

## The NCHS Reference and the Growth of Breast- and Bottle-Fed Infants<sup>1,2</sup>

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**ABSTRACT** The current international growth reference, the National Center for Health Statistics (NCHS) reference, is widely used to compare the nutritional status of populations and to assess the growth of individual children throughout the world. Recently, concerns were raised regarding the adequacy of this reference for assessing the growth of breast-fed infants. We used the NCHS reference to evaluate infant growth in one of the most developed areas of Brazil. Infants who were exclusively or predominantly breast-fed for the first 4–6 mo, and partially breast-fed thereafter, grew more rapidly than the NCHS reference in weight and length during the first 3 mo, but appeared to falter thereafter. The average growth of all infants, regardless of feeding pattern, was faster than the NCHS reference until ~6 mo, after which their growth became slower than that of the NCHS sample. To substantiate this finding, the NCHS growth curves were then compared with growth data of breast-fed infants in developed countries from pooled published studies, formula-fed North American and European infants and predominantly bottle-fed U.S. infants monitored by the Centers for Disease Control and Prevention (CDC) Pediatric Surveillance System. In all three cases, weights showed the same pattern as the Brazilian infants—higher than NCHS in the early months but an apparent decline thereafter. The pattern for length gain was similar but less marked. Breast-fed infants showed more pronounced declines than those who were predominantly bottle-fed. These findings suggest that the infancy portion of the NCHS reference does not adequately reflect the growth of either breast-fed or artificially fed infants. This probably results from characteristics of the original sample and from inadequate curve-fitting procedures. The development of an improved international growth reference that reflects the normal infant growth pattern is indicated. *J. Nutr.* 128: 1134–1138, 1998.

**KEY WORDS:** • *breast-feeding* • *bottle-feeding* • *infant nutrition* • *humans*

Growth charts are widely used throughout the world for assessing the nutritional status of young children. When these began to be widely disseminated in the 1970s, there was considerable debate as to whether separate growth standards should be developed for each country or whether a single international reference would suffice. Some argued that the growth of children of high socioeconomic status was very similar throughout the world, irrespective of ethnic background (Graitcer and Gentry 1981, Habicht et al. 1974, Matorell 1985). Others believed that although international references were useful for comparing across populations, country-specific standards were essential for assessing the growth of individual children (Goldstein and Tanner 1980). The debate was eventually won by the former (Editorial 1984) and the United States' National Center for Health Statistics (NCHS) growth reference (Hamill et al. 1977 and 1979) was adopted for inter-

national use by the World Health Organization, both for comparisons across populations (Waterlow et al. 1977) and for monitoring the growth of individual children (WHO 1978). This resulted in wide international dissemination of NCHS-based growth charts (de Onis and Yip 1996).

The NCHS reference was developed in the United States in 1975 by pooling four different sources of data (Hamill et al. 1979). The reference for 2- to 18-y olds was based on data from three representative surveys conducted in the U.S. between 1960 and 1975, but data from children <2 y came from the Fels Longitudinal Study conducted in Yellow Springs, OH, over a 46-y period (1929–1975). The Fels study was carefully conducted with rigorous anthropometry protocols (Roche 1992). However, several questions have been raised recently regarding its adequacy as an international reference (WHO 1995a), for the following reasons: 1) the children were of restricted socioeconomic and genetic background; 2) they were predominantly bottle-fed; 3) weight and length were measured only at birth, 1, 3, 6, 9, 12, 18 and 24 mo, precluding precise curve fitting; 4) sample sizes differed by age, ranging from 298 for both sexes at birth to 935 at 18 mo (Roche 1994); and 5) the curve-fitting procedures employed are outdated by present standards. An important problem with the NCHS

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**TABLE 1**

Numbers of infants studied in the Pelotas 1993 birth cohort, and proportions in the breast-fed subset (exclusive or predominant breast-feeding up to 4–6 mo; complemented breast-feeding thereafter) at different ages

	Numbers intended	Numbers interviewed	% in the breast-fed subset	Anthropometric status ascertained	
				Weight-for-age	Height-for-age
Birth	—	5249 <sup>1</sup>	98.3	5232	5162
1 mo	655	649 (99.1%)	61.3	649	648
3 mo	655	644 (98.3%)	30.4	643	642
6 mo	1460	1414 (96.8%)	33.9 <sup>2</sup>	1411	1410
12 mo	1460	1363 (93.4%)	22.7 <sup>2</sup>	1357	1355

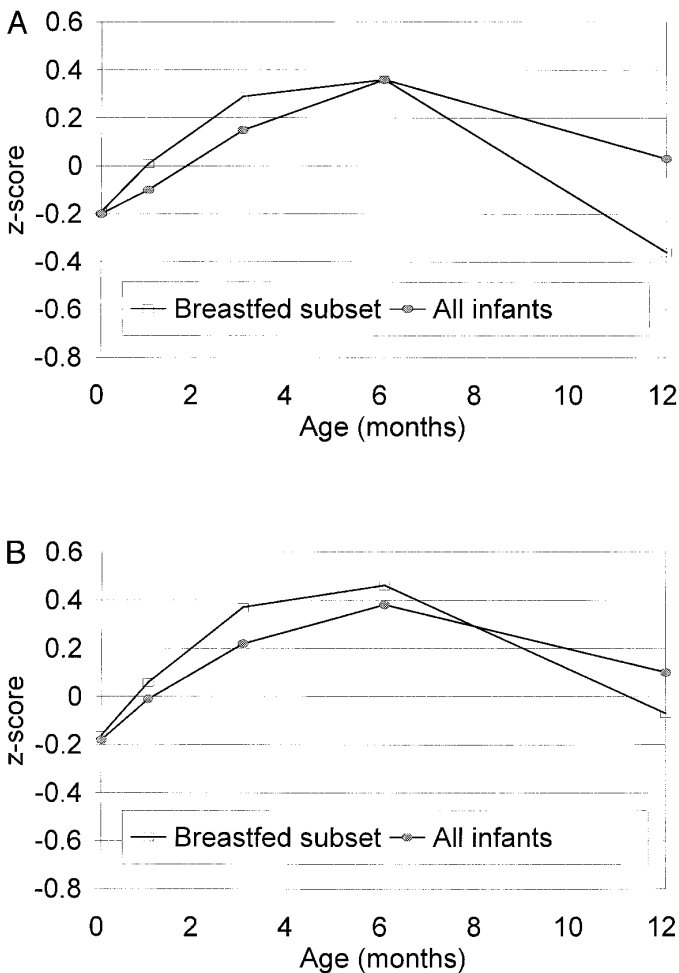
<sup>1</sup> Live births only.

<sup>2</sup> Proportions based on weighted analysis (see text).

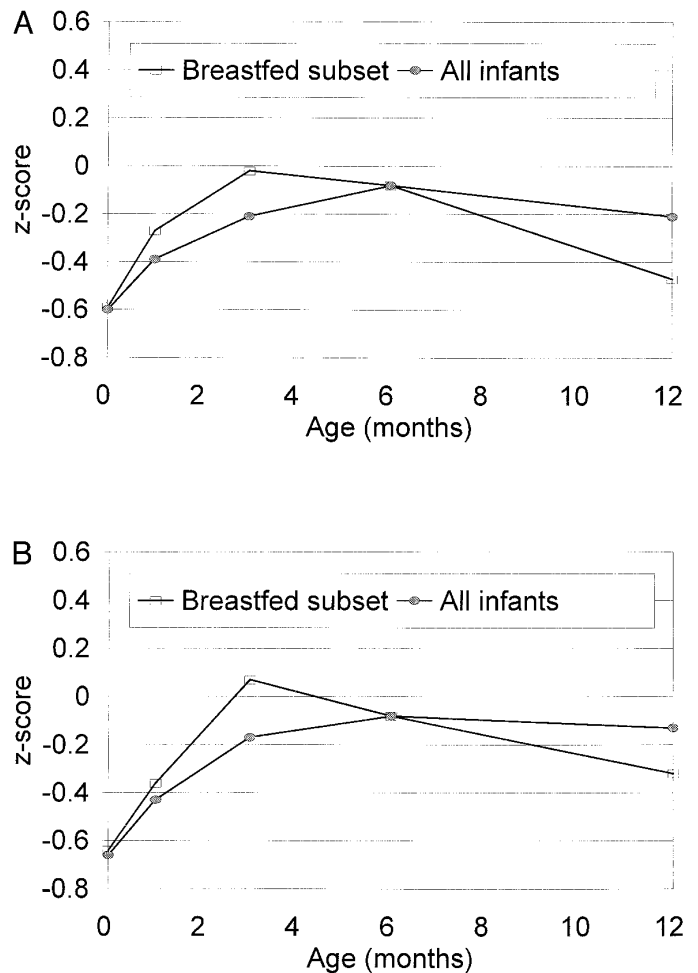
reference is a marked disjunction in height at 24 mo (de Onis and Yip 1996, Dibley et al. 1987). The Fels sample length-based curves are ~1.8 cm (or 0.5 SD) higher than the height-based curves from the U.S. representative sample. This also affects the weight-for-height curves. In addition, the NCHS reference is characterized by positive skew in the weight distri-

bution, reflecting a substantial level of childhood obesity (de Onis and Yip 1996).

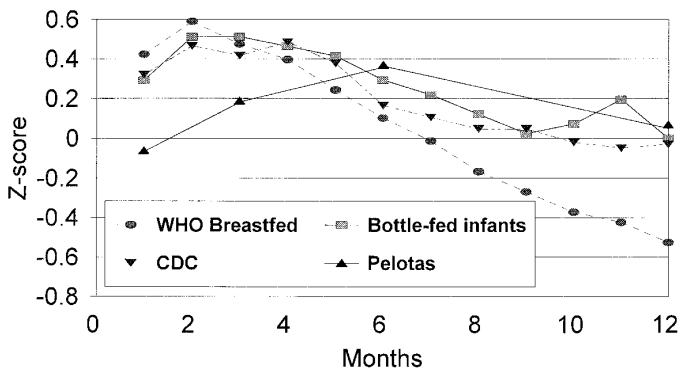
A major concern was that the NCHS reference did not appropriately reflect the growth of infants fed according to the recommendations of international agencies such as WHO and UNICEF (WHO 1995a). In 1979, these agencies had recom-



**FIGURE 1** Weight-for-age of infants in the breast-fed subset and of all infants, plotted against the NCHS reference, for boys (A) and girls (B). Values are mean Z-scores. Both groups showed faster growth than NCHS reference in the first 6 mo, but showed a relative decline thereafter.



**FIGURE 2** Length-for-age for infants in the breast-fed subset and of all infants, plotted against the NCHS reference, for boys (A) and girls (B). Values are mean Z-scores. Both groups showed faster growth than NCHS reference in the first 3–6 mo, but breast-fed infants showed a relative decline thereafter.



**FIGURE 3** Weight-for age for infants in the Pelotas sample, WHO Breastfed Set, Bottle-fed set and in Centers for Disease Control and Prevention (CDC) Pediatric Surveillance System. Values are mean Z-scores. All samples showed a relative decline after the first few months, particularly the WHO breast-fed set.

mended that all infants should be exclusively breast-fed for 4–6 mo, and that breast-feeding with appropriate complementary feeding be continued until 24 mo and beyond (WHO 1995c). However, breast-fed infants belonging to families with a high socioeconomic status, studied in various geographical areas, were shown to falter relative to the NCHS curves from mo 3 of life onwards, and to stay below the reference during the second semester of life while receiving breast milk plus solid foods (WHO 1994 and 1995b). There was concern that these negative deviations might cause health workers and families to diagnose “growth faltering” and lead to the early introduction of non-human milk or other complements, thus increasing the risk of infectious diseases, particularly diarrhea. The concern regarding the trade-off between late introduction of complementary foods (with consequent faltering) or early introduction (and the subsequent increased risk of diarrhea) had been described many years before as “the weanling dilemma,” (Rowland et al. 1978) but the idea that the growth references themselves might be at fault came later (Whitehead and Paul 1984). It is only in the last several years that this idea has gained wider acceptance (WHO 1995b).

In this paper, we address the issue of whether the perceived problems with the NCHS reference are due to the predominance of nonbreast-fed infants in the original sample, or to other problems with that reference, possibly related to the space between measurements and to poor curve fitting. We do this by comparing the growth of a cohort of Brazilian children, stratified according to feeding pattern, with the NCHS reference. We also use published data from developed countries to address these issues.

## SUBJECTS AND METHODS

The study was conducted in the city of Pelotas (population 300,000), a relatively developed area in the South of Brazil. The median monthly family income in the city is ~U.S. \$500 and the infant mortality rate is 21.7 per thousand live births, compared with a rate of 51 per thousand in the country as a whole. The study was approved by the Medical Ethics Committee of the Universidade Federal de Pelotas.

All hospital births occurring during the 1993 calendar year were studied. Over 99% of all births in the city take place in a hospital (Barros et al. 1990). After excluding 16 children (nine refusals and seven early hospital discharges; 0.3% of the total), 5304 children were enrolled in the study, of whom 117 died in the perinatal period. Mothers were interviewed regarding socioeconomic, demographic and other variables.

Subsamples of this birth cohort were followed up at 1, 3, 6 and 12 mo. Children selected for follow-up at 1 and 3 mo were chosen by systematic sampling with a fixed weekly quota that resulted in a total sample of 655 children (12.6% of those eligible). The subsamples studied at 6 and 12 mo were larger. They included a systematic 20% sample of all children (including the 655 studied at 1 and 3 mo) plus all children born with a birthweight <2500 g.

At birth, children were weighed by the hospital staff using pediatric scales with an accuracy of 10 g that were calibrated weekly by the research team. The children’s supine length was measured to the nearest millimeter by the research team using especially designed length boards (AHRTAG baby length measurers; London, UK). At the ages of 1, 3, 6 and 12 mo, children were measured at home with the same equipment and weighed naked by using portable spring hanging scales with an accuracy of 100 g (CMS PBW-25; London, UK). Standardized procedures were used in all measurements (Cameron 1984).

At every interview, information on feeding practices was obtained by prompted 24-h dietary recalls. This included the type of milk consumed, the intake of other fluids (water, teas, fruit juices), of solid and semisolid foods. The original plan was to select a “breast-fed subset” of infants who complied with the current WHO feeding recommendations (exclusive breast-feeding up to 4–6 mo; breast-feeding with complementary foods thereafter) (WHO 1995c). Because few children were exclusively breast-fed at any age, infants who were predominantly breast-fed at 1 and 3 mo (i.e., receiving breast milk plus any of water, teas or fruit juices, but no artificial milk) were also included in the breast-fed subset. The same definition was used for classifying feeding patterns at the hospital interview that took place soon after birth.

Children’s weights and lengths were converted into Z-scores using the NCHS reference (Hamill et al. 1977) and the ANTHRO software (CDC/WHO 1992). Mean Z-scores were calculated for each age group. Low birthweight infants were statistically down-weighted in the 6- and 12-mo analyses to correct for the oversampling.

Mean Z-scores for children in the breast-fed subset at each age were standardized to the whole-population distribution of maternal education (grouped as 0, 1–4, 5–8, and  $\geq 9$  y) and family income ( $\leq 1$ , 1.1–3, 3.1–6, 6.1–10 and  $>10$  minimum wages). This adjustment made little difference to the results, and only the adjusted values are shown below.

