

Bioavailability of Iron from Infant Foods: Studies with Stable Isotopes

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Iron deficiency is common among infants and young children both in industrialized and in developing countries (1). Besides inadequate intake of iron, poor availability of ingested iron is a major cause of poor iron nutrition. Development of strategies to combat iron deficiency has been impeded by lack of precise information about the availability to infants and young children of food iron and fortification iron. This lack of information is due to a reluctance to use radioisotopes in studies of infants and young children, although administration of radioiron poses a very negligible hazard. However, the use of stable (nonradioactive) isotopes has recently become feasible as a result of the development of suitable mass spectrometry instrumentation, such as inductively coupled plasma mass spectrometry (ICP/MS). The feasibility of using ^{58}Fe , the least abundant stable isotope of iron (natural abundance 0.322 weight%), for studies of iron metabolism in infants has been demonstrated (2,3). Enrichment of circulating erythrocyte iron following administration of a tracer amount of ^{58}Fe can be determined with sufficient precision to permit use of the erythrocyte incorporation approach for comparative studies. This approach is more convenient than the isotope balance method, which requires prolonged periods of stool collection.

GENERAL METHODOLOGY OF STABLE ISOTOPE STUDIES OF IRON

Whole body counting following the administration of radioiron (^{55}Fe or ^{59}Fe) is considered the most precise method to determine iron bioavailability (4). Obviously, an equivalent approach does not exist for stable isotopes. Since the cumbersome nature of isotope balance studies limits their use, erythrocyte incorporation studies are the approach of choice for availability studies with the use of stable isotopes. The main limitation of this approach

Nutritional Sources of Iron in Infants and Toddlers

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In this review, dietary sources of iron during infancy will be discussed briefly, and emphasis will be placed on sources of dietary iron for toddlers. In a recent study in Denver (unpublished), we found an unexpected incidence of iron depletion and deficiency in 18- to 24-month-old toddlers from low-income families. Nutrient analysis revealed that dietary iron intake was limited in these children. A subsample of these children was given a low-dose iron supplement, and a repeat assessment of iron nutriture was performed 6 months later. In this review, the nutritional and laboratory data collected in Denver will be compared with that collected in Scandinavian and North and Central American countries.

DIETARY IRON IN INFANCY: BIRTH THROUGH 12 MONTHS

For breast-fed infants, the elegant studies of Siimes et al. (1) showed that 33 solely breast-fed infants could maintain an adequate iron nutritional status until 6 months of age. The maintenance of an adequate iron status during this period of rapid growth demonstrates the excellent bioavailability of iron from human milk. However, if human milk continues to be the major source of nutrients for longer than 6 months, an iron supplement must be provided.

DIETARY SOURCES OF IRON SUPPLEMENTS

Among formula-fed infants, the majority will receive cow's milk-based products, which are generally supplemented with 12 mg of iron/liter. Providing such products over the first 12 months of life insures both adequate iron nutrition and the establishment of reserves. Since iron deficiency in infancy may be related to the early provision of cow's milk (2), it is of some concern that the American Academy of Pediatrics in 1983 sanctioned

the introduction of whole cow's milk at 6 months of age for infants who were receiving at least 30% of their diets as mixed solids (3). This concern is supported by the observations of Tunnessen and Oski (4), who showed that infants fed cow's milk at 6 months had, by 12 months of age, diminished reserves and a higher incidence of iron deficiency and lower hemoglobin values than formula-fed controls. The deficiencies occurred even though iron-fortified cereals were provided to many children receiving whole cow's milk. The study on intestinal blood loss by Ziegler in this volume provides additional support for continued feeding of iron-fortified formula in the latter half of the first year of life.

Another often-encountered practice consists of giving formulas low in iron because of concerns over gastrointestinal upsets associated with iron-fortified cow's milk products. The problems are generally described as a combination of frequent spitting up, cramping, and hard stools.

In a controlled study by Nelson and colleagues (5), the only demonstrable difference between infants fed the iron-fortified or low-iron cow's milk formula was the color of stools, which were more often dark brown, green, or black in the iron-supplemented group. Since pediatricians at times are obliged to give into parental wishes, a reasonable approach would be to permit a low-iron formula during the first 2 to 3 months of life when neonatal iron reserves are being mobilized. Later, iron-supplemented formula should be strongly recommended.

