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The Centers for Disease Control and Prevention 2000 growth charts and the growth of breastfed infants

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Aim: To evaluate the performance of the 2000 Centers for Disease Control and Prevention (CDC) growth charts in comparison with the National Center for Health Statistics/World Health Organization (NCHS/WHO) reference as a tool for assessing growth in healthy breastfed infants. *Methods:* Weight and length measurements were obtained from a pooled longitudinal sample of 226 healthy breastfed infants. Weight-for-age (WA), length-for-age (LA) and weight-for-length (WL) z-scores based on the CDC and NCHS/WHO references were computed for each child. Age-specific mean z-scores and proportions below and above specific cut-off points were calculated. *Results:* Breastfed infants grow more rapidly in the first 2 mo of life and less rapidly from 3 to 12 mo in relation to the CDC WA curves. Similarly, breastfed infants experience greater linear growth than the CDC median until age 4 mo. Thereafter, the mean LA z-score declines until month 9. Apart from a 1-mo difference in the time when linear growth begins to falter, the pattern of growth is remarkably similar when compared with the two references. The growth trajectories indicate that infants in the CDC reference are heavier and shorter than the NCHS/WHO reference population. Combining the two measurements as WL reveals that higher weight overrides lower length in the CDC versus the NCHS population, thus the estimated prevalence of wasting is higher by the CDC reference.

Conclusion: As was the case when compared with the NCHS/WHO reference, there are notable differences in the growth trajectory of breastfed infants examined against the CDC reference. A reference based on healthy breastfed infants is required if the growth patterns of infants following international feeding recommendations are to be correctly assessed.

Key words: *Breastfeeding, growth references, infant growth, recumbent length, weight*

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The interpretation of the growth trajectory of breastfed infants, commonly used to assess lactation adequacy and to advise mothers on when to introduce complementary foods, is highly dependent on the reference data used. The accuracy of feeding advice may be erroneous if the reference growth charts used do not adequately represent the physiological growth pattern of breastfed infants (1–3).

In 1993 a WHO expert committee (4) drew attention to a number of technical and biological problems with the National Center for Health Statistics/World Health Organization (NCHS/WHO) growth reference currently recommended for international use. Among other concerns, the committee challenged the reference's appropriateness as a tool for assessing the growth of breastfed infants (5, 6).

In May 2000, the Centers for Disease Control and Prevention (CDC) released new growth charts for the United States. These charts were, for the most part, created using data from five cross-sectional child growth surveys involving nationally representative samples. The infancy section, however, uses US Vital Statistics records, the Fels Longitudinal Study and the Pediatric Nutrition Surveillance System (PedNSS) data to fill gaps in the NHANES II and III national survey data (7). Improved statistical techniques were used to create smoothed percentile growth curves, thus addressing some of the technical limitations noted by the 1993 WHO expert committee of the 1977 NCHS growth charts (8) and the NCHS/WHO normalized curves that constitute the current international reference (9, 10). However, the new reference still includes relatively few infants that were breastfed for more than a few months. In this study we evaluate the adequacy of the new CDC growth charts for assessing the growth patterns of healthy breastfed infants and how the interpretation of growth performance and introduction of complementary foods might be affected by using the new reference.

Table 1. Data sets used to construct the Centers for Disease Control and Prevention 2000 infant growth charts.

Data set	Years	Data source	Subject ages (mo)	Gender	Chart variable[a]
NHANES II	1976–1980	National survey	6.0–35.9	M, F	L, HC
			6.0–281.9	M	W
			6.0–245.9	F	W
NHANES III	1988–1994	National survey	3.0–35.9	M, F	L
			2.0–35.9	M, F	HC
			2.0–71.9	M, F	W
United States Vital Statistics	1968–1980	Birth certificates	Birth	M, F	W
	1985–1994				
State of Wisconsin Vital Statistics	1989–1994	Birth certificates	Birth	M, F	W,L[b]
State of Missouri Vital Statistics	1989–1994	Birth certificates	Birth	M, F	W, L[b]
Fels Longitudinal Study	1960–1994	Hospital records[c]	Birth	M, F	HC
Paediatric Nutrition Surveillance System (selected clinics)	1975–1995	Clinical records	0.01–4.9	M, F	L

Source: Adapted from Kuczmarski et al. 2000 (7).
[a] W: weight; L; length; HC: head circumference.
[b] Data from Wisconsin and Missouri were used at birth for the length-for-age and weight-for-length charts, but were not used in the infant weight-for-age charts.
[c] Measured in the hospitals by Fels staff.

Methods

Data from a pooled sample of 226 healthy breastfed infants from seven studies in North America and Northern Europe were used (11). Infants included in the pooled breastfed sample were required to meet the following criteria: 1) breastfed for at least 4 mo of age, 2) no solid foods before age 4 mo, 3) no formula or other milks before 4 mo, and 4) continued breastfeeding for at least 12 mo. The second and third criteria correspond to the category defined by WHO as "predominantly breastfed" (12). However, it should be noted that some infants in some of the studies were occasionally given other milks or formulas, and investigators generally did not exclude or fully document such cases. In five of the seven studies preterm or low-birthweight infants were excluded; and in three studies large-for-gestational age infants were also excluded (11). A detailed description of the pooled breastfed sample can be found elsewhere (6, 11, 13).

The infancy section of the new CDC charts replaces the Fels Longitudinal Study data set, which was used to construct the 1977 growth charts, with data from two national surveys (NHANES II (1976–1980) and NHANES III (1988–1994)). However, since there were no national survey data prior to 2 and 3 mo (NHANES II data begin at age 6 mo, while NHANES III data begin at 2 mo for weight and 3 mo for length), supplementary data were incorporated (7). To anchor the weight-for-age curves at birth, birthweight data from the United States Vital Statistics birth certificates (1968–1980; 1985–1994) were used. For length at birth, data from Vital Statistics (1989–1994) for the States of Wisconsin and Missouri were used, as these were the only two states that included length information in birth certificates. The data for these two states were used for the length-for-age (LA) and weight-for-length (WL) charts, but not for the weight-for-age (WA) charts. In addition, the LA chart includes supplementary length data for ages 0.01–4.9 mo taken from about 200 clinics of the Pediatric Nutrition Surveillance System (PedNSS). The clinics were selected on the basis that at ages 3–11 mo, the mean and standard deviation (SD) of their recorded length and weight and the skewness of weight were comparable with the combined NHANES II and III data (7). The PedNSS was initiated in 1972 to monitor the health and nutritional characteristics of low-income US children who participated in publicly funded health and nutrition programmes (14). The data sets used to construct the revised CDC infant growth charts are presented in Table 1.

We used the pooled breastfed sample to evaluate what differences might be expected in growth patterns and population estimates of malnutrition using the new CDC curves compared with the NCHS/WHO international reference. We calculated z-scores based on the NCHS/WHO reference using the age-specific regression equations described by Dibley et al. (9). For the CDC reference, z-scores were calculated using the following formula taken from the CDC website, (http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/datafiles.htm):

$$Z = \frac{(X/M)^{L} - 1}{LS}$$

where X is the physical measurement and L, M, S, respectively, denote the parameters *Lambda* (the power needed to remove skewness, transforming the data into a Normal distribution), *Mu*, the population mean estimated by the observed 50th centile value for the measurement, and *Sigma*, the coefficient of variation. The application of this formula thus corrects for skewness in the reference data when calculating a z-score for a given sex and age or length.

The reference data tables on the CDC website present

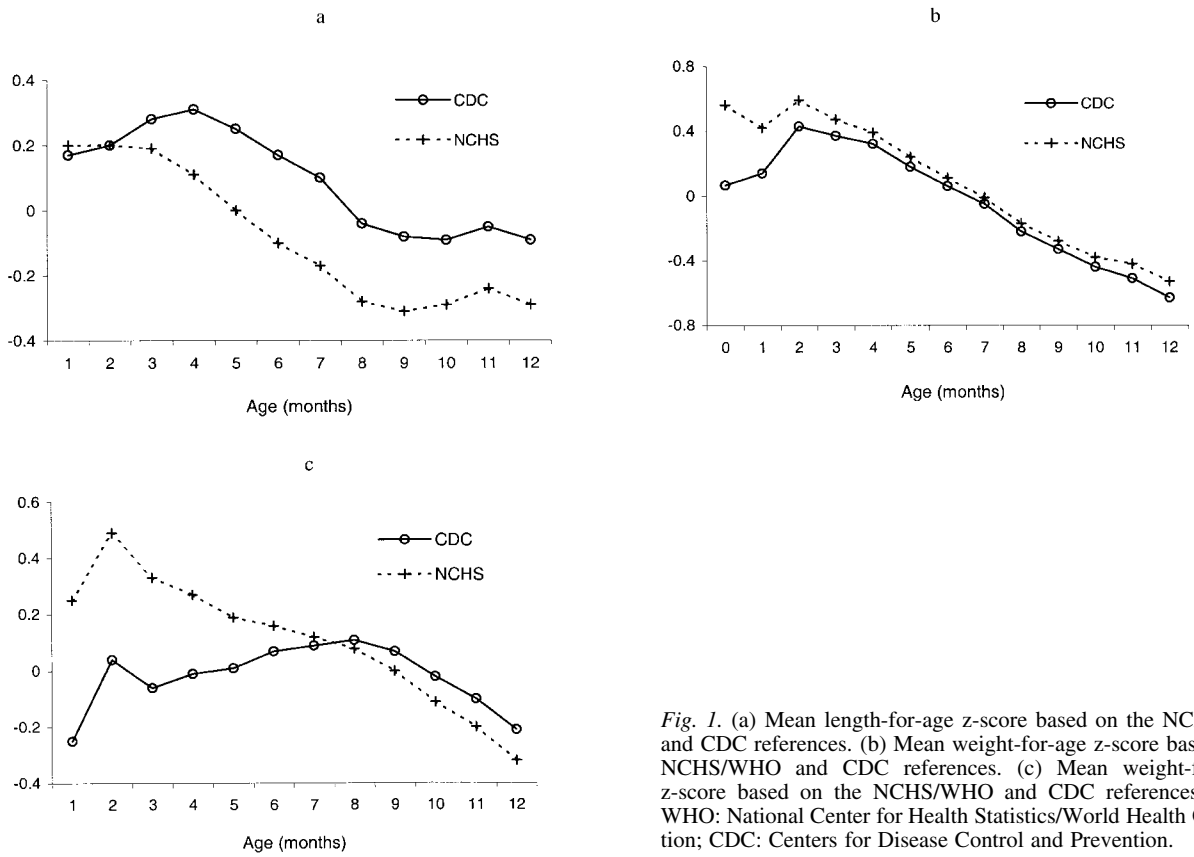

Fig. 1. (a) Mean length-for-age z-score based on the NCHS/WHO and CDC references. (b) Mean weight-for-age z-score based on the NCHS/WHO and CDC references. (c) Mean weight-for-length z-score based on the NCHS/WHO and CDC references. NCHS/WHO: National Center for Health Statistics/World Health Organization; CDC: Centers for Disease Control and Prevention.

data for ages 0, 0.5, 1.5, 2.5, etc. Since the breastfed infants' ages were recorded in full months, we estimated L, M and S values corresponding to those exact age points by linear interpolation. The output was exported to SPSS Version 10.1 for Windows, where we created a series of dichotomous variables for different indicators and cut-offs, and aggregated the data to create mean anthropometric z-scores. We examined the plots (sexes combined) of mean LA, WA and WL from birth to 12 mo.

Results

Birthweight in the pooled breastfed sample ranged from 2.6 to 4.7 kg for boys (mean 3.5 ± 0.4 kg) and 2.6 to 5.0 for girls (mean 3.5 ± 0.4 kg). By comparison, the median birthweights for boys and girls were 3.3 and 3.2 kg, respectively, in the NCHS/WHO reference, and 3.5 and 3.4 kg, respectively, in the CDC reference population. Birth lengths were not available in the pooled breastfed sample for comparison with the reference populations.

The mean z-scores for LA, WA and WL are presented in Fig. 1. Figure 1a shows that at ages 1 and 2 mo, the LA of breastfed infants is 0.2 SD units above the two reference medians. Compared with the CDC median, there is a positive slope in average length gain by the breastfed sample for the first 4 mo, while the NCHS/WHO reference suggests a length gain parallel to the median until age 3 mo. The breastfed mean z-score versus the CDC median drops by 0.4 SD units between 4 and 9 mo of age, while the comparative decline relative to the NCHS/WHO is somewhat larger (0.5 SD units from 3 to 9 mo). Apart from the one-month difference in the time when linear growth begins to falter relative to the median, the pattern of growth is remarkably similar using the two references. The difference of about 0.2 SD units between the two curves from 3 to 12 mo indicates that the CDC reference population is shorter than the NCHS/WHO reference during this period.

The pattern of growth in WA is remarkably similar when assessed against the two references (Fig. 1b). Both curves begin to cross WA centiles downwards from 2 mo of age and maintain this negative trend throughout infancy to reach final mean z-scores of -0.5 and -0.6 at 12 mo on the NCHS/WHO and CDC references, respectively. The greatest disparity between the two references is evident at age 0–1 mo, where the WA z-scores of the breastfed sample relative to the NCHS/WHO reference are 0.5 and 0.3 SD units above the

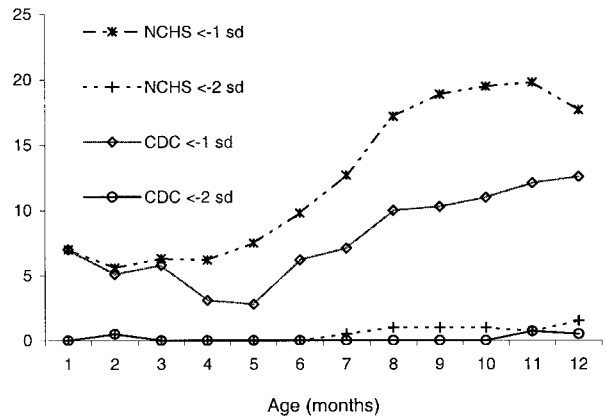

Fig. 2. Prevalence below −1 or −2 z-score length-for-age based on the NCHS/WHO and CDC references. NCHS/WHO: National Center for Health Statistics/World Health Organization; CDC: Centers for Disease Control and Prevention.

respective CDC z-scores. The breastfed mean WA z-score plots show that infants in the CDC reference population are, on average, heavier than the NCHS/WHO population.

In Fig. 1c it is shown that from birth to 3 mo of age the pattern of mean WL is similar when compared against the two references, but the breastfed infants appear to be 0.5 SD lighter in the first 2 mo when assessed using the CDC reference. From 3 mo onwards the two means move in opposite directions until they cross at 7–8 mo. Thereafter, both WL means follow a downward trend where the breastfed infants appear to become progressively lighter until the end of infancy.

Prevalences below and above defined z-score cut-offs are plotted in Figs 2 to 4. In Fig. 2 it is shown that, although very few of the breastfed babies could be defined as stunted (i.e. below −2 SD LA) by the NCHS/WHO reference at any time during infancy, the proportions below −1 SD slightly exceed the expected 15.9% at ages 8–12 mo. This corresponds to the mean LA z-score that stays between −0.2 and −0.3 SD in the same age period. According to the CDC reference, the proportion of breastfed infants below −1 SD is well below the expected rate (range 2.8–12.6%) and stunting is virtually absent. From age 5 mo onwards, there is a steep and sustained increase in the proportion of breastfed infants below −1 SD relative to the CDC median. The proportions of the breastfed sample with LA above +1 and +2 SDs are not reported here as this is of less interest for public health purposes.

The proportions below and above the defined cut-offs for WA are shown in Fig. 3. Based on the NCHS/WHO reference, none of the breastfed infants was underweight in the first 5 mo of life (Fig. 3a). Prevalences below −2 SD slightly exceed the expected 2.3% in a healthy population from 8 mo onwards, the highest percentage being 4.3% at 11 mo. Proportions below −1 SD also remained extremely low in the first half of infancy (0–6.6%) but increase from 12.2% at 7 mo to 33.7% at 12 mo. The CDC reference classifies breastfed babies similarly to the NCHS/WHO reference, but has systematically higher percentages below −1 and −2 SD, respectively, except for months 10 and 11 where the prevalence below −1 SD of the CDC reference is lower. According to Fig. 3b, the proportion of breastfed infants above 2 SD WA is very similar for both references, the highest prevalence being 3.7% at 5 mo and 4.1% at 4 mo for the NCHS/WHO and CDC references, respectively. The patterns of prevalence above 1 SD are similar for both references, but the proportions are systematically lower by the CDC reference, especially in the early part of infancy where differences range from 7.5% at 2 mo to 2.4% at 6 mo.