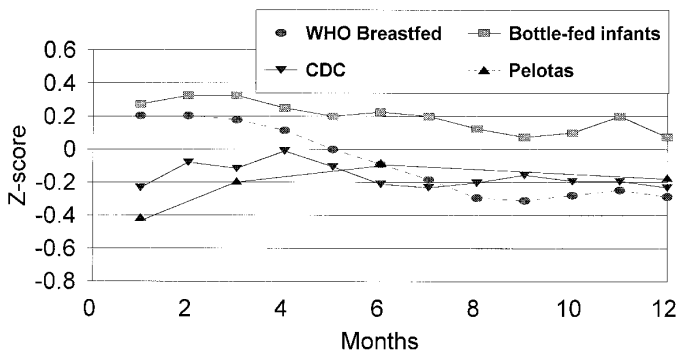
## RESULTS

**Table 1** shows the numbers of infants examined in each of the follow-up studies. At 12 mo, 6.6% of the cohort children could not be traced. The proportion of children who received breast milk (with or without other non-milk fluids) at 1 and 3 mo was 61.3 and 30.4%, respectively. At 6 and 12 mo, 33.9 and 22.7%, respectively, of the children were receiving breast milk plus complements, which included other types of milk and/or other foods.

The birthweight distributions of children in the breast-fed subset at different ages were very similar to those of the overall population. The prevalence of stunting and underweight (below  $-2$  Z-scores of the NCHS reference) at 12 mo was 6.1 and 3.8%, respectively.

**Figure 1** shows the mean weight-for-age NCHS Z-score for all boys and girls, as well as for the breast-fed subset. The latter results were standardized by maternal education and family income to resemble the distribution for the whole population. Both groups, particularly infants in the breast-fed subset, gained more weight than the NCHS reference in the first 6 mo, and showed a sharp decline thereafter.

The corresponding curves for length-for-age are shown in **Figure 2**. Relative to the NCHS reference, Pelotas infants started at a lower point than was observed for weight. The initial catch-up phase was also observed for both groups, with a marked faltering after 3 mo for those in the breast-fed subset



**FIGURE 4** Length-for age for infants in the Pelotas sample, WHO Breastfed Set, Bottle-fed set and in Centers for Disease Control and Prevention (CDC) Pediatric Surveillance System. Values are mean Z-scores. Infants in the WHO breast-fed set appeared to falter from the age of 3 mo.

(a drop of 0.43 Z-score), but only a slight decline from 6 mo onward for all infants taken together (a drop of 0.09 Z-score).

## DISCUSSION

The Pelotas data refer to a population-based study with a high rate of follow-up. The relatively low infant mortality rate and prevalences of malnutrition reveal a population with a reasonable health and nutritional status in terms of a developing country.

When interpreting the above results, one should bear in mind that it was not possible to assemble a sufficiently large group of infants who compiled exactly with the WHO Feeding Recommendations due to the small percentage of children exclusively breast-fed, particularly at 3 mo. In fact, this has been observed in many different countries (UNICEF 1996). A comparison of the small group of exclusively breast-fed infants in our sample with the larger group of those who were predominantly breast-fed showed very minor differences in growth (Victora et al. 1998). It is thus unlikely that the present results would be affected by this adaptation of the classification.

A limitation of the present dataset is that feeding patterns refer to the 24 h that preceded the interview. Thus, infants who, for example, had been given other milks before the recall day, but not on that day, would still be classified as "exclusively" or "predominantly" breast-fed, or vice-versa, infants who were predominantly breast-fed but received an occasional bottle feed on that day would be classified as "partially" breast-fed. Because misclassification could occur in both directions, its effect would be to reduce the actual differences in growth patterns according to feeding practices.

When compared with the NCHS reference, infants in the breast-fed subset grew rapidly in the first 3 mo but after that appeared to be faltering. This finding is in agreement with the literature (WHO 1994, 1995a and 1995b). Perhaps more surprising, however, is that similar patterns were also observed for all children in the sample; they grew more rapidly than the NCHS reference until ~6 mo, and declined afterwards. Thus, regardless of how the children were fed, their growth pattern diverged substantially from that in the NCHS. In spite of this, there was no important anthropometric deficit in the study sample at 12 mo, as shown by the prevalences described above. This suggests a fundamental difference between the shapes of the Pelotas and NCHS growth curves.

Recently published data on the growth of children from developed countries were sought to further investigate this

issue. Figures 3 and 4 show the comparison of three groups of infants with the NCHS reference. These groups are as follows:

1. The WHO breast-fed set. This is a group of 226 infants from developed countries who were fed according to WHO recommendations. The dataset was obtained by pooling information from seven different growth studies (WHO 1994 and 1995b).
2. The bottle-fed set. These data were pooled by the same WHO committee (WHO 1994 and 1995b) from two separate studies: the DARLING study in the United States with 45 infants (Dewey et al. 1992) and the Euro-nut study (F. Haschke, unpublished, 1993, quoted in WHO 1994) with 148 children. None of these children were breast-fed for more than 3 mo.
3. The U.S. Pediatric Nutrition Surveillance data. The height and weight data originate from low income U.S. children measured in public health clinics and collected by the Centers for Disease Control and Prevention (CDC) Pediatric Nutrition Surveillance System (Atlanta, GA). The data plotted are from over 4 million records of children <5 y of age from over 5000 clinics in the United States, in 1994. The majority of these children were formula-fed from birth, and <20% were still breast-fed by 3 mo of age. For practical purposes, these children can be regarded as predominantly formula-fed and very few of them would meet the WHO feeding recommendations (Yip and Mei, in press).

Both groups of bottle-fed infants showed very similar growth patterns in weight (Fig. 3). They grew faster than the NCHS reference in the first 3 mo and started to decline thereafter. A similar pattern was also observed for the breast-fed group, although the faltering was much more marked. In terms of length for age (Fig. 4), the differences between the two bottle-fed groups and NCHS were less pronounced, although some decline was apparent after 3–4 mo. The breast-fed set showed marked faltering from 2–3 mo of age.

The data from these studies in developed country are remarkably consistent with the Brazilian findings reported here. The most interesting finding is that both breast- and bottle-fed infants from four distinct datasets showed similar patterns when plotted against the NCHS reference, i.e., rapid growth to 2–3 mo of age, then gradual decline after 4 mo. The main difference between bottle- and breast-fed infants was the extent of the weight decline from 6 to 12 mo. Because the data presented here originate from middle-class infants in Brazil, Europe and North America, it is not reasonable to ascribe the observed decline to poor socioeconomic conditions leading to inadequate growth. It thus appears that a more general problem affects the infant segment of the NCHS reference, which is not due solely to differences in feeding practices. The likely reasons for this problem include: 1) the long intervals between measurements in the Fels data used for the NCHS reference; 2) inadequate curve-fitting techniques; 3) the types of formulas fed to these infants; and 4) perhaps other peculiarities of this sample of children from a single North American town (de Onis and Yip 1996, WHO 1995a).

The NCHS reference has served a useful purpose by allowing global comparisons of the nutritional status of populations. It was also widely used in growth charts for assessing the growth of individual children. For either type of use, it is important that growth curves should model as closely as possible the growth of children in nonconstrained environments, which, as discussed above, is not occurring. Beyond the problems described here with the infancy portion of the NCHS references, there are also problems at older ages, particularly at 2 y when the Fels curves were merged with data from repre-

sentative samples of U.S. children. A substantial disjunction in the height-for-age curves occurs at this point (WHO 1995a).

The replacement of the NCHS curves by a new international reference was recently recommended by WHO (de Onis and Habicht 1996, WHO 1995a). This decision was based largely on the WHO Committee's concern that differences in growth could lead to inappropriate decisions regarding the early introduction of non-human milk or complementary foods, which in many settings are often contaminated and/or of poor nutritional quality. The present findings show that the development of a new international reference is an urgent priority, regardless of how children are fed. However, given the recognized health, nutritional, fertility and psychological benefits, the recommendation of basing the new reference on a sample of breast-fed infants seems appropriate (WHO 1995a).

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