The study from Chile by Herrtrampf and colleagues is reassuring to physicians who have prescribed soy-based formula products for those infants who cannot tolerate cow's milk (6). Good levels of hemoglobin and other indicators of iron status were present at 9 months of age in 47 infants who received soy formula for a period of 6 to 7 months. A 27% incidence of anemia was found, however, in a breast-fed group that served as the control. Although soy formula has long been considered to inhibit iron absorption, increased ascorbic acid concentration in the formula may compensate for the less favorable properties of a soy protein isolate.

EFFECT OF IRON-FORTIFIED CEREALS ON IRON NUTRITION

There is some evidence that solid foods or infant cereals fortified with iron do little to improve iron status. Anemia was a frequent finding in the Chilean breast-fed infants, although solid foods were introduced at 3 to 4 months of age (6). Similarly, in the Syracuse study (4), 91% of infants fed whole cow's milk were eating fortified cereal at 8 months of age. By 12 months, 62% of the infants were still taking iron-supplemented cereals, but this practice did little to improve their hematological status. Whether this results from mixing fortified cereal with cow's milk and formation of iron phosphate-insoluble complexes remains unknown.

IRON-FORTIFIED CEREALS AND IMPROVED BIOAVAILABILITY

The fortification of cereals and infant foods was discussed by Rees et al. in 1985 (7). Compared to one decade earlier (Table 1), the use of iron compounds of low bioavailability had markedly decreased by 1982. Infant cereals may now be fortified to levels of 13.5 mg of iron/ounce. Ferric phosphate salts at the time were found only in regular, not infant, cereals.

The benefits of providing iron-supplemented formulas and cereals for low income groups have been described for recipients of the Special Supplemental Food Program for Women, Infants, and Children (WIC) (8,9). In a study in New Haven, Connecticut, the mean hemoglobin level of 324 children enrolled in the WIC program who were followed at an inner city health center was 0.7 g/dl higher in 1984 than in 1971 (8). Similarly, Miller and colleagues (9), in a retrospective analysis of 1977 data from Minneapolis, showed that participation in the WIC program caused significant improvement of iron reserves in infants and a lesser incidence of low hematocrit and iron depletion in toddlers.

The subjects of fortification and bioavailability have been reviewed by Dallman (10), whose suggestions to improve iron nutrition in weanlings include increased use of ascorbic acid-enriched foods or juices and mixing meats with other solid foods after 6 months of age. However, it may be more practical to consider iron supplements for term infants when particular feeding practices are encountered. During the first 3 months of life, mobilization of iron from neonatal reserves is sufficient to cover needs. Thereafter, depending on the type of formula or milk provided, supplementation at a dose of 10 to 15 mg of iron daily should be considered for the later quartiles of the first year (Table 2).

TABLE 1. Bioavailability of iron used in cereal fortification: changes between 1972 and 1982

	Iron bioavailability (%)	
	High ^a	Low ^b
1972		
Infant cereals	50	50
Cereal-based infant foods	60	40
Cereals	65	35
1982		
Infant cereals	100	-
Cereal-based infant foods	100	-
Cereals	88	12

^aHigh bioavailability: iron sulfate, small particle reduced iron, iron fumarate.

^bLow bioavailability: large particle reduced iron, iron phosphate salts.

^cAdapted from ref. 7 with permission, J.B. Lippincott Co., © 1985.

The iron needs of premature infants are quite different and vary with birth weight and the degree of prematurity. Generally, after the second month, supplementation at a dose of 2 to 4 mg/kg/day is recommended (11).

DIETARY IRON IN THE TODDLER YEARS: THE DENVER STUDY OF CHILDREN IN LOW-INCOME HOUSEHOLDS

This project was designed to determine the effect of a multivitamin supplement containing iron and zinc on hematological parameters, plasma zinc concentration, dietary intake, growth rate, and developmental performance. Infants enrolled in the study received their routine pediatric care at the Westside Health Center in Denver, a clinic that primarily serves low-income families.

Recruitment was aimed at toddlers who were 18 to 24 months of age at the start of the 6-month observation and follow-up period. A large poster with sign-up sheets was placed in the entry hall of the Clinic, where about 15,000 pediatric encounters occur annually. Recruitment was generally voluntary. As an additional incentive, a stipend of \$45 was offered to those who completed all aspects of the study. Of the first 190 subjects who entered the study, 140 (74%) completed the project. The data discussed in this chapter concern this group only.

An additional 40 subjects participated in the program; however, they were recruited by telephoning those families with children whose immunization schedules were up to date. Compliance was markedly better in this group, as 35 (87.5%) of the children completed the project. Dietary data were not collected for these children because the emphasis was mainly on growth velocity; for 12 of the 40 children, finger sticks only were performed upon the first visit.

Subjects were randomