# Effectiveness of Iron-Fortified Infant Cereal in Prevention of Iron Deficiency Anemia

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**ABSTRACT.** *Background.* **Iron deficiency continues to be a common problem among infants throughout the world. Iron-fortified formula is effective in preventing iron deficiency but the benefit of iron-fortified cereal is controversial.**

*Methods.* **We compared iron-fortified rice cereal to unfortified rice cereal in infants who were exclusively breast-fed for more than 4 months and to iron-fortified formula in infants who were weaned to formula before 4 months of age. The design was double blind in respect to the presence or absence of fortification iron in the cereal or formula and included 515 infants who were followed on the protocol from 4 to 15 months of age. Rice cereal was fortified with 55 mg of electrolytic iron per 100 g of dry cereal and infant formula with 12 mg of ferrous sulfate per 100 g of dry powder, levels approximating those in use in the United States. Measures of iron status were obtained at 8, 12, and 15 months. Infants with hemoglobin levels of <105 g/L were excluded from the study and treated.**

*Results.* **Consumption of cereal reached plateaus at means of about 30 g/d after 6 months of age in the formula-fed groups and 26 g/d after 8 months in the breast-fed groups; these amounts are higher than the 19-g/d mean intake by the 73% of infants who consume such cereal in the United States. Among infants weaned to formula before 4 months, the cumulative percentages of infants excluded for anemia by 15 months were 8%, 24%, and 4%, respectively, in the fortified cereal, unfortified cereal and formula, and fortified formula groups ($P < .01$ unfortified vs either fortified group; the difference between the two fortified groups was not significant). In infants breast-fed for more than 4 months, the corresponding values were 13% and 27%, respectively, in the fortified and unfortified cereal groups ($P < .05$). Mean hemoglobin level and other iron status measures were in accord with these findings.**

*Conclusion.* **Iron-fortified infant rice cereal can contribute substantially to preventing iron deficiency anemia.** *Pediatrics* **1993;91:976–982;** ***iron deficiency, anemia, infant, cereal.***

ABBREVIATION. INTA, Institute of Nutrition and Food Technology.

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There is substantial evidence that iron-fortified infant formula is a reliable means of preventing iron deficiency anemia. In contrast, as was recently pointed out by Fomon,[1] there has been relatively little evidence that infant cereal plays a similarly useful role. He concluded that "at present, the major reason for recommending iron-fortified infant cereal appears to be long-established tradition." The most optimistic data in regard to the effectiveness of cereal as a vehicle for fortification iron were the studies of Rios and coworkers.[2] Iron 59 was used as an extrinsic label to estimate the absorption of fortification iron from rice cereal and infant formula. Absorption of electrolytic iron from cereal was about 4%, roughly the same percentage as from the ferrous sulfate iron that was used to fortify infant formula. However, there was some doubt about the applicability of these results to the infant cereals that are most widely used in the United States because of differences in particle size of the electrolytic iron.[1] The electrolytic iron used in the absorption studies had a smaller particle size distribution than the electrolytic iron routinely used to fortify infant cereal. Since iron of smaller particle size is better absorbed than larger particles, it is possible that iron was better absorbed in the tracer studies than it would be from commercially available iron-fortified infant cereal.

In accord with this interpretation, many subsequent studies of absorption of labeled iron from infant cereals, mostly done in adults, showed that only a very low percentage was absorbed.[3] The addition of ascorbic acid could enhance the absorption of iron. But the lability of ascorbic acid during processing and storage remains a problem. Most importantly, any estimate of effectiveness of fortified cereal in preventing iron deficiency anemia has been based primarily on extrapolation from absorption data. The sort of carefully monitored field trials that have helped to establish the efficacy of iron-fortified infant formula[4–8] have not been performed with iron-fortified cereal.

The generally skeptical and pessimistic view that iron is poorly absorbed not only from cereal but also from legume products may not be justified. Of special interest in this regard is the study of the effect of soy-based formula on iron nutrition in infants from the Institute of Nutrition and Food Technology (INTA), Universidad de Chile, Santiago.[7] Despite extremely poor bioavailability from extrinsically labeled iron when measured in adults, iron-fortified soy formula proved to be essentially as effective as iron-fortified cow milk formula in preventing iron deficiency anemia when it was fed to infants during their first year. When there is a such striking discrepancy between an extrapolation and the actual clear-cut prevention of iron deficiency anemia under conditions of normal feeding, the latter carries far more credibility. An infant feeding trial would therefore be a useful means of establishing the effectiveness of iron-fortified infant cereal in preventing iron deficiency anemia.

