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Symposium: A New 21st-Century International Growth Standard for Infants and Young Children

Comparison of the WHO Child Growth Standards and the CDC 2000 Growth Charts[1]

Mercedes de Onis,[2]* Cutberto Garza,[3] Adelheid W. Onyango,[2] and Elaine Borghi[2]

[2]Department of Nutrition, World Health Organization, Geneva, Switzerland and [3]Boston College, Chestnut Hill, MA

Abstract

The evaluation of child growth trajectories and the interventions designed to improve child health are highly dependent on the growth charts used. The U.S. CDC and the WHO, in May 2000 and April 2006, respectively, released new growth charts to replace the 1977 NCHS reference. The WHO charts are based for the first time on a prescriptive, prospective, international sample of infants selected to represent optimum growth. This article compares the WHO and CDC curves and evaluates the growth performance of healthy breast-fed infants according to both. As expected, there are important differences between the WHO and CDC charts that vary by age group, growth indicator, and specific Z-score curve. Differences are particularly important during infancy, which is likely due to differences in study design and characteristics of the sample, such as type of feeding. Overall, the CDC charts reflect a heavier, and somewhat shorter, sample than the WHO sample. This results in lower rates of undernutrition (except during the first 6 mo of life) and higher rates of overweight and obesity when based on the WHO standards. Healthy breast-fed infants track along the WHO standard's weight-for-age mean Z-score while appearing to falter on the CDC chart from 2 mo onwards. Shorter measurement intervals in the WHO standards result in a better tool for monitoring the rapid and changing rate of growth in early infancy. Their adoption would have important implications for the assessment of lactation performance and the adequacy of infant feeding and would bring coherence between the tools used to assess growth and U.S. national guidelines that recommend breast-feeding as the optimal source of nutrition during infancy. J. Nutr. 137: 144–148, 2007.

Introduction

In April 2006 the WHO released new standards for assessing the growth and development of children from birth to 5 y of age (1,2). The WHO Child Growth Standards are the product of a systematic process initiated in the early 1990s involving various reviews of the uses of anthropometric references and alternative approaches to developing new tools to assess growth. The new standards adopt a fundamentally prescriptive approach designed to describe how all children should grow rather than the more limited goal of describing how children grew at a specified time and place (3).

In May 2000 the U.S. CDC released growth charts, which are based on 5 nationally representative surveys conducted between 1963 and 1994 (4,5). Both the WHO standards and the CDC charts were developed to replace the 1977 National Center for Health Statistics growth reference, which suffered from a number of drawbacks that made it inappropriate for assessing the growth pattern of individual children and populations (6,7). This article compares the WHO and CDC curves for weight-for-age, length/height-for-age, weight-for-length, weight-for-height and BMI, and evaluates the growth performance of healthy breast-fed infants according to the WHO standards and the CDC charts.

Methods

WHO child growth standards

The WHO standards are based on primary data collected through the WHO Multicentre Growth Reference Study (MGRS). The MGRS was a population-based study conducted between 1997 and 2003 in Brazil, Ghana, India, Norway, Oman, and the United States. The MGRS combined a longitudinal follow-up from birth to 24 mo with a cross-sectional component of children aged 18–71 mo. In the longitudinal component, mothers and newborns were enrolled at birth and visited at home a total of 21 times at wk 1, 2, 4 and 6; monthly from 2–12 mo; and bimonthly in the 2nd y.

The study populations lived in socioeconomic conditions favorable to growth (8). The individual inclusion criteria were: no known health or environmental constraints to growth, mothers willing to follow MGRS feeding recommendations (i.e., exclusive or predominant breast-feeding for at least 4 mo, introduction of complementary foods by 6 mo of age,

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* To whom correspondence should be addressed. E-mail: deonism@who.int.

and continued breast-feeding to at least 12 mo of age), no maternal smoking before and after delivery, single term birth, and absence of significant morbidity (9). Full-term low birth–weight infants were not excluded. Eligibility criteria for the cross-sectional component were the same as those for the longitudinal component with the exception of infant feeding practices. A minimum of 3 mo of any breast-feeding was required for participants in the study's cross-sectional component.

Rigorously standardized methods of data collection and procedures for data management across sites yielded exceptionally high-quality data (10–12). A full description of the MGRS and its implementation in the 6 study sites is found elsewhere (9). Of 1743 mother-child dyads enrolled in the MGRS longitudinal sample, 882 complied fully with the study's infant-feeding and nonsmoking criteria and completed the follow-up period of 24 mo. This sample was used to construct the WHO standards from birth to 2 y of age combined with 6669 children from the cross-sectional sample from age 2–5 y (1).

Data from all sites were pooled for the purpose of constructing the standards (13). The generation of the standards followed state-of-the-art statistical methodologies that are described in detail elsewhere (1,14). Weight-for-age, length/height-for-age, weight-for-length or height, and BMI-for-age percentile and Z-score values were generated for boys and girls aged 0–60 mo. The full set of tables and charts is available on the WHO website (www.who.int/childgrowth/en).

CDC 2000 growth charts

The CDC charts from birth to 20 y of age are based on national data collected in a series of 5 surveys between 1963 and 1994 (4,5). The infancy section of the CDC charts replaces the Fels Longitudinal Study data set, which was used to construct the 1977 NCHS reference, with data from 2 national surveys [NHANES II (1976–80) and NHANES III (1988–1994)]. However, because there were no national survey data for children less than 2 and 3 mo of age (NHANES II data began 6 mo, whereas NHANES III data began at 2 mo for weight and 3 mo for length), supplementary data were incorporated (4). To anchor the weight-for-age curves at birth, the birth weight data from the United States Vital Statistics birth certificates (1968–80; 1985–94) were used. For length at birth, data from Vital Statistics (1989–94) for the states of Wisconsin and Missouri were used, as these were the only states that included length information in birth certificates. The data for these 2 states were used for the length-for-age and weight-for-length charts, but not for the weight-for-age charts. In addition, the length-for-age chart includes supplementary length data for ages 0.01–4.9 mo taken from ~200 clinics of the Pediatric Nutrition Surveillance System (PedNSS). The PedNSS was initiated in 1972 to monitor the health and nutritional characteristics of low-income U.S. children who participated in publicly funded health and nutrition programs (15). As was the case for the 1977 NCHS reference, the CDC charts continue to be based on relatively few infants who were breast-fed for more than a few months (16,17). A detailed description of methods and development of the CDC charts is provided elsewhere (4,5) and is also available on the Internet (www.cdc.gov/growthcharts).

Descriptive comparisons

Two sets of comparisons are presented in this article. First, we compare the WHO and CDC Z-score curves for boys' weight-for-age, length/height-for-age, weight-for-length, weight-for-height, and BMI. Second, we use monthly (0–12 mo) longitudinal data from a pooled sample of 226 healthy breast-fed infants from 7 studies in North America and Northern Europe (18,19) to evaluate the adequacy of the WHO standards vs. the CDC charts for assessing growth patterns of healthy breast-fed infants.

Results

Figure 1 compares the WHO and CDC weight-for-age Z-score curves for boys. The main differences in the weight-for-age curves occur during infancy. The mean weight of infants included in the WHO standards is above the CDC median during the first half of infancy, crosses it at ~6 mo, and remains below the median to ~32 mo, after which the medians overlap until the

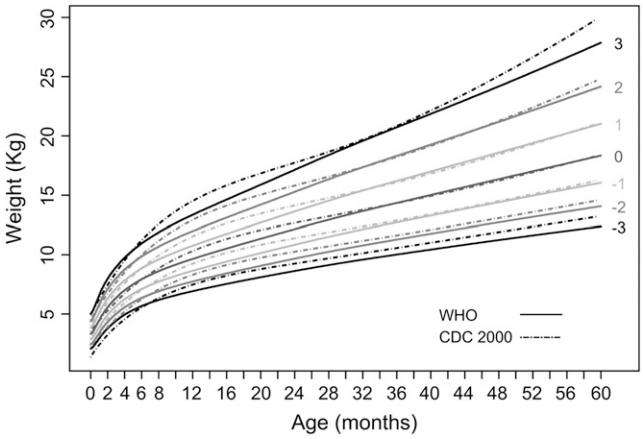

Figure 1 Comparison of the WHO and CDC weight-for-age Z-score curves for boys.

age of 60 mo. In general, the CDC sample seems to be heavier. Based on the −2 SD cut-off point, the prevalence of underweight will be higher during the first 6 mo of life when based on the WHO standard, and lower thereafter throughout childhood.

Figure 2 compares the WHO and CDC length/height-for-age Z-score curves for boys. The shape of the 2 sets of curves is very similar; although, on average, children in the WHO standard are somewhat taller than those in the CDC reference. A notable difference is the tighter variability of the WHO curves. For all age groups, stunting rates (i.e., < −2 SD) will be higher when based on the WHO standard.

Figure 3 compares the WHO and CDC weight-for-length Z-score curves for boys. The U.S. children are generally heavier, and this applies, as expected, to all older children as well as to the upper centiles of younger children. Consequently, estimates of overweight (> +2 SD) and obesity (> +3 SD) will be higher when based on the WHO standard and, for similar reasons, estimates of wasting (< −2 SD) and severe wasting (< −3 SD) will decrease from ~70 cm onward. Another notable distinction between the WHO and CDC curves is evident at lengths <53 cm in the distribution of the weight-for-length centiles below the median.

The weight-for-height charts (**Fig. 4**) depict a similar pattern to that of the weight-for-length charts, with U.S. children being generally heavier, especially at older ages. Again, based on this

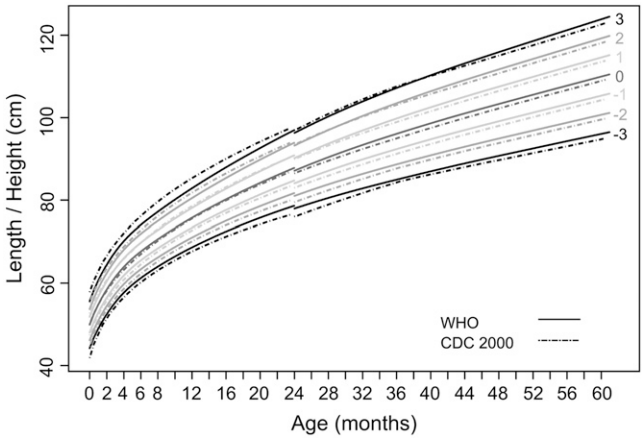

Figure 2 Comparison of the WHO and CDC length/height-for-age Z-score curves for boys.

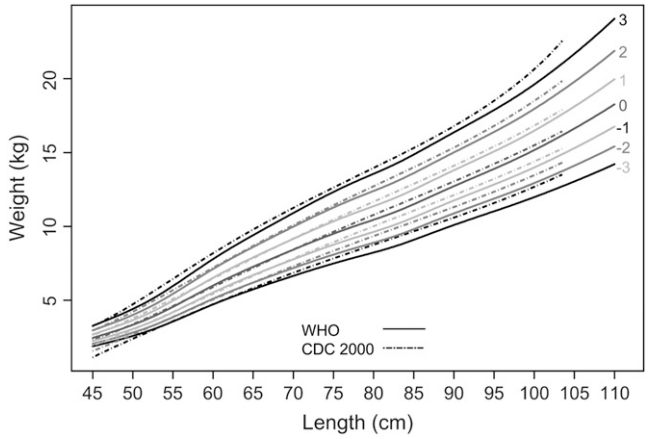

Figure 3 Comparison of the WHO and CDC weight-for-length Z-score curves for boys.

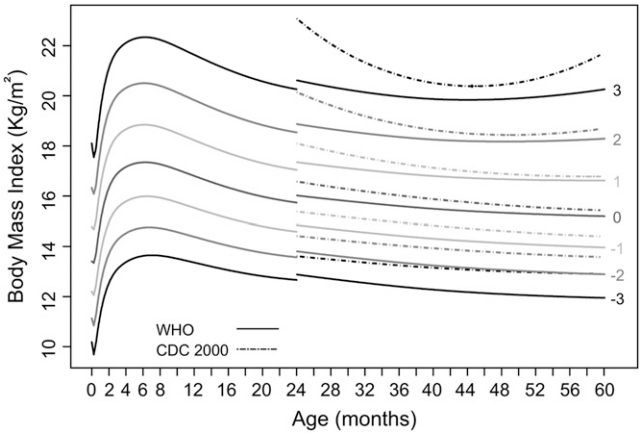

Figure 5 Comparison of the WHO and CDC BMI-for-age Z-score curves for boys.

indicator, estimates of overweight and obesity will increase, and those of wasting and severe wasting will decrease, when based on the WHO standard.

The BMI-for-age curves begin at birth on the WHO standard and at 2 y of age on the CDC chart. The 2 sets of BMI curves are dramatically different, partly reflecting obesity in the U.S. sample and probably also some edge effects in the CDC curve-smoothing algorithm (**Fig. 5**). Estimates of overweight and obesity, as well as undernutrition, will be substantially different when based on the WHO standard vs. the CDC reference.

Lastly, **Figure 6** shows the pattern of growth in mean weight during infancy of the pooled breast-fed sample based on the WHO standard and CDC chart. As expected, based on the different shapes of the weight-for-age curves, the pooled breast-fed set tracks along the WHO-standard's mean Z-score while appearing to experience growth- faltering from 2 mo onward when compared with the CDC median.

The patterns described for boys are the same for girls (data available on request) for all comparisons presented.

Discussion

There are important differences between the WHO standards and the CDC charts that vary by age group, growth indicator, and specific Z-score curve. For weight-for-age, differences are particularly important during infancy. The divergence in the shape of the curves is likely due to *1*) issues related to study design (i.e., sample size and measurement intervals) and *2*) characteristics of the sample, mainly differences in type of feeding. Concerning the study design, empirical weight data were not available between birth and 2 mo of age for the CDC growth charts, and sample sizes for the remainder of infancy were considerably below the 200 observations per sex and age group recommended for the construction of growth curves with stable outer centiles. This is especially the case during the first 6 mo when the sample per age group is <100 (*5*). Consequently, the CDC curves probably fail to capture the rapid and changing rate of weight gain in early infancy. In contrast, the infancy portion of the WHO standard is based on a much larger sample size (428 boys and 454 girls) and shorter measurement intervals [at birth, d 7, d 14, and then every 2 wk up to 2 mo and monthly thereafter (10)]. These design characteristics allowed the WHO curves to capture the rapidly changing pattern of growth in early infancy, including the physiological weight loss that takes place in the first few days of life (1).

Differences in feeding types are also likely to contribute to the divergent growth patterns in weight-for-age during early infancy. Whereas the WHO standards are based solely on breast-fed infants (2), the CDC charts, like the NCHS reference, are still based on relatively few infants who were breast-fed for more than a few months. Briefly, about half (54.7%) of the NHANES III sample initiated breast-feeding, only 21% were exclusively

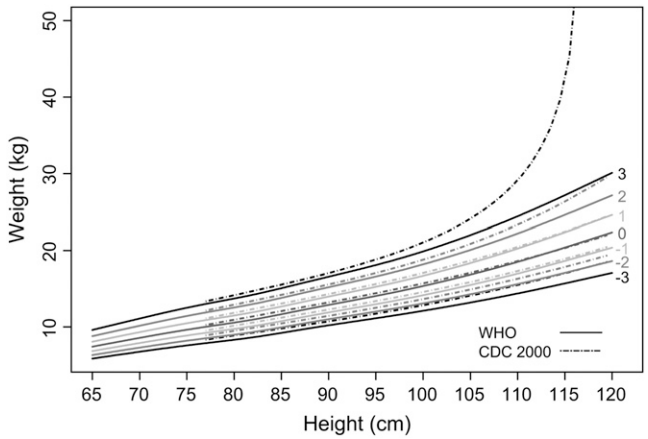

Figure 4 Comparison of the WHO and CDC weight-for-height Z-score curves for boys.

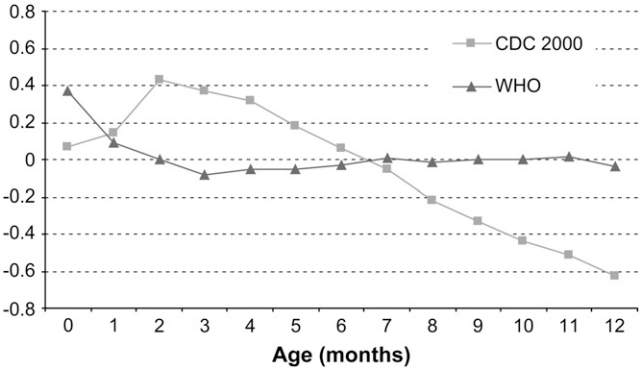

Figure 6 Mean weight-for-age Z-scores of healthy breast-fed infants relative to the WHO standard and the CDC chart.

breast-fed for 4 mo, 9.8% were partially breast-fed (i.e., supplemented daily with formula, other milk, or solids) for ≥4 mo, and 24% had been completely weaned by 4 mo of age (16). The prevalence of breast-feeding was even lower in earlier surveys and PedNSS data; that is, only 27.2% in NHANES I and II and 24.4% in PedNSS were ever breast-fed (20). Indeed, the CDC growth charts have proven to be inadequate for monitoring the growth of breast-fed infants (17). The difference in the shapes of the weight-based curves makes the interpretation of growth performance strikingly different depending upon whether the WHO standard or the CDC chart is used, and this in turn has important implications for the advice given to mothers concerning lactation performance and the introduction of complementary foods.

The tighter variability of the WHO length/height-for-age standard is likely due to the prescriptive approach and standardization of the measurements in the WHO sample vs. the use of multiple datasets in the construction of the CDC charts [Vital Statistics birth registry data from 2 states to anchor the curves at birth, data from PedNSS up to 4.9 mo, and data from NHANES II (from 6 mo) and NHANES III (from 3 mo)]. The use of several datasets with no standardization of measurements across them was prone to have artificially inflated the variability of the CDC chart. The important finding that children in the WHO standard are, on average, taller than those in the CDC chart should dispel concerns that breast-fed infants might fail to meet their potential for growth of fat-free tissue because of marginal intakes of energy, protein, and/or other nutrients.

The comparison of the weight-for-length and weight-for-height charts shows that the U.S. children are generally heavier than those included in the WHO sample. This applies to all the older children, as expected, but also to the upper centiles at younger ages, which likely reflects greater skewness in U.S. infant weights. The dramatic departure of the +3 SD in the CDC weight-for-height chart is likely a consequence of applying the LMS method, which fits the data very well, to a heavy sample. This flaw makes the CDC weight-for-height curves inadequate for monitoring obesity from ~100 cm onward, insofar as, for example, children measuring 115 cm have a similar Z-score whether they weigh 30, 40, or 50 kg. Similarly, the pattern of the lower centiles of the CDC weight-for-length chart below 53 cm may reflect peculiarities of the birth registry data used to anchor the CDC curves.

The WHO's weight-for-length curves extend to a greater length than the CDC curves (110 cm vs. 103 cm) to facilitate assessment of tall 2-y–olds and older children who, for whatever reason (e.g., malnutrition or agitation), are unable to stand. Similarly, the WHO weight-for-height curves start earlier (65 cm) than the CDC curves (78 cm) to facilitate assessment of populations with high rates of stunting.

The BMI-for-age curves are dramatically different, partly reflecting obesity in the U.S. sample, and probably as well, edge effects in the CDC smoothing algorithm. The gap at 5 y of age is in line with the gap observed at 20 y of age in the CDC curves where the 97th BMI-for-age centile for boys and girls is, respectively, 32.1 and 33.9, well above the recommended BMI obesity cutoff of 30 for adults (21). Estimates of overweight and obesity will increase substantially when the WHO BMI-for-age standard is used. Similarly, the significant difference in the −2 SD and −3 SD in the BMI-for-age curves will result in lower estimates of undernutrition when based on the WHO standard. The latter point is important in light of research that reports a substantial overestimation of the prevalence of undernutrition in relatively well-nourished populations in developing countries based on the 1977 NCHS BMI reference (22).

The WHO standards are based on a sample of healthy breast-fed infants (23) with high-quality complementary diets (24) and provide a better tool than the CDC 2000 growth charts for monitoring the growth of breast-fed infants (Fig. 6). The establishment of the breast-fed child as the norm for growth brings coherence between the tools used to assess growth and U.S. national infant feeding guidelines that recommend breast-feeding as the optimal source of nutrition during infancy (25). The WHO standards are made even more relevant to the U.S. child population by the inclusion of American children in the sample (26) whose growth tracks along the median of the pooled international sample (27).

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