The proportions below and above 1 and 2 SD for WL are presented in Fig. 4. Unlike WA, where the prevalences below and above the defined cut-offs

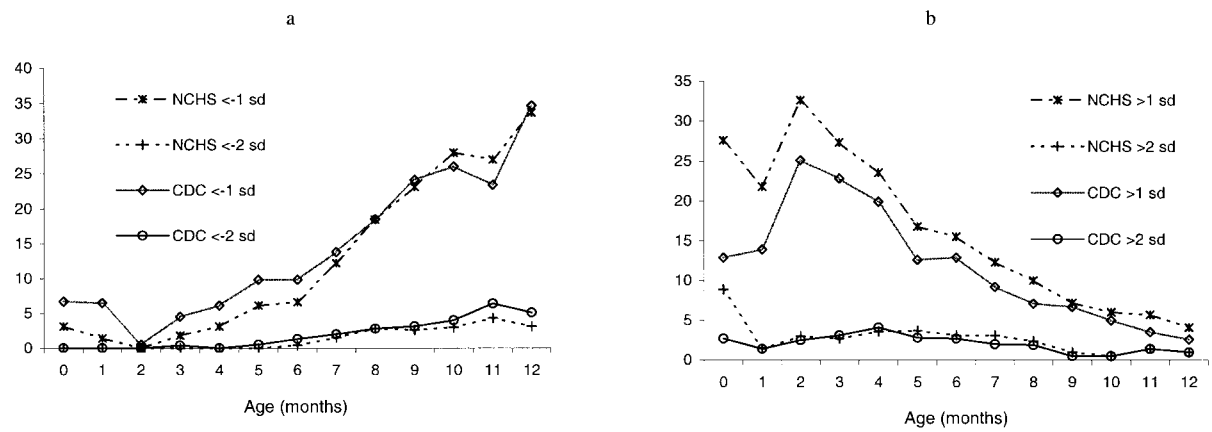

Fig. 3. (a) Prevalence below −1 or −2 z-score weight-for-age based on the NCHS/WHO and CDC references. (b) Prevalence above +1 and +2 z-score weight-for-age based on the NCHS/WHO and CDC references. NCHS/WHO: National Center for Health Statistics/World Health Organization; CDC: Centers for Disease Control and Prevention.

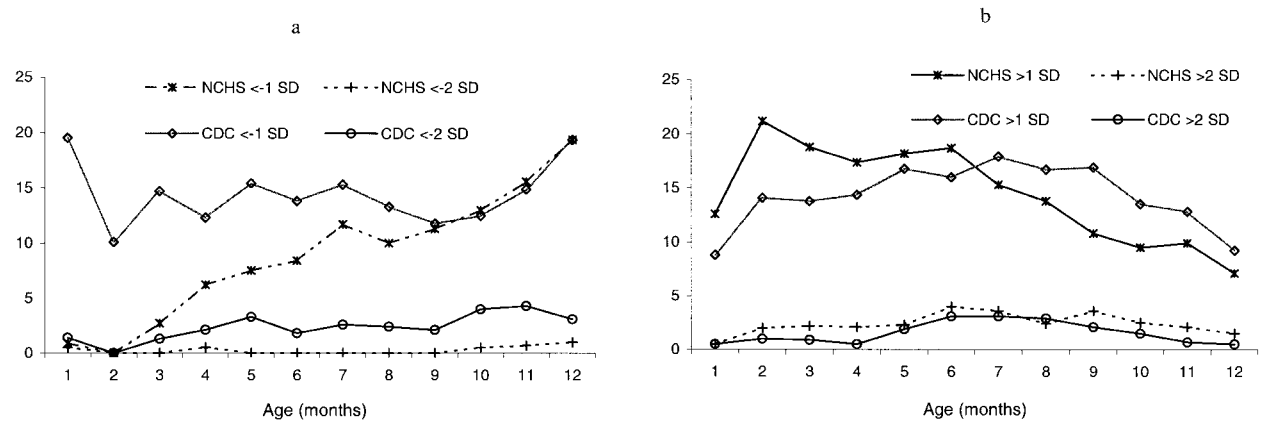

Fig. 4. (a) Prevalence below −1 or −2 z-score weight-for-length based on the NCHS/WHO and CDC references. (b) Prevalence above +1 and +2 z-score weight-for-length based on the NCHS/WHO and CDC references. NCHS/WHO: National Center for Health Statistics/World Health Organization; CDC: Centers for Disease Control and Prevention.

follow corresponding patterns, the positive and negative tail distributions of WL seem to be unrelated to each other, especially with the 1 SD cut-offs. With regard to the prevalence of wasting, the CDC reference systematically classifies more breastfed infants below −2 SD than does the NCHS/WHO reference.