The purpose of this study was to determine the effectiveness of a dry rice cereal as it is currently fortified and marketed in the United States in preventing iron deficiency anemia in infants when used under optimal conditions. The results are based on 515 healthy infants who weighed more than 3000 g at birth and who were fed cereal starting at 4 months of age. Under the conditions used, an average of 25 to 30 g of infant cereal consumed per day proved to be a useful means of preventing iron deficiency anemia.

## MATERIALS AND METHODS

The infant cereal used in this study was the dry infant rice cereal manufactured by Gerber Products Company (Fremont, MI). The cereal was provided in two forms. The first was fortified with electrolytic iron to a level of 55 mg/100 g dry cereal, the same as in the commercial product. Note that the actual content of iron in cereal is usually somewhat higher than the label claim amount of 45 mg/100 g to meet the Food and Drug Administration requirement that the content be as least as high as claimed on the label. The second form of cereal was identical with the first except that fortification iron was omitted.

Infant formula for the study was formulated by INTA, Chile, in iron-fortified and iron-unfortified forms.[9] The fortified product contained added ferrous sulfate to supply 12 mg of iron per reconstituted liter. The unfortified product contained no added iron. Both products were supplemented with other minerals and vitamins, corresponding to the composition of currently marketed products in Chile and in accord with the US Infant Formula Act of 1985.[10] The formula contained added ascorbic acid, 66 mg per reconstituted liter.

### Study Design

The population of infants was from a low and low-middle income group living in urban Santiago, Chile, and receiving their routine pediatric care in a Ministry of Health outpatient clinic. All infants weighed more than 3000 g at birth and had no serious medical problems. Other criteria for initial inclusion in the study were presence of a consistent caretaker and history of having received no iron-fortified formula or supplemental iron in the past. All mothers were literate and capable of keeping records of food consumptions and morbidity. Infants whose hemoglobin concentration was less than 95 g/L at 4 months of age were not included in the study. The assignment to groups was based first on whether the period of exclusive breast-feeding was less or greater than 4 months. Infants who were weaned to formula before 4 months of age were randomized to three groups as shown in Fig. 1. Weaning was defined as more than 50% of estimated caloric requirements coming from a source other than breast milk. Group 1 received iron-fortified cereal but unfortified formula and can be considered the cereal test group. Group 2 received unfortified cereal and unfortified formula, in accord with current nutrition management in Chilean Ministry of Health clinics. On similar regimens, the experience has been that about 20% of infants will have developed mild iron deficiency anemia at 12 months of age.[8] Group 3 received unfortified cereal and iron-fortified formula. In this setting, a milk formula fortified with similar levels of iron and ascorbic acid resulted in only 1% having iron deficiency anemia at 12 months of age.[8]

Infants who were still exclusively breast-fed at 4 months of age were randomized to two groups. Group 4 received the iron-fortified cereal and group 5, the unfortified cereal. When infants were subsequently weaned at some time after 4 months of age, the unfortified formula was supplied. Solid foods were recommended for all babies according to the usual practice in Chile: fruits and juices starting at 3 months, vegetables and meat at 4 months, legumes at 6 months, and regular "table" food at 9 months.

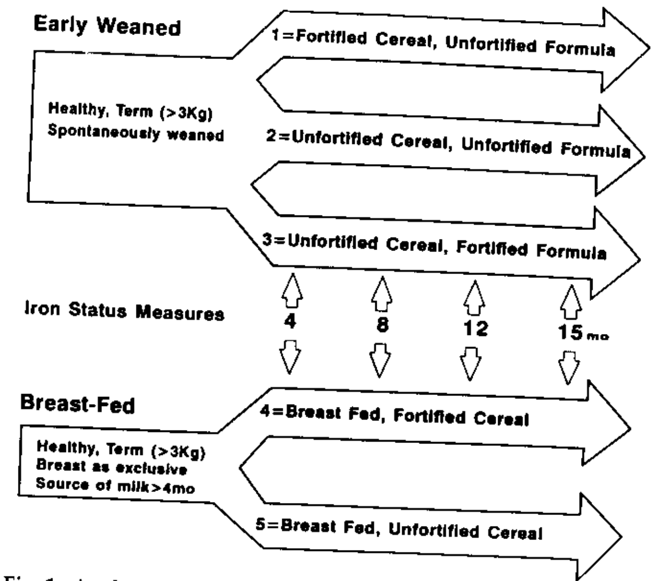


**Fig 1.** A schematic representation of the experimental design. Included are three groups of formula-fed infants (groups 1 through 3) and two groups of breast-fed infants (groups 4 and 5).

The five groups were similar in birth weight, sex ratio, growth pattern, and socioeconomic level. The other solid foods used were not iron-fortified and there was little meat in the diet. Once enrolled in the study, the most common reasons for failure to complete the protocol were a move of the household to another area (6.8%) and failure to comply with the feeding regimen or with record keeping of food consumption and morbidity (5.6%). The total percentage of infants excluded was 20.6%.

### Procedures

Pediatricians participating in the study performed monthly clinical and anthropometric evaluations from 4 to 15 months of age; in addition, they provided routine health maintenance and sick visit care. Morbidity since the previous visit was also recorded. A registered field dietitian performed weekly home visits during this period to instruct mothers on feeding, well-baby care, and the daily recording of formula consumption and illnesses or symptoms. Formula and cereal intake were estimated by the mother, who was given a measuring spoon for preparing cereal and formula from the dry forms in which they were supplied. All formulas were provided at no charge. Initial hemoglobin screening for inclusion in the study was by capillary heel-stick (HemoCue, Leo Diagnostics, Helsingborg, Sweden). Iron nutritional status was subsequently determined from venous blood at 8, 12, and 15 months of age. The following were measured as previously described[8]: hemoglobin, mean corpuscular volume (Coulter model ZBI, Hialeah, FL), iron concentration and iron-binding capacity, erythrocyte protoporphyrin (Hematofluorometer AVIV, Lakewood, NY), and serum ferritin (Ferrizyme, Abbott Diagnostics, North Chicago, IL). Serum ferritin values for infants receiving iron-fortified formula were lower than historical control values from INTA. However, they were carefully verified by reassay against an international standard and previous samples.

Mean, standard deviation, Student's $t$ test, and $\chi^2$ were used in the statistical analysis. Questions about differences between groups that were generated by our hypotheses generally involved comparing two groups: fortified cereal vs unfortified cereal, fortified cereal vs fortified formula, breast-fed + fortified cereal vs breast-fed + unfortified cereal.

The protocol was approved by the Ethics Committee for Human Research of the INTA. Informed consent was obtained verbally from parents prior to inclusion in the study.

## RESULTS

### Growth, Morbidity, and Attrition

Weight and length at 8, 12, and 15 months were essentially the same in the three formula-fed and two breast-fed groups, respectively. Only at 8 months of age were the breast-fed infants very slightly but significantly heavier than the formula-fed infants ($P < .001$) (Fig. 2). At each age, both breast-fed and formula-fed groups had mean weights just above the 50th percentiles of US standards.[11] Morbidity was expressed as number of clinic outpatient visits per year per infant and consisted primarily of respiratory infections (mean: 2.54 visits) and diarrhea (mean: 0.51 visits). There were no significant differences in morbidity as a function of iron fortification or breast-feeding vs formula-feeding. There were essentially no differences among groups in the percentage of infants who dropped out of the study for reasons other than the development of anemia.

### Cereal Consumption

Mean cereal consumption in all three formula-fed groups (groups 1 through 3) closely approached the target level of 30 g/d within 3 weeks of initiation of cereal at 4 months of age (Fig. 3). Cereal consumption was then maintained at that level for the entire period of the study, to 15 months of age. Fewer than 20% of infants failed to maintain their cereal consumption above 24 g/d.

The two breast-fed groups (groups 4 and 5) were slower to reach target levels of cereal consumption and reached a slightly lower plateau of mean intake than the formula-fed infants (fig. 3). The mean intake reached 20 g at 6 months and 25 g at about 7.5 months. This was despite the encouragement of cereal consumption by the nutritionists on the weekly home visits and may be attributable to the difference in ease of feeding cereal mixed with formula and fed from the bottle compared to feeding it with a spoon as a gruel.

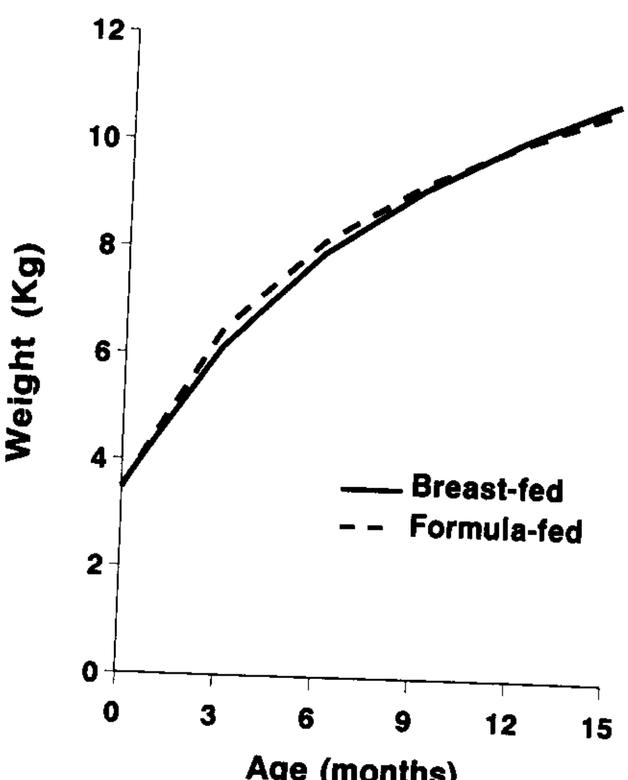


Fig 2. Mean weight gain of formula-fed and breast-fed infants.

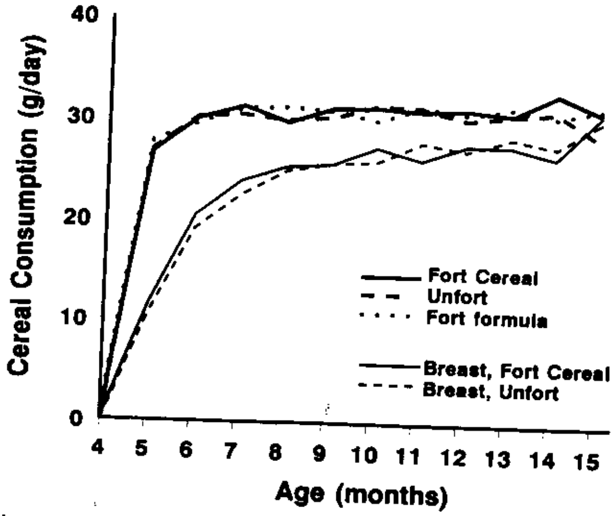


Fig 3. A real consumption of formula-fed and breast-fed infants. The breast-fed infants were slower to increase their cereal consumption and did not reach as high an intake as the formula-fed infants.

Infants in groups 4 and 5 remained breast-fed for a relatively long time, about half still being exclusively breast-fed at 8 months of age. They were categorized as formula-fed even if they received as little as one bottle per day. Cereal consumption was slightly higher in infants who were weaned to formula than among those who continued exclusively breast-feeding. The difference was calculated for each month and was about 1 g/d in group 4 and 1 to 4 g/d in group 5 between 6 and 12 months of age; the difference was not statistically significant except at 8 months in group 5 ($P < .05$).

### Formula-Fed Infants

The Table summarizes the laboratory data at 8, 12, and 15 months of age. Group 1 infants who received fortified cereal but unfortified formula had significantly higher hemoglobin values ($P < .01$) at all three ages compared to group 2 infants, who received no fortified foods. There were no significant differences in hemoglobin concentration between group 1 (fortified cereal) and group 3 (fortified formula). However, mean values for mean corpuscular volume, and transferrin saturation were higher and erythrocyte protoporphyrin was lower in group 3. Among the breast-fed infants, the hemoglobin concentration was significantly higher ($P < .05$) at 12 and 15 months in group 4, which received iron-fortified cereal, compared with group 5, which received unfortified cereal.

Figure 4 shows the cumulative percentage of infants who were excluded from the protocol because they had a hemoglobin concentration of less than 105 g/L. Group 3, fed iron-fortified formula, maintained a plateau of about 3% after 8 months of age, in accord with previous studies from INTA. Group 1, fed iron-

