Cross-cultural patterns of growth and nutritional status of breast-fed infants$^{1–5}$

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ABSTRACT  Growth patterns and iron status of infants who were breast-fed throughout their first year of life were examined in four populations: 1) a group of high socioeconomic status in California (the DARLING Study), 2) infants of normal birth weight (NBW) but from low-income families in Honduras, 3) low-birth-weight (LBW), full-term infants in Honduras, and 4) infants in Ghana. z Scores were calculated by using both the current National Center for Health Statistics reference data and a pooled data set based on breast-fed infants in six industrialized countries. The NBW infants in Honduras showed rapid growth in the first few months and were similar in weight-for-age to the DARLING infants until ≈9 mo. By contrast, the LBW infants remained far below the other cohorts throughout the first 12 mo, despite an initial period of catch-up growth. In the Ghanaian infants, weight-for-age faltered beginning at 3–4 mo, but length-for-age did not falter until after 9 mo. Weight-for-length was highest in the NBW Honduran infants and lowest in the Ghanaian infants. When z scores were adjusted for birth weight and maternal height, no significant faltering was evident in either weight or length in any of the cohorts during the first 12 mo. Thus, when breast-feeding is continued during the first year of life and efforts are made to ensure adequate complementary feeding after 6 mo, if growth faltering occurs it is probably attributable to prenatal factors and maternal stature. Population differences in iron status reflected variation in birth weight and in the use of iron-rich foods. Therefore, efforts to prevent child stunting and malnutrition must pay attention to prenatal as well as postnatal factors.

KEY WORDS  Stunting, malnutrition, iron status, infant growth, breast-feeding, children, Honduras, Ghana

INTRODUCTION  Researchers have been studying child growth for many decades and it might seem that there should be little left to discover in this field. Nonetheless, understanding the patterns and determinants of growth during the first few years of life remains an area of active investigation, in part because we now know that what happens during infancy has important long-term consequences. Despite the numerous studies of infant growth reported in the literature, there has been little systematic evaluation and interpretation of the differences across populations. Even less is understood about the sources of variability in other indexes of nutritional status, such as biochemical measures of micronutrient status. My purpose herein is to compare and contrast the patterns of growth and nutritional status of infants in four different studies that I and others have conducted over the past 10 y, with the goal of furthering our understanding of the determinants of nutritional status during this critical age. Before doing so, however, it is necessary to describe briefly the current state of affairs regarding the use of reference data for evaluating infant growth.

EVALUATING INFANT GROWTH: WHAT IS THE APPROPRIATE REFERENCE POPULATION?  The growth chart currently used worldwide by the World Health Organization (WHO) is based on data from the US National Center for Health Statistics (NCHS). For children aged 2–18 y, these data come from a nationally representative sample. However, it is not always recognized that for infants from birth to 2 y, the reference data are based on a nonrepresentative sample from the Fels Longitudinal Study, which was conducted in Yellow Springs, OH, between 1929 and 1975. There are several limitations to this data set. First, the sample was relatively homogeneous with regard to ethnicity and socioeconomic status. Second,
measurements were made only every 3 mo, which is not ideal for adequately characterizing growth during early life. Third, most of the infants in the study were bottle-fed, and if they were breast-fed it was for a short duration. Because it is now recognized that growth patterns differ between breast-fed and formula-fed infants, the third limitation has generated concern about the appropriateness of this reference for worldwide use (1).

We first began to study this issue when we initiated the DARLING Study (Davis Area Research on Lactation, Infant Nutrition and Growth) in 1986. Our objectives were to compare growth patterns, nutrient intake, morbidity, and activity levels of matched cohorts of breast-fed and formula-fed infants during the first 2 y of life. To document these outcomes when breast-feeding continued throughout the first year of life, the selection criterion for the breast-fed group was that no other source of milk would be used during the first 12 mo except for an occasional bottle containing < 120 mL/d. We were able to select such a sample because of the relatively high rates of long-term breast-feeding in our community. Recruitment of the formula-fed group was more difficult: for that cohort we included infants who were not breast-fed for > 3 mo and who received an iron-fortified, cow milk formula until 12 mo. In both groups, the infants were healthy, born at term with a birth weight of > 2500 g, and did not receive solid foods before 4 mo. Stratified matching procedures were used to ensure that the groups would be similar in parental socioeconomic status, education, ethnic group, and anthropometric indexes, as well as infant sex and birth weight.

The results of the DARLING Study are summarized in Table 1. Briefly, we found that growth in weight, but not length, of breast-fed infants differed from the NCHS reference data and from that of formula-fed infants from 3 to 12 mo, and that this was accompanied by lower energy intakes in the breast-fed cohort. The relatively low energy intake of breast-fed infants appeared to be a function of infant self-regulation, not inadequate maternal milk production (5), and was not associated with any adverse functional outcomes with regard to motor development, activity, or morbidity (8). Therefore, on the basis of available information, the slower weight gain of breast-fed infants after the first few months can be considered a normal pattern. From these findings, we concluded that a new growth chart was needed that would better reflect the growth of breast-fed infants.

Since we completed the DARLING Study, the WHO conducted an extensive evaluation of infant growth (1) and decided to develop new reference data based on breast-fed infants. This decision was based in large part on a pooled analysis of data from seven longitudinal studies conducted in North America and northern Europe (1, 12). By pooling these data, it was possible to achieve a much larger sample size than with any single study: of the 453 infants, 226 were breast-fed for ≥ 12 mo. Studies were eligible for inclusion only if the socioeconomic conditions of the study population were consistent with the achievement of growth potential: two were conducted in the United States (including the DARLING Study) and there was one each from Canada, Denmark, Sweden, Finland, and the United Kingdom. There was remarkable similarity in the growth patterns of breast-fed infants in these seven populations: all of them showed a large decline in weight-for-age z scores from 3 to 12 mo when compared with the NCHS reference, despite the relatively optimal environmental conditions. The average z score at 12 mo was −0.53 for weight-for-age. There was a smaller difference for length-for-age, with an average z score of −0.29 at 12 mo. As a result, infants were also lower in weight-for-length, with an average z score of −0.32 at 12 mo. These analyses showed that, if a new growth chart were based on breast-fed infants, it would deviate significantly from the current NCHS chart not only in the placement of the percentiles but also in their curvature. This has significant implications for interpreting the adequacy of growth in the first year of life (1, 13).

After carefully evaluating the pros and cons of different approaches, the WHO concluded that a new growth chart should be developed by using data from infants who are fed according to recommended guidelines, which include breast-feeding during the first 12 mo. A single chart will be created, rather than separate charts for breast-fed and formula-fed infants. A multicountry study is currently being initiated to collect data from households of high socioeconomic status that represent a wide range of genetic backgrounds.

### CROSS-CULTURAL PATTERNS OF GROWTH OF BREAST-FED INFANTS

One of the purposes of the DARLING Study was for the study population to serve as a comparison group for studies of breast-fed infants in disadvantaged populations. We completed three such studies, two in Honduras (one that was a general sample of low-income subjects (14, 15) and one that focused on low-birth-weight (LBW), full-term (ie, small-for-gestational-age) infants (16)) and one in Ghana (17). In the analyses reported herein, the data from the first study in Honduras are limited to data for

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**TABLE 1**

Summary of results of the DARLING Study

1) Growth in weight, but not length, of breast-fed infants from 3 to 12 mo differs from the National Center for Health Statistics reference data and from that of formula-fed infants (2)

2) Breast-fed infants are leaner than formula-fed infants at 9–15 mo of age (3)

3) Energy and protein intakes are lower in breast-fed than in formula-fed infants at 3, 6, and 9 mo (4)

4) The relatively low energy intake of breast-fed infants is due to infant self regulation, not to inadequate maternal milk production (5)

5) Maternal BMI is related to milk fat concentration, but infants compensate by altering the volume consumed (6)

6) Energy intake of breast-fed infants is not related to the age of introduction of complementary foods; foods given before 6 mo largely displace breast milk (7)

7) The lower intake and weight gain of breast-fed infants are not related to any adverse functional outcomes regarding motor development, activity, or morbidity (8)

8) Incidence of diarrhea and otitis media are lower in breast-fed than in formula-fed infants, even in an affluent population (9)

9) Lactation enhances maternal weight loss postpartum if breast-feeding continues for ≥ 6 mo (10)

10) Duration of postpartum amenorrhea is much longer in breast-feeding women and is inversely related to maternal BMI (11)
infants whose birth weight was >2500 g, ie, infants of normal birth weight (NBW), to compare them with the LBW infants in the second study. In both Honduran studies, infants were breastfed exclusively during the first 4 mo and then were randomly assigned to continue breast-feeding exclusively until 6 mo or to receive commercially prepared, nutritionally enhanced solid foods in addition to breast milk between 4 and 6 mo. At 6 mo, all mothers received nutrition education regarding the preparation of safe and nutritious complementary foods. In both studies, >93% of the infants were still breast-fed at 12 mo.

In the study in Ghana, breast milk was the predominant source of nutrients for ≥3 mo (mothers were advised to breast-feed exclusively for ≥6 mo, but most introduced small amounts of other foods before then). At 6 mo, infants were randomly assigned to four intervention groups that received different versions of a complementary food mixture (different combinations of maize, soybeans, peanuts, and fish powder), one of which was fortified with micronutrients, from 6 to 12 mo. Because growth patterns did not differ significantly among the intervention groups, data herein are presented for the group as a whole. Nearly all of the Ghanaian infants were still breast-fed at 12 mo.

Selected characteristics of subjects in the four studies are shown in Table 2. There were large differences in birth weight, maternal height, and educational level. Birth weight was highest in infants in the DARLING Study, followed by the infants in Ghana, the NBW infants in Honduras, and the LBW infants in Honduras. Maternal height differed in the same order as birth weight, with a 15-cm difference between the DARLING mothers and the mothers of LBW infants in Honduras. Primiparity was a selection criterion for the first Honduran study; in the others, the percentage primiparous ranged from 23% in Ghana to 42% in the DARLING Study. The percentage of male compared with female infants was similar across the four studies.

Weight-for-age z scores, with use of the NCHS reference data, of infants in the four groups are shown in Figure 1. As was seen in the pooled analyses of breast-fed infants from the seven affluent populations described above, there was an initial increase in weight-for-age in the first 2–3 mo, followed by a steady decline thereafter in all four groups. The magnitude of the initial increase in z scores was much greater in the Honduran and Ghanaian infants than in the DARLING Study infants, indicating considerable catch-up growth in the early months.

z Scores were also calculated using the pooled WHO breast-fed cohort (1) as the reference, permitting comparisons to be made against a group that was also breast-fed during the first year of life. For the purposes of these analyses, faltering will be defined as a negative trend in the average z score, beginning at a point below the median of the breast-fed reference. Weight-for-age z scores with use of the WHO cohort, which appear much flatter than those in Figure 1, are shown in Figure 2. The NBW infants in Honduras were similar to the DARLING infants between 3 and 9 mo of age, but showed some faltering thereafter. By contrast, the Ghanaian infants began to falter as early as 3–4 mo of age. This could have been due partly to the difference in birth weight, but also to the fact that the Honduran infants were breast-fed exclusively for a longer period of time than the Ghanaian infants. In environments where sanitation is poor, exclusive breast-feeding during the first 6 mo is usually associated with less growth faltering (18). Growth patterns of the LBW infants were generally parallel to those of the NBW infants in Honduras, but were on a much lower level. Several other studies showed that small-for-gestational-age infants never completely catch-up to their NBW peers, even in affluent populations (19–27).

Length-for-age z scores relative to the breast-fed reference group are shown in Figure 3. The DARLING infants were significantly longer than infants in the other groups at nearly all of the time points. Although the Ghanaian infants showed faltering in weight as early as 3–4 mo, their length z scores did not show this until after 9 mo of age. Length measurements did not begin until 4 mo of age in the NBW cohort in Honduras; their z scores were not significantly different from those of the Ghanaian infants from 4 to 12 mo. By contrast, the LBW infants remained

### Table 2

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<thead>
<tr>
<th>Subject characteristics in the four cohorts</th>
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<tr>
<td>US, DARLING Study (n = 46)</td>
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<tr>
<td>Birth weight (g)</td>
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1 NBW, normal birth weight; LBW, low birth weight.
far below the other groups throughout the first year, with less catch-up in length than was shown in weight.

Weight-for-length $z$ scores relative to the breast-fed reference group are shown in Figure 4. There were few differences among the DARLING, LBW, or Ghanaian cohorts in the first 2–3 mo. Thereafter, the NBW infants in Honduras were heavier for their length and after <6 mo the LBW and Ghanaian infants had lower weight-for-length $z$ scores than the DARLING infants.

Differences in growth patterns during infancy could be due to a variety of factors, including 1) postnatal variables such as morbidity and nutrition, particularly the dietary quality of complementary foods; 2) prenatal variables affecting birth size and proportions, including the possible effects of intrauterine growth retardation on “programming” of postnatal growth (28); and 3) parental anthropometric characteristics, which could reflect genetic differences or the past nutrition of the mother and father. It is important to sort out which of these is most influential because the programmatic implications for prevention of child stunting will vary considerably depending on the cause of stunting. Some of the key pathways by which the factors listed above may be related to attained size at 12 mo are illustrated in Figure 5.

In the four studies described herein, variability in growth due to postnatal nutrition was reduced because of the selection of infants who were nearly all breast-fed throughout the first year and the provision of complementary foods (Ghana) or nutrition education in how to prepare complementary foods (Honduras). This probably explains why, compared with other populations in developing countries, the Ghanaian and Honduran infants showed relatively little faltering in length (ie, decline in $z$ scores over time) relative to the breast-fed reference group. Under these circumstances, it would be revealing to estimate how much of the differences in growth patterns among groups could be attributable to other factors, such as prenatal nutrition and parental stature. To do this, the comparisons of $z$ scores among groups were repeated after pooling the data and adjusting for birth weight or maternal height or both. The results reflect what the $z$ scores of the Ghanaian and Honduran cohorts would be (theoretically) if these infants had the same mean birth weight or maternal height as the DARLING cohort. In other words, these analyses remove the component of variability in postnatal growth status that is explained by birth weight or maternal height or both (or unmeasured variables that are strongly correlated with these factors).

Weight-for-age $z$ scores (using the breast-fed reference) adjusted for birth weight are shown in Figure 6. When compared with Figure 2, it is clear that birth weight explained nearly all of

FIGURE 2. Length-for-age $z$ scores of the four cohorts, with use of a breast-fed reference data set (1). Differences between cohorts are significant ($P < 0.05$, least-squares-means tests) for the following months: US compared with Honduran (HOND) normal-birth-weight (NBW) infants, 1 and 12 mo; US compared with Honduran low-birth-weight (LBW) infants, 1–3 mo; US compared with Ghanaian infants, 1–3 and 5–12 mo; Honduran NBW compared with LBW infants, 1–12 mo; Honduran NBW compared with Ghanaian infants, 1–12 mo; and Honduran LBW compared with Ghanaian infants, 1–12 mo.

FIGURE 3. Weight-for-length $z$ scores of the four cohorts, with use of a breast-fed reference data set (1). Differences between cohorts are significant ($P < 0.05$, least-squares-means tests) for the following months: US compared with Honduran (HOND) normal-birth-weight (NBW) infants, 4–12 mo; US compared with Honduran low-birth-weight (LBW) infants, 1–12 mo; US compared with Ghanaian infants, 1–12 mo; Honduran NBW compared with LBW infants, 4–12 mo; Honduran NBW compared with Ghanaian infants, none; and Honduran LBW compared with Ghanaian infants, 1–12 mo.

FIGURE 4. Weight-for-length $z$ scores of the four cohorts, with use of a breast-fed reference data set (1). Differences between cohorts are significant ($P < 0.05$, least-squares-means tests) for the following months: US compared with Honduran (HOND) normal-birth-weight (NBW) infants, 4–6 mo; US compared with Honduran low-birth-weight (LBW) infants, 10 and 11 mo; US compared with Ghanaian infants, 6–12 mo; Honduran NBW compared with LBW infants, 5–12 mo; Honduran NBW compared with Ghanaian infants, 4–12 mo; and Honduran LBW compared with Ghanaian infants, 1, 3–5, 8, and 9 mo.
the differences in $z$ scores between the LBW infants in Honduras and the other three groups (not surprisingly). Birth weight also explained much of the difference in weight-for-age between the Ghanaian and DARLING Study infants, with faltering not evident until after 7 mo of age when adjusted values were used. After birth weight was adjusted for, the NBW infants in Honduras showed significantly higher weights-for-age than did the other three groups until 10 mo of age. Adjusting for maternal height did not explain as much of the variability as did adjusting for birth weight (results not shown), but adjusting for both birth weight and maternal height (Figure 7) revealed that none of the Honduran or Ghanaian cohorts showed significant faltering during the first year of life.

Length-for-age $z$ scores adjusted for birth weight are shown in Figure 8. This adjustment corrected the early deficit in length-for-age of the LBW cohort, but there was faltering after 4 mo of age. There was little difference among the other three cohorts at any time point. Adjusting for both birth weight and maternal height (Figure 9) completely corrected the deficit in length-for-age of the LBW cohort. The adjusted length-for-age $z$ scores of the NBW Honduran infants and the Ghanaian infants were significantly higher than those of the DARLING and LBW cohorts at many time points, particularly before 9 mo.

Several caveats are necessary regarding interpreting the adjusted $z$ scores. First, the values are somewhat artificial, particularly for the LBW cohort in which none of the infants had a birth weight even remotely close to the average of the DARLING infants. Second, because of the multitude of tests necessary to compare groups at each time point, the statistical significance of the differences should be interpreted cautiously. Finally, it is possible that birth weight and maternal height are also proxies for variables other than prenatal nutrition and parental stature, such as socioeconomic status. Because of this potential confounding, it is difficult to completely separate the relative influence of prenatal, postnatal, and parental factors affecting postnatal growth.

Confounding would be most problematic if birth weight or maternal height were associated with the principal proximate determinants of postnatal growth: nutrient intake and morbidity. To examine this issue, the correlations among selected variables were examined in each of the cohorts. In Ghana, birth weight and maternal height were not significantly correlated with any of the infant morbidity variables between 6 and 12 mo (prevalence of diarrhea or fever or respiratory infection; $r = -0.07$ to 0.12). Because the study design involved provision of free complementary foods to all infants, it is unlikely that either birth weight or maternal height was significantly associated with dietary quality. Maternal nutrition during lactation may have been a factor, but breast milk volume and composition are relatively well buffered against malnutrition,
with the exception of certain vitamins and trace elements that are not thought to strongly affect infant growth (29).

In the NBW cohort in Honduras, neither birth weight nor maternal height was significantly correlated with infant morbidity between 6 and 12 mo, nor with the infant’s frequency of consumption of selected food groups at 9 mo (with the exception of egg consumption, which was inversely related to birth weight). In the LBW cohort, birth weight and maternal height were unrelated to the dietary measures at 9 mo; birth weight was also unrelated to morbidity from 6 to 12 mo but there was a significant inverse correlation between maternal height and symptoms of respiratory illness ($r = -0.25, P < 0.01$). However, there was no association between respiratory illness and growth between 6 and 12 mo. In the DARLING Study, birth weight and maternal height were not significantly correlated with infant morbidity during the first year of life, nor with infant intake of protein or animal products or the percentage of solid foods that were animal products (all of which are considered to be markers of dietary micronutrient quality) from 6 to 12 mo.

These findings indicate that confounding is probably not a major problem when interpreting the results adjusted for birth weight and maternal height. Therefore, these cross-cultural comparisons suggest that when breast-feeding is continued throughout the first year of life and efforts are made to ensure adequate complementary feeding after 6 mo, any growth faltering that occurs in the first year of life is probably attributable primarily to prenatal factors and maternal stature. This is not to imply that postnatal morbidity is not important—in fact, several studies have shown inverse associations between illness prevalence and infant growth (18, 30)—but rather that optimal feeding practices can largely prevent or ameliorate the effect of infant illness. Also note that these analyses covered only the first year of life, so the relative importance of prenatal compared with postnatal factors related to later faltering (eg, in the second year of life) could not be examined.

CROSS-CULTURAL PATTERNS OF MICRONUTRIENT STATUS IN BREAST-FED INFANTS

There is much less to say about micronutrient status than about growth, simply because there are few comparative data for breast-fed infants. I will focus on iron status, which was assessed in the Honduran and Ghanaian cohorts. The percentage of infants at various ages with low hemoglobin and plasma ferritin concentrations is shown in Table 3. In the first 6 mo, there was a wide discrepancy between the prevalence of low hemoglobin and the prevalence of low ferritin: relatively few infants had a ferritin concentration $< 12 \mu g/L$, whereas the percentage with hemoglobin $< 110 \text{ g/L}$ ranged from 46% of NBW infants in Honduras at 6...
mo to 79% of LBW infants in Honduras at 2 mo. Even when a lower cutoff for hemoglobin was used (<103 g/L), there were more infants with low hemoglobin than with low ferritin in the first 6 mo, which is the opposite of what is expected if depletion of iron stores precedes development of anemia. There was little evidence of any other micronutrient deficiencies that might cause anemia in the Honduran cohorts (31). Thus, there is a need to reevaluate the validity of indicators of iron status during infancy.

In the LBW cohort, infants with hemoglobin <100 g/L at 2 or 4 mo were given medicinal iron drops for ≥2 mo. In the NBW cohort in Honduras, some of the infants received iron-fortified complementary foods from 4 to 6 mo, and in the Ghanaian cohort one of the four intervention groups received an iron-fortified product from 6 to 12 mo. Data in Table 3 are shown separately for infants who did or did not receive supplemental iron or iron-fortified foods. LBW infants who had not received iron supplements were more likely to have low ferritin concentrations at 6 mo than were infants who had received such supplements (23% compared with 3%, P < 0.05). This is consistent with the finding that LBW infants, who are born with low iron stores, are at high risk for iron deficiency after the first few months of life. For this reason, it is recommended that LBW infants receive iron drops beginning at 2–3 mo of age (32). For the NBW infants in Honduras, 5% of those who received iron-fortified foods had low ferritin concentrations at 6 mo, compared with 12% of those who were breast-fed exclusively (difference not significant); of those who weighed >3 kg at birth, none had a low ferritin concentration at 6 mo. In the Ghanaian infants, the percentage with low ferritin concentrations increased from 14% at 6 mo to 52% at 12 mo for those who did not receive iron-fortified foods, whereas the percentage with low ferritin remained constant for those who consumed the iron-fortified product. These results suggest that cross-cultural differences in iron status (assessed with use of ferritin) of breast-fed infants reflect differences in birth weight and in the use of iron-rich foods. Further research is needed to define the appropriate cutoffs for iron deficiency anemia during infancy.

CONCLUSIONS

Data from the DARLING Study and other studies in affluent countries show that growth patterns of breast-fed infants are similar across different populations from Europe and North America but differ markedly from the current NCHS growth chart. For this reason, the growth patterns of breast-fed infants in the three disadvantaged populations described herein were compared with a breast-fed reference group. The unadjusted z scores with use of this reference group showed large differences in the weight and length status of these three cohorts. The NBW infants in Honduras, who were breast-fed exclusively for 4–6 mo, showed rapid catch-up growth in the first few months and were similar to the DARLING cohort in weight-for-age thereafter, until ≈9 mo when some faltering was evident. By contrast, the Ghanaian infants, who were generally not breast-fed exclusively during the first 4–6 mo, began to falter in weight-for-age at ≈3–4 mo. The LBW infants remained far below the other cohorts throughout the first year of life, despite an initial period of catch-up in the first 4 mo. Although the Ghanaian infants showed early faltering in weight-for-age, this was not the case for length-for-age; values were similar to those of the NBW Honduran infants and neither group showed significant faltering until after 9 mo of age. Weight-for-length was highest in the NBW Honduran infants and lowest in the Ghanaian infants.