Discussion

These analyses demonstrate that there remain notable differences in the growth trajectory of healthy breastfed infants examined against the new CDC growth charts. As was the case when compared with the NCHS/WHO reference (6, 11), breastfed infants grow faster than the CDC reference WA in the first 2 mo and less rapidly from 3 to 12 mo. For linear growth, the pattern is similar for the two references, except that apparent faltering in the breastfed sample is delayed by one month when using the CDC reference.

Several studies have demonstrated that the growth pattern described above is found consistently among healthy breastfed infants in various countries (15–21). Weight growth in the breastfed sample appears to be somewhat erratic from birth to 2 mo irrespective of which reference is used. One of the main criticisms of the Fels data was that babies were measured at wide intervals that could not capture the pattern of growth (3, 4). 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—especially during the first 6 mo—were considerably below the 200 observations per sex and age group recommended for the construction of growth curves with stable outer centiles (22, 23). Consequently, the CDC curves also fail to capture the true pattern of weight gain in young breastfed infants. The timing and slope of decline in weight gain relative to age from 3 to 12 mo by the breastfed sample are similar in both references. This suggests that the two reference populations have similar characteristics save for an overall shift to the right in the weight distribution of the CDC reference population. The latter reflects an overall increase in US infant weights between the earlier national surveys and NHANES III (7, 24), and the overall pattern of growth is consistent with the observation that, in fact, the new reference is still based on relatively few infants who were breastfed for more than a few months. A detailed description of breastfeeding patterns and duration in the NHANES III sample is provided by Hediger et al. (16). Briefly, about half (54.7%) of the sample initiated breastfeeding, with only 21% exclusively breastfeeding for 4 mo, 9.8% partially breastfeeding (i.e. supplemented daily with formula, other milk or solids) for ≥4 mo, and 24% completely weaned by age 4 mo. After 4 mo, the prevalence of full breastfeeding declined rapidly so that only 15.8% of the infants exclusively breastfed for 4 mo continued through 6 mo with no intake of supplementary formula or milk (16). The prevalence of breastfeeding was even lower in earlier surveys and PedNSS data: only 27.2% in NHANES I and II and 24.4% in PedNSS were ever breastfed (25). The short duration of any breastfeeding in the CDC reference might explain to a large extent the slower gains in both weight and length experienced by the breastfed sample when compared with the CDC charts. In fact, the PedNSS data have already been shown to be inadequate for monitoring the growth of breastfed infants (25).

Comparing the breastfed sample with the CDC versus the NCHS/WHO reference improves the rating of linear growth in breastfed infants, showing a positive slope in the first four months and a less precipitous drop in LA that amounts to about 0.2 SD units less of a deficit in the latter half of infancy. Despite this shift, the apparent downturn in length growth at 4 mo still occurs too soon

in the light of previous findings (4, 11, 26). Furthermore, in populations where the highest morbidity and mortality risks are associated with premature initiation of complementary feeding, most healthcare workers depend on the WA indicator. Therefore, the implications of using the CDC reference in such populations are influenced by the assessment of infant growth based on WA rather than LA. For field and research applications, the CDC reference—like the NCHS/WHO reference—suggests a faltering in weight gain from age 2 mo, with the consequent risk that breast milk is judged to be insufficient for growth from this early age. The impact of this "misinterpretation" on infant morbidity and mortality from infectious diseases world-wide is potentially serious (27, 28).

The proportions of infants classified as underweight, overweight, wasted or stunted depend on both the median and the SD. For example, the overall upward shift in the WA median curve of the CDC reference would result in infants being classified more frequently as underweight (and fewer as overweight) when population medians are compared. Similarly, the prevalence of wasting based on the −2 SD WL cut-off is higher when using the CDC reference as it systematically classifies more infants below −2 SD than the NCHS/WHO reference. The fact that the CDC median LA is lower than the NCHS/WHO reference would result in less frequent classification of stunting or low LA.

Growth references for infants and young children are among the most widely used instruments in public health and clinical medicine (4). Paediatric health professionals throughout the world rely mainly on the evaluation of growth to assess maternal lactation performance and determine the optimal timing of the introduction of complementary foods. Judgements regarding the adequacy of infant growth are strongly influenced by the reference growth curves used. The results of these analyses indicate that the new CDC growth charts are no more suitable than the NCHS/WHO reference for assessing the growth of breastfed infants. New reference data based on healthy breastfed infants are needed if growth patterns of infants following international feeding recommendations—exclusive breastfeeding for 6 mo, with the introduction of complementary foods and continued breastfeeding thereafter (26, 29, 30)—are to be correctly assessed.

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