**TABLE.** Laboratory Data*

| Age mo | Groups | n | Hb, g/L | Hb < 105, % | MCV, fL | EP, μg/dL RBC | SAT, % | SF,† μg/L |
|---|---|---|---|---|---|---|---|---|
| 8 | 1. Fortified cereal, unfortified formula | 84 | 118 ± 1.0 | 6.0 | 73.9 ± 0.4 | 128 ± 6 | 11.7 ± 0.7 | 10 (5–22) |
| | 2. Unfortified cereal, unfortified formula | 93 | 114 ± 1.5 | 12.9 | 72.0 ± 0.4 | 136 ± 5 | 10.0 ± 0.6 | 8 (3–19) |
| | 3. Unfortified cereal, fortified formula | 94 | 121 ± 0.9 | 3.2 | 77.3 ± 0.4 | 120 ± 5 | 13.1 ± 0.7 | 10 (5–20) |
| | 4. Fortified cereal, breast-fed | 85 | 116 ± 0.9 | 10.6 | 75.0 ± 0.5 | 103 ± 5 | 11.3 ± 0.6 | 16 (7–37) |
| | 5. Unfortified cereal, breast-fed | 88 | 114 ± 1.0 | 14.8 | 73.7 ± 0.5 | 127 ± 7 | 10.6 ± 0.6 | 13 (6–32) |
| 12 | 1. Fortified cereal, unfortified formula | 71 | 124 ± 1.0 | 2.8 | 75.4 ± 0.4 | 107 ± 5 | 13.5 ± 0.8 | 9 (4–18) |
| | 2. Unfortified cereal, unfortified formula | 74 | 120 ± 1.0 | 8.1 | 73.2 ± 0.6 | 130 ± 7 | 11.7 ± 0.9 | 7 (3–15) |
| | 3. Unfortified cereal, fortified formula | 77 | 125 ± 0.9 | 0.0 | 76.1 ± 0.4 | 95 ± 3 | 15.4 ± 0.8 | 11 (6–20) |
| | 4. Fortified cereal, breast-fed | 74 | 121 ± 0.9 | 1.4 | 75.1 ± 0.4 | 110 ± 7 | 12.9 ± 0.8 | 15 (7–30) |
| | 5. Unfortified cereal, breast-fed | 74 | 117 ± 1.0 | 10.8 | 72.5 ± 0.5 | 129 ± 7 | 11.6 ± 0.8 | 10 (4–24) |
| 15 | 1. Fortified cereal, unfortified formula | 67 | 126 ± 1.1 | 0.0 | 76.3 ± 0.4 | 100 ± 4 | 15.0 ± 1.0 | 10 (5–21) |
| | 2. Unfortified cereal, unfortified formula | 64 | 121 ± 1.6 | 9.1 | 74.3 ± 0.6 | 116 ± 6 | 11.8 ± 0.8 | 8 (4–16) |
| | 3. Unfortified cereal, fortified formula | 73 | 126 ± 1.0 | 1.4 | 76.4 ± 0.4 | 95 ± 3 | 15.8 ± 0.9 | 11 (5–22) |
| | 4. Fortified cereal, breast-fed | 72 | 124 ± 1.0 | 1.4 | 76.8 ± 0.5 | 105 ± 6 | 14.7 ± 1.0 | 11 (6–21) |
| | 5. Unfortified cereal, breast-fed | 64 | 119 ± 1.0 | 5.2 | 75.3 ± 0.5 | 118 ± 6 | 13.4 ± 0.9 | 10 (5–21) |

* Mean and SEM are indicated. Difference in Hb between groups: 1 vs 2: $P < .01$ at all ages; 1 vs 3: not significant at all ages; 4 vs 5: $P < .05$ at 12 and 15 months. Abbreviations: Hb, hemoglobin; MCV, mean corpuscular volume; EP, erythrocyte protoporphyrin; RBC, red blood cells; SAT, tranferrin saturation; SF, serum ferritin.
† Geometric mean ± 1 SD range.

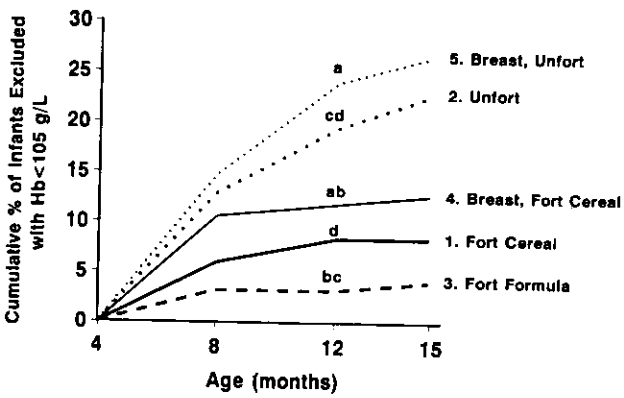


Fig 4. Cumulative percentage of infants excluded from the regimen on the basis of a concentration of hemoglobin (Hb) <105 g/L. At 12 months of age, fewer formula-fed infants had been excluded if they had received either fortified cereal (Fort Cereal) or formula (Fort Formula) than if they had received neither food in the fortified form (Unfort). Fewer breast-fed infants had been excluded from the fortified cereal group (Fort Cereal) than from the unfortified cereal group. Infants fed iron-fortified formula were less frequently excluded than breast-fed infants fed iron-fortified cereal.

fortified cereal, had a cumulative exclusion rate of 6% at 8 months, leveling off at 8% at 12 and 15 months. In marked contrast, group 2, which had received no fortified food, had 13% excluded at 8 months, and increasing cumulative totals of 19% at 12 months and 24% at 15 months of age, respectively. Chi-square analyses for differences in exclusion rates between groups were done at 12 months, a common time for anemia screening in practice and a period where study infants had been on the dietary regimens for 8 months. Each formula-fed group receiving some form of fortification (group 1 or 3) was significantly less likely than unfortified group 2 to have a hemoglobin concentration of less than 105 g/L ($P < .05$ for 1 vs 2 and $P < .001$ for 2 vs 3). Although the values suggested a slight advantage of group 3 over group 1, the difference between the two groups was not statistically significant.

