 y from the WHO growth standards for age 0–5 y to the growth references for children and adolescents (1). The qualitative and quantitative differences between the NCHS, new WHO, and other growth references have been reviewed by expert panels and summarized previously (1, 4).

A significant innovation of the WHO references was the development of BMI z scores to identify individuals who are overweight (>2 SD), obese (>3 SD), or thin (<−2 SD). This new index effectively replaced the NCHS z score of weight-for-height, used to estimate the prevalence of wasting, which could be calculated only for girls aged <10 y and boys aged <11.5 y.

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The WHO references no longer calculate \( z \) scores of weight-for-age for children up to 18 y for both sexes, but stop at 10 y (1).

Previous studies have compared the effect of the application of different growth reference thresholds to classify children as stunted, underweight, overweight, or obese in different populations, but these studies were before the publication of the 2007 WHO growth references (5–9). We are not aware of any studies that have applied the 2007 WHO BMI-for-age growth references to calculate \( z \) scores in school-age children and adolescents in undernourished populations. Anthropometric indexes are used widely in school health programs in low-income countries and are common outcome measures for nutritional interventions (10, 11). The current study, therefore, aimed to inform programs that will apply the 2007 WHO growth references.

The first aim of this analysis was to examine the anthropometric status of a large sample of children aged 5–17.9 y from 11 low-income countries and to compare the \( z \) scores of height-for-age and the prevalence of stunting with the use of the old NCHS references, with values calculated with the use of the 2007 WHO references. The second aim was to describe the WHO \( z \) scores of BMI-for-age and to compare this new index with the NCHS \( z \) scores of weight-for-height.

SUBJECTS AND METHODS

Cross-sectional data were collected from convenience samples obtained through school-based surveys conducted by Save the Children USA. The agency conducts routine surveys of the health and anthropometric status of school-age children to identify health and nutrition interventions for school health programs in each country in which it works. Data were available for surveys conducted in Bangladesh, Bolivia, Burkina Faso, Ethiopia, Haiti, Malawi, Mali, Mozambique, Pakistan, the Philippines, and Tajikistan. Each baseline survey typically included a random sample of schools from the agency’s program sites. In most cases a stratified sample of children from each school was selected that was composed of equal numbers of boys and girls from each class or grade. The age ranges in each country reflect the ages at which children are enrolled in basic education. In some countries data from more than one site were available for analysis. All surveys were conducted with the approval of the Ministry of Health and the Ministry of Education in each country and were a part of school health programs being implemented by Save the Children, rather than being undertaken for research purposes. The data from Ethiopia came from a representative national survey of schoolchildren undertaken on behalf of the Government of Ethiopia by Save the Children (12). Ethical approval for the survey was given by the Ethiopia Science and Technology Commission and the University of Westminster, London. The data from Pakistan were collected during home visits rather than in schools, as a part of another study (13), but only data from enrolled children were included in the analysis.

The height of each child was measured with the use of a portable stadiometer, most commonly a Leicester stadiometer (Child Growth Foundation, London, United Kingdom) to a precision of 0.1 cm, except in Bangladesh, Mali, and Burkina Faso, where the measurements were rounded to the nearest 0.5 cm or 1.0 cm. The weight of each child was measured with the use of a digital electronic scale, with the child wearing light clothing and no shoes, to a precision of 0.1 kg, except in Bangladesh, Malawi, and Mozambique, where it was recorded to the nearest 0.5 kg.

In 4 countries (Bangladesh, Haiti, Malawi, and Mali, which composed 31% of the total sample of children), the children’s age was reported in years, so 15 June of the year of birth was taken as the estimated date of birth. In the remaining countries the date of birth was recorded from school records.

\( Z \) scores of height-for-age, weight-for-age, and weight-for-height were calculated for each child with the use of Anthro software (Centers for Disease Control, Atlanta, GA) (14), which applies the NCHS reference values (2). These are referred to as NCHS \( z \) scores. Weight-for-height can be calculated only for girls aged <10 y and boys aged <11.5 y.

\( Z \) scores of height-for-age, weight-for-age, and BMI-for-age were calculated for each child with the use of Anthropometric Standards software (University of Michigan) (15), which applies the 2007 WHO reference values. These are referred to as the WHO \( z \) scores. Weight-for-age can be calculated only for children aged ≤10 y. Statistical analysis was done with the use of PASW, version 18 (SPSS Inc, Chicago, IL).

Children with a \( z \) score of height-for-age, weight-for-age, weight-for-height, or BMI-for-age of \( \leq -2.0 \) were classified as stunted, underweight, wasted, or thin, respectively (1). The arbitrary minimum sample size applied for reporting of results was 50 observations in each year of age and sex.

Eighty-four subjects were excluded from the analysis because their records were flagged by the anthropometry software because the \( z \) scores exceeded the following values: weight-for-age of \( < -6 \) SD or \( > 5 \) SD; height-for-age of \( < -6 \) SD or \( > 6 \) SD; and BMI-for-age of \( < -5 \) SD or \( > 5 \) SD (1, 14). The distribution of \( z \) scores were examined for compliance with the assumptions of normality.

For each subject, the difference between the 2 \( z \) scores of height-for-age was calculated as WHO \( z \) score − NCHS \( z \) score. To examine the distribution of these differences by sex, a frequency distribution was plotted. To examine the differences by age, the difference in \( z \) scores was plotted against the WHO \( z \) scores separately by sex and age for children between 5 and 17 y.

To compare the \( z \) scores of WHO BMI-for-age and NCHS weight-for-height first, a simple scatter graph of values was plotted. The difference in the percentage of children who were classified as thin and those who were classified as wasted was calculated for each sex and year of age.

RESULTS

The sample size ranged from 604 to 7548 per country, and anthropometric data were available for a total of 20,605 children from all 11 countries, as shown in Table 1. The sample sizes of children by sex and year of age are shown in Table 2.

Height-for-age \( z \) scores

Plots of the mean \( z \) scores of height-for-age for girls and boys calculated with the use of the NCHS and WHO references, with the difference between the 2 \( z \) score means in \( z \) scores for each year of age, are shown in Figure 1. The WHO mean values for preadolescent girls were slightly lower than the NCHS means, whereas the mean values for boys were similar up to the age of 11 y. The greatest divergence between the sexes occurred in the
next 3 y: the mean WHO values for girls were 0.13 z scores higher than the NCHS means, whereas for boys they were \( -0.13 \) z scores lower. The distribution of the differences between the WHO and NCHS z scores of height-for-age by sex (WHO \( - \) NCHS) is shown in Figure 2. For the girls, 61.3% of differences were negative, compared with 38.7% positive; for the boys, 39.5% of differences were negative, compared with 60.5% positive. This meant that for both sexes combined there were almost equal percentages of negative (50.2%) and positive (49.8%) differences between the WHO and NCHS z scores, so the differences between the sexes were cancelled out and the average z scores were almost the same (WHO, \( \bar{z} = 1.39 \); NCHS, \( \bar{z} = 1.40 \); \( P = \text{NS} \)).

There were also significant variations in the size of the differences between the z scores by age, as well as by sex. The estimated regression lines of the differences for each individual between the WHO and NCHS z scores of height-for-age (WHO \( - \) NCHS) plotted against the WHO z score values for girls and boys separately for each year of age are shown in Figure 3. The slopes of regression lines ranged from positive to negative and the average correlation coefficient \( (r) \) was 0.91 for boys and 0.95 for girls \( (P < 0.001) \). There was no consistent pattern of differences between the 2 indexes by age or sex, as shown in Figure 3.

The prevalences of stunting in the total sample according to the WHO and NCHS references were the same: 32.6% and 32.6%.

<table>
<thead>
<tr>
<th>Country</th>
<th>Site of survey</th>
<th>Year of survey</th>
<th>No. of schools</th>
<th>Age range</th>
<th>Age</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Meherpur district</td>
<td>2008</td>
<td>36</td>
<td>78–186</td>
<td>117 ± 22</td>
<td>883 (47.7)</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Caracollo municipality</td>
<td>2005</td>
<td>17</td>
<td>63–170</td>
<td>114 ± 23</td>
<td>604 (48.2)</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Boulikiende, Oudalan, Sanguié, Sanmatenga, Zoundweogo provinces</td>
<td>2001</td>
<td>21</td>
<td>61–199</td>
<td>118 ± 26</td>
<td>1365 (59.6)</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>National</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haiti</td>
<td>Messaide region</td>
<td>2002</td>
<td>27</td>
<td>66–210</td>
<td>134 ± 35</td>
<td>1465 (49.8)</td>
</tr>
<tr>
<td>Desaline</td>
<td></td>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malawi</td>
<td>Mangochi district</td>
<td>1998</td>
<td>51</td>
<td>90–210</td>
<td>157 ± 26</td>
<td>2612 (50.2)</td>
</tr>
<tr>
<td>Balaka district</td>
<td></td>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mali</td>
<td>Kolondieba district</td>
<td>2000</td>
<td>60</td>
<td>67–212</td>
<td>135 ± 27</td>
<td>1497 (51.1)</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Gaza province</td>
<td>1998</td>
<td>20</td>
<td>102–210</td>
<td>157 ± 19</td>
<td>947 (50.1)</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Allai valley</td>
<td>2006</td>
<td>54</td>
<td>78–176</td>
<td>110 ± 16</td>
<td>1464 (50.4)</td>
</tr>
<tr>
<td>Philippines</td>
<td>Metro Manila</td>
<td>2000</td>
<td>54</td>
<td>78–176</td>
<td>110 ± 16</td>
<td>1464 (50.4)</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>Khuroson, Jomi, Panjakent, Aini</td>
<td>2007</td>
<td>42</td>
<td>88–178</td>
<td>127 ± 6</td>
<td>1368 (49.8)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,605 (50.9)</td>
</tr>
</tbody>
</table>

\(^1\) Mean \( \pm \) SD (all such values).
respectively. However, the proportions of children who were classified as stunted varied between the sexes and by age, depending on the growth reference used. The difference in the prevalence of stunting for each age group by sex, in which a negative value means that the WHO prevalence is lower than the NCHS prevalence, is shown in Figure 4. For boys between the ages of 5 and 10 y the difference was −1.3% and then was sharply higher by nearly 7% at the age of 13 y. Among girls between the ages of 5 and 10 y the difference rose from 0.5% to 4.3% and then fell to −6.2% at 13 y of age. Thus, the largest total difference between the sexes, of ≈13%, occurred for children aged 13 y, but they roughly cancelled each other out when the overall prevalence of stunting was estimated. This analysis was also performed after the exclusion of the countries with estimated dates of births of the children (Bangladesh, Haiti, Malawi, and Mali). The magnitude and direction of the difference in the prevalence of stunting according to age and sex remained the same (results not shown).

The prevalence of stunting for boys and girls separately in each country estimated with the use of the NCHS and WHO references is shown in Table 3. The difference varied between the sexes and from country to country. The greatest difference in the estimated prevalence of stunting in girls was 6.3% observed in the Philippines and in boys was 4.5% in Mozambique. There was no correlation between the prevalence of stunting estimated with either of the growth references and the difference in prevalence for the data for all 11 countries, except for the WHO prevalence for boys, which was weakly significant ($P < 0.05$), which indicates that the difference was mostly independent of the prevalence (Table 3).
BMI-for-age z scores

The mean z scores of BMI-for-age calculated with the use of the WHO growth references for boys and girls aged 5–17 y old indicates that boys’ z scores tend to decline steadily with age by \(-2.0.1\) z score per year of age, as shown in Figure 5. The values for girls also appeared to decline by about the same amount as boys until \(\sim 12\) y of age, but then to increase by \(\sim 0.5\) z scores over the next 6 y as their values diverged from boys. However, these data are cross-sectional rather than longitudinal, so the interpretation of them in terms of growth may not be justified, although it is done in practice (16).

Comparisons between z scores of weight-for-height and BMI-for-age can be made only for girls up to 10.0 y and boys up to 11.5 y because of the limits imposed on weight-for-height by the adolescent growth spurt. A plot of the z scores of weight-for-height against the z scores of BMI-for-age for 8097 children and the best-fit line, a third-order polynomial, which gave the highest value of \(r^2\), are shown in Figure 6. Values of the z score of BMI-for-age tend to be lower than values of the z score of weight-for-height and the differences increase toward extremes of weight-for-height. For example, a z score of BMI-for-age of \(-3.0\) is roughly equivalent to a z score of weight-for-height of \(-2.5.\)

The prevalence of wasting and thinness in each country by sex for boys <11.5 y and girls <10.0 y is shown in Table 4. The differences in the estimated prevalence of wasting and the prevalence of thinness were relatively large, particularly in Bangladesh (9.4% difference in girls and 18.7% difference in boys), Ethiopia (12.4% difference in boys), and the Philippines (8.9% difference in girls and 13.6% difference in boys).

The differences by sex and year of age between the percentage of children classified as thin by the WHO references and wasted by the NCHS references are shown in Figure 7. Positive values indicate that BMI-for-age classifies more children as thin than weight-for-height classifies children as wasted. The maximum difference by sex between the prevalence of thinness and the prevalence of wasting for girls was 8% in age group 9–10 y, and for boys it was 14% in the age group 11–11.5 y. The new WHO z score of BMI-for-age identified only 5 children (0.8%) as