When the z scores were adjusted for birth weight and maternal height, the results were different. No significant faltering in the adjusted scores was evident for either weight or length in any of the three cohorts during the first year of life. In fact, the two Honduran cohorts were generally higher than the DARLING cohort in adjusted weight-for-age and weight-for-length, and the NBW Honduran and Ghanaian cohorts were generally higher than the DARLING cohort in adjusted length-for-age. The Ghanaian infants remained lowest in weight-for-length during the second 6 mo. The differences in weight-for-length among groups could reflect genetic variations in body proportions or fatness. It is noteworthy that average skinfold thickness was significantly lower in Ghanaian infants than in the DARLING infants from 4 to 12 mo for triceps skinfold thickness and from 8 to 10 mo for subscapular skinfold thickness (P < 0.001; data not shown). There might have been differences in the measurement techniques used that could account for this, but arm circumference, which is less subject to measurement bias, was also lower in the Ghanaian cohort from 1 to 12 mo (P < 0.01). These data suggest that body fatness was lower in the Ghanaian infants. Further research on body composition is needed to investigate differences in infant anthropometric characteristics across populations.

The adjusted results should be interpreted cautiously because of the limitations described previously. Nonetheless, they imply that maternal stature and prenatal factors that affect birth weight explain a large proportion of the variability in infant growth across populations. This was likely to have been more evident in these cohorts, in which breast-feeding was prolonged and complementary feeding was reasonably adequate, than in infants who are weaned early or receive inadequate complementary feeding. In any case, the results suggest that efforts to prevent child stunting must pay attention to both prenatal and postnatal factors and that it may take several generations before the change in maternal stature would be sufficient to completely eliminate anthropometric deficits in children.

In the past, malnutrition in infants and young children has been defined primarily on the basis of anthropometric criteria, ie, stunting and wasting. However, the nonspecificity of the term malnutrition can create confusion regarding the appropriate

| TABLE 3 |
|---|---|---|---|
| Indexes of iron status | Percentage with low hemoglobin | Percentage with low ferritin |
| | <110 g/L | <103 g/L | <12 µg/L |
| Honduras, LBW | | | |
| 2 mo | 79 | 48 | 0 |
| 4 mo | 54, 62 | 13, 19 | 4, 5 |
| 6 mo | 48, 55 | 14, 25 | 3, 23 |
| Honduras, NBW | | | |
| 6 mo | 46, 66 | 20, 29 | 5, 12 |
| Ghana | | | |
| 6 mo | 60 | 36 | 14 |
| 12 mo | 70 | 47 | 12, 52 |

1 LBW, low birth weight; NBW, normal birth weight.
2 Values given are for children given iron supplements or iron-fortified foods and those who were not, respectively.
avenues for preventing or resolving the problem. If a child is stunted because his or her postnatal size has been programmed prenatally, nutrition workers are likely to be frustrated by the ineffectiveness of child nutrition programs. Terms that reflect the onset of the anthropometric deficit, such as prenatal stunting and postnatal stunting, may be helpful in suggesting which types of interventions are most needed. Even these terms, however, do not adequately reflect the etiology of different manifestations of malnutrition. In recent years we have begun to recognize that micronutrient deficiencies are even more widespread than anthropometric deficits. The data on iron status described above suggest that some characteristics, such as birth weight, are risk factors for both poor growth and iron deficiency, whereas others, such as the iron content of complementary foods, may be related to iron status but not growth. We need a new lexicon for describing malnutrition that allows both scientists and policymakers to better understand the complexity of the problem and the most appropriate strategies for its resolution.

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