Figure 5 compares the groups in respect to the laboratory measurements of iron status at 8 months of age, before any infants had been excluded for anemia. The height of the bars represents the percentage of infants with iron deficiency anemia in each diet group. Iron deficiency anemia was defined essentially as previously,[8] as a hemoglobin concentration of less than 110 g/L in combination with two or three additional abnormal iron status measures out of 3 (mean corpuscular volume <70 fl, SAT <10%, and serum ferritin <10 μg/L). These results parallel those depicted in Fig. 4, but are more specific to iron deficiency as a cause of anemia. In groups 1 and 3, 6% and 4%, respectively, had iron deficiency anemia, significantly fewer than the 17% in group 2 (both $P < .05$ by $\chi^2$).

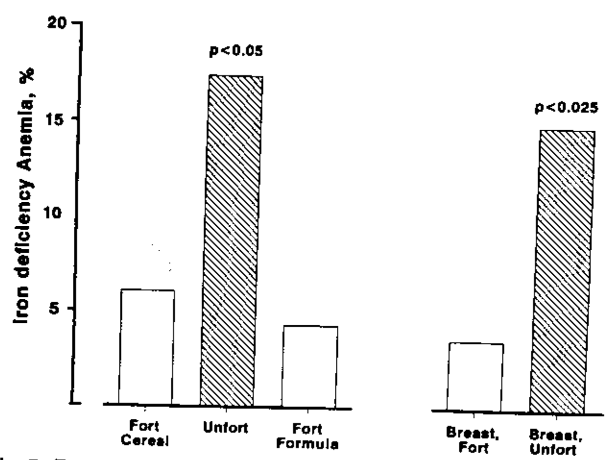


Fig 5. Prevalence of iron deficiency anemia at 8 months of age. Among the formula-fed infants, groups 1 and 3, who received iron-fortified cereal (Fort Cereal) and iron-fortified formula (Fort Formula), respectively, had a significantly lower prevalence of anemia than the group 2 infants, who received neither fortified cereal nor formula (Unfort). Breast-fed infants receiving iron-fortified cereal (Breast, Fort) had a significantly lower prevalence of iron deficiency anemia than those who received unfortified cereal (Breast, Unfort).

### Breast-Fed Infants

Infants who were breast-fed more than 4 months and who were fed iron-fortified cereal (group 4) had a significantly higher ($P < .05$) mean hemoglobin concentration than unfortified cereal group 5 infants at 12 and 15 months of age (Table). The cumulative percentage of group 4 infants excluded from the protocol on the basis of a hemoglobin concentration of less than 105 g/L reached a value of 11% at 8 months of age and scarcely rose above that level subsequently (Fig. 4). In contrast, the corresponding percentage in group 5 continued to increase from 15% at 8 months to 24% at 12 and 27% at 15 months of age. At 12 months of age, group 4 had had significantly fewer individuals excluded for a hemoglobin concentration of less than 105 g/L than group 5 ($P < .025$). Figure 5 shows that the percentage with iron deficiency anemia in group 4 was a surprisingly low 3%, in the same low range as in the two formula-fed groups that received some form of iron fortification, either from cereal or from formula. However, 15% of the breast-fed infants receiving unfortified cereal had developed iron deficiency anemia, a significantly higher percentage than in group 4 ($P < .01$).

## DISCUSSION

There is now virtual agreement about the guidelines for infant feeding in the United States.[12] The promotion of breast-feeding is universally supported, and iron-fortified formula rather than cow milk or unfortified formula is recommended at weaning if, as is the case with most infants, weaning occurs before 12 months of age. One issue that has remained unresolved is the efficacy of iron-fortified infant cereal as an alternative source of fortification iron.[1] Infant cereal is the most commonly used first nonmilk food in the infant diet, and it is recommended as a source of iron for late infancy,[13] when the risk of iron deficiency is greatest and milk should no longer be the sole source of calories.

Under the conditions of this study, infant cereal fortified with electrolytic iron in the same way as in the United States was quite effective in preventing iron deficiency anemia when it was the only iron-fortified product used. It is worth emphasizing that all infants whose hemoglobin concentration fell below 105 g/L were taken out of the study and given iron. Had this not been the case, the differences between the iron-supplemented and unsupplemented groups would probably have been substantially greater. For this reason, Fig. 5, giving the prevalence of anemia at 8 months, and Fig. 4, showing the cumulative percent of infants excluded from each group, best depict the benefits of iron fortification. In contrast, in the Table the differences between groups at 12 and 15 months may at first seem less impressive, presumably because the most iron-deficient infants have been excluded. Consequently, those remaining in the study were infants who were most resistant to iron deficiency, perhaps through individual variations such as higher neonatal iron stores. The Table suggests that iron-fortified formula had a modest though not statistically significant advantage over iron-fortified cereal at 8 months.

Figure 4 shows the *cumulative* percentage of infants in each group who were excluded on the basis of a hemoglobin concentration below 105 g/L. Since values below 105 g/L have been associated with impaired psychomotor development, these are the infants about whom there is concern in regard to the physiological consequences of iron deficiency.[14,15] As shown in Fig. 4, all three groups that received either iron-fortified cereal or formula had a clear advantage over the other two groups (upper curves) that were given no iron-fortified foods. It is noteworthy that individuals in groups 1, 3, and 4 were most likely to become anemic at 8 months of age and showed relatively little increase subsequently, after these most anemic infants had been removed from the study for iron treatment. In contrast, groups 2 and 5 (no fortification) showed a steadily increasing percentage that developed anemia (hemoglobin <105 g/L). Group 3 (iron-fortified formula) had the fewest infants with a hemoglobin level of less than 105 g/L, about 3%. Group 1 (iron-fortified cereal) reached slightly higher values for prevalence of anemia of 6% at 8 months and 9% at 12 and 15 months, but there was no statistically significant difference with group 3. However, group 2, which had received no iron-fortified food, steadily diverged from these results, with 20% who were anemic (hemoglobin <105 g/L) at 12 months and 22% at 15 months.

The next issue to address is how well the cereal results in Chile reflect conditions in the United States. In the broadest terms, although the study population is less well off economically than a comparable US population, the advantages of excellent pediatric care and access to ample food, electricity, and running water help to explain why anthropometric[11] and morbidity data do not differ substantially from the United States. Two factors that probably promoted the effectiveness of iron-fortified cereal in Chile were the relatively high consumption of cereal and the fact that it was fed, as is customary in Chile, mixed with a formula that was fortified with ascorbic acid, a known enhancer of iron absorption. A recent survey in the United States showed that the average consumption of infant cereal between 6 and 12 months of age was 19 g/d among the 73% of infants who consumed cereal.[16] However, iron-fortified cereal in the United States is probably fed with a more ascorbic acid-rich diet. Furthermore, even "unfortified" US formulas comply with the Infant Formula Act of 1985 by adding iron to a concentration of at least 1.0 mg/L,[9] an amount that is considerably higher than that of the INTA formula in this study, which contained about 0.5 mg of endogenous iron per liter. The INTA formula is similar in iron content to that used in the distribution program of the Chilean Ministry of Health.

### Iron-Fortified Cereal in Breast-Fed Infants

Infants who were breast-fed for 4 or more months also showed marked benefit from receiving iron-fortified cereal. In these infants, cereal was fed by spoon, as in the United States until weaning to the bottle, when it was added to the formula in the manner that is customary in Chile. The Table shows that hemoglobin and other measures of iron nutrition were indicative of significantly better iron status in fortified group 4 compared to unfortified group 5, especially at 12 and 15 months of age, by which time cereal had been consumed for a more prolonged period. Figure 4 shows the differences even more clearly. By 15 months of age, hemoglobin had fallen below 105 g/L in 27% of infants in group 5 compared to 12% in group 4.

It is also worth comparing breast-fed, fortified-cereal group 4 with the fortified formula-fed group 3. Although the concentration of hemoglobin in group 4 was lower at 8 months (Table), when the breast-fed infants had had a relatively brief exposure to the fortified cereal, the difference, though significant ($P < .05$), diminished by 12 and 15 months of age.

The results for the breast-fed infants are in accord with other recent studies showing that there is a substantial risk of iron deficiency anemia after about 6 months of age unless a source extra iron is provided.[8,17] This may be attributed to an exhaustion of storage iron during rapid growth[18] and, to a lesser degree, a declining concentration of iron in breast milk.[19] It is possible that the provision of iron-fortified cereal to breast-fed infants in the United States provides better protection against iron deficiency than in this study since sources of ascorbic acid, such as fruit and fruit juices, are more often fed with cereal and would further enhance the absorption of fortification iron. Furthermore, when infants are weaned, they are given iron-fortified formula according to present recommendations. In contrast, the Chilean infants are weaned to a formula that contains less iron than provided by "unfortified" formula in the United States. However, the current pattern of cereal consumption in the United States is more variable and, on the average, less is consumed per day than in this study.[14]

### Role of Cereal as a Vehicle for Iron Fortification

Infant cereal was first fortified in the United States in 1940s and 1950s, shortly after World War II. Initially cereal was fortified with iron pyrophosphate or orthophosphate, compounds that allowed for a prolonged shelf-life but that subsequently proved to be poor sources of absorbable iron. Since 1972, electrolytic iron has been most widely used in the fortification of infant cereal in the United States,[3] currently at a label claim level of 45 mg/100 g dry cereal. However, the effectiveness of infant cereal as a vehicle for fortification iron has not become as well established as is the case with infant formula.

Tracer studies of electrolytic iron absorption from cereal were initially encouraging,[2] but the particle size of the fortificant studied differed from that in commercial use and made it difficult to extrapolate to infants eating the marketed products.[1] In the meantime, iron-fortification of formula proved to be effective in preventing iron deficiency in infants, and recommendations for infant feeding increasingly reflected a sole reliance on infant formulas for this purpose.[18]

It may at first seem unnecessary to have a continuing interest in infant cereal as a vehicle for fortification iron for infants. The biggest disadvantage of infant cereal as the sole source of iron is that the amount that is consumed varies considerably from infant to infant. Of course, the same is true of the long-accepted iron fortification of cereal and flour products consumed by the general population. However, in infants, the issue is of more critical importance because iron deficiency anemia is associated with a delay in psychomotor development that may be long-lasting and not completely reversible, even when the deficiency is reversed.[14,15] The problem of inconsistent cereal consumption could probably be alleviated if it were routinely dealt with as a part of nutrition counseling during a health maintenance visit.

There are several reasons to give infant cereal continued attention as a vehicle for fortification iron. First, cereal products are relatively inexpensive and quite stable on storage even after the package has been opened. Low cost is an important factor in the planning of public assistance programs such as the Women, Infants, and Children (WIC) program in the United States. It is also a factor in infant feeding programs internationally, and the Agency for International Development continues to distribute cereal and legume products fortified with iron and ascorbic acid on a large scale to developing countries.[21] Another reason that cereal is an attractive vehicle is that it is traditionally among the most important weaning foods in the United States and in many countries around the world. It is therefore consumed during a period when iron deficiency is most common. It is also a food that helps to make the transition out of the physiologically high fat diet that is exemplified by breast milk and that is necessary for rapid infant growth. A diet higher in carbohydrate is more appropriate for the slower growth of childhood and is currently recommended for this group.

## CONCLUSION

Iron-fortified dry infant cereal plays a meaningful role in the prevention of iron deficiency anemia in infancy.

## ACKNOWLEDGMENT

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# COMORBIDITY BETWEEN ADDH AND LEARNING DISABILITY: A REVIEW AND REPORT IN A CLINICALLY REFERRED SAMPLE


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**Abstract.** A widely variable overlap ranging from 10 to 92% has been reported in the literature between attention deficit disorder with hyperactivity (ADDH) and learning disability (LD), most likely a result of inconsistencies in the criteria used to define LD in different studies. The following study seeks to more accurately determine rates of LD in clinically referred children. Using a psychometrically reliable approach, it was expected that the rate of LD in ADDH children would be far more modest than previously reported. Subjects were referred children with ADDH ($N$ = 60), children with academic problems ($N$ = 30), and normal controls ($N$ = 36) of both sexes with available psychological and achievement testing. Using a liberal definition of LD, significant differences were found between the groups (ADDH = 38% versus academic problems = 43% versus normals = 8%; $p$ = 0.002). In contrast, more modest rates were found using two more stringent methods of assessment (23 and 17%; 10 and 3%; 2 and 0%, respectively; $p$ = 0.02). Arithmetic-based LD appears to be equally identified by both stringent methods, whereas the liberal definition overidentified children in all three groups. These findings show that a liberal definition of LD overidentifies LD not only in ADDH children but also in normal children. *J. Am. Acad. Child Adolesc. Psychiatry* 1992;31:439–448. Key Words: learning disability, attention deficit disorder, attention-deficit hyperactivity disorder, comorbidity.