### Table 3

<table>
<thead>
<tr>
<th>Country</th>
<th>Girls</th>
<th></th>
<th></th>
<th></th>
<th>Boys</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>% stunted</td>
<td>% stunted</td>
<td>% stunted</td>
<td>n</td>
<td>% stunted</td>
<td>% stunted</td>
<td>% stunted</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>462</td>
<td>34.2</td>
<td>29.9</td>
<td>4.3</td>
<td>421</td>
<td>36.8</td>
<td>37.5</td>
<td>-0.7</td>
</tr>
<tr>
<td>Bolivia</td>
<td>313</td>
<td>26.5</td>
<td>24.3</td>
<td>2.2</td>
<td>291</td>
<td>25.8</td>
<td>27.5</td>
<td>-1.7</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>551</td>
<td>24.3</td>
<td>22.0</td>
<td>2.3</td>
<td>814</td>
<td>25.8</td>
<td>25.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>3788</td>
<td>20.2</td>
<td>19.7</td>
<td>0.5</td>
<td>3760</td>
<td>20.2</td>
<td>24.1</td>
<td>-3.9</td>
</tr>
<tr>
<td>Haiti</td>
<td>736</td>
<td>27.0</td>
<td>26.6</td>
<td>0.4</td>
<td>729</td>
<td>35.9</td>
<td>35.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Malawi</td>
<td>1302</td>
<td>40.1</td>
<td>42.4</td>
<td>-2.3</td>
<td>1310</td>
<td>55.8</td>
<td>54.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Mali</td>
<td>732</td>
<td>52.5</td>
<td>51.1</td>
<td>1.4</td>
<td>765</td>
<td>50.5</td>
<td>50.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Mozambique</td>
<td>473</td>
<td>35.7</td>
<td>38.3</td>
<td>-2.6</td>
<td>474</td>
<td>51.1</td>
<td>46.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Pakistan</td>
<td>338</td>
<td>45.6</td>
<td>44.7</td>
<td>0.9</td>
<td>514</td>
<td>41.4</td>
<td>41.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Philippines</td>
<td>726</td>
<td>42.1</td>
<td>35.8</td>
<td>6.3</td>
<td>738</td>
<td>47.4</td>
<td>48.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>687</td>
<td>29.1</td>
<td>23.7</td>
<td>5.4</td>
<td>681</td>
<td>15.1</td>
<td>15.9</td>
<td>-0.8</td>
</tr>
<tr>
<td>Total</td>
<td>10,108</td>
<td>30.4</td>
<td>29.3</td>
<td>1.1</td>
<td>10,497</td>
<td>34.7</td>
<td>34.3</td>
<td>0.4</td>
</tr>
</tbody>
</table>

\(^1\) WHO % stunted - NCHS % stunted.

WASTING, THINNESS, AND STUNTING IN SCHOOLCHILDREN

![Figure 5](https://academic.oup.com/ajcn/article-abstract/94/2/571/4597926/12571459936/45712571459936)

**FIGURE 5.** Mean (95% CI) z scores of World Health Organization (WHO) BMI-for-age by year of age for girls (n = 10,084) and boys (n = 10,455) in 11 low-income countries. The values have been offset on the x axis on either side of the middle of the year of age so that the 95% CIs do not overlap.

![Figure 6](https://academic.oup.com/ajcn/article-abstract/94/2/571/4597926/12571459936/45712571459936)

**FIGURE 6.** A regression line of z scores of National Center for Health Statistics (NCHS) weight-for-height against World Health Organization (WHO) BMI-for-age for 8097 children for whom both values were calculated by anthropometric software (see Subjects and Methods). The dashed diagonal line is the line of equivalence. The equation for the third-order polynomial regression was \(y = 0.008x^3 - 0.0654x^2 + 0.9248x - 0.2356; r^2 = 0.9271.\)
wasted who were not also classified as thin, but identified an additional 598 children as thin and not wasted. Of the 8105 children compared, 15.0% were thin and 7.7% were wasted.

**DISCUSSION**

This analysis of >20,000 schoolchildren from 11 low-income countries examined the effect of the change from the NCHS to the WHO growth references, both of which are based on the same underlying data (1). The overall differences in the mean \( z \) scores and prevalence of stunting were small, but the differences for individuals were in opposite directions for each sex, whereas they varied considerably and in no consistent pattern by age for each sex as well (Figures 2 and 3). The differences in the prevalence of stunting between the 2 references (WHO and NCHS) are almost the opposite for girls and boys and were largest for early adolescent children, because 7% more 13-y-old boys were stunted compared with 6% fewer girls, as shown in Figure 4. But when the data on both sexes were combined there was little difference in the overall prevalence of stunting. In schools in which boys predominate, the use of the WHO references is likely to lead to a higher prevalence of stunting, whereas in single-sex girls’ schools it will fall.

The difference in prevalence of stunting in each country varied from 0% to 6% (Table 3). The magnitude of this difference is likely to reflect the age structure of the sample from each country, as well as the range of \( z \) score values. Similar differences in \( z \) scores by age and sex were reported in a comparison of the Centers for Disease Control and Prevention 2000 and NCHS 1977 growth references for school-age children in the Philippines (5).

When the WHO index BMI-for-age was compared with the NCHS index weight-for-height, BMI-for-age classified more children as thin than were classified as wasted by weight-for-height: up to 9% more girls and 18% more boys, with the biggest differences in Bangladesh and the Philippines (Table 4). This could lead to a 2-fold increase in the numbers of children <11.5 y who are identified as in need of supplementary food, if a threshold of \(-2 \) \( z \) scores of BMI-for-age is applied.

The data set analyzed here came from a large, pooled sample of children aged 5–17 y from a wide geographic range of low-income countries. The data are not necessarily representative of each country but show a wide range in the prevalence of stunting, from 15% to 52%, which is useful for analytic purposes. The inaccurate dates of birth will have led to inaccurate \( z \) scores; however, because the comparisons between growth references used the same dates of birth, the degree of error should have been the same for both estimates. If the age in years was correct, the date of birth used for children for whom it was not known would have underestimated or overestimated the age of children born before or after 15 June. If births were evenly distributed throughout the year, this would not lead to a systematic under- or overestimation of \( z \) scores. However, the \( z \) score estimates for Bangladesh, Mali, Malawi, and Haiti may be less reliable than those of other countries because the dates of birth were recorded with a precision of only a year. If age was generally underestimated, which is thought to have occurred in Ethiopia (12),

![FIGURE 7.](https://academic.oup.com/ajcn/article-abstract/94/2/571/4597926 by guest on 24 November 2018)
this will have led to a national systematic underestimate of the prevalence of stunting.

The samples of schools may not be representative of schools in each country and the children were measured while they attended school, so the samples may not represent school-age children in general. The data from Pakistan were collected during a comparison of enrolled and non-enrolled children, which showed no major differences in anthropometric status or health (13), but studies in Ghana and Tanzania reported significant differences (17, 18). The differences between the sexes in the anthropometric status of adolescent boys and girls may be a result of differences in enrollment or dropout. For example, the higher z scores of BMI-for-age of girls aged 13–16 y than boys may be because affluent and better-nourished girls remain enrolled in school, whereas poor, undernourished girls drop out. This has been noted before (10). There can be considerable differences between populations in the onset of the adolescent growth spurt and the rate of physical maturation (19), which may affect the comparison of BMI values of adolescents in low- and high-income countries (9). The apparent worsening of z scores of BMI-for-age among boys therefore may be transient if the populations under study continue to grow in late adolescence and early adulthood, when physical maturity may have already been achieved in the reference population.

The WHO growth standards for children aged 0–5 y are conceptually and practically different from the WHO growth references for children aged 5–19 y: the former capture optimal growth (20), whereas the latter are based on the original NCHS data and therefore share some of the same limitations as the old NCHS references (8).

The differences between the WHO and NCHS growth references in height-for-age are likely to stem from the curve construction methods (1). Whereas the median curves for both references overlap almost completely, the differences are greater at more distant centiles (1). For samples of children of similar age and sex, only small differences in the overall prevalence of stunting will occur with the new WHO growth references. However, when data are disaggregated by sex, more boys and fewer girls will be stunted according to the WHO references. In contrast, the estimated prevalence of thinness is likely to be higher than the prevalence of wasting by as much as 17%. The use of thinness as an indicator of undernutrition in children and adolescents is relatively new and may be different from weight/(height)$^2$ as an indicator because of the different scaling of weight/height as opposed to weight/(height)$^2$. A prospective study of the health outcomes of 5- to 11-y-old children who are thin but not wasted and both thin and wasted could shed light on the clinical implications of applying this index to undernourished children.

The new WHO index of BMI-for-age has the significant advantage over NCHS weight-for-height of being able to be calculated for children of all ages, not just for preadolescents. Calculating BMI-for-age will generate a new body of data to assess obesity as well as acute undernutrition in countries with a double burden of malnutrition in school-age children, a relatively neglected age group. This analysis presents new information on BMI-for-age z scores of 20,000 children and adolescents in 11 low-income countries and describes differences in the prevalence of stunting, wasting, and thinness that may arise when the WHO growth references are applied. The findings will help agencies and school health programs interpret anthropometric data from new and existing surveys.

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REFERENCES

5. Eckhardt CL, Adair LS. Differences in stunting prevalences calculated from two similar growth references may be large and inconsistent in undernourished children. Ann Hum Biol 2002;29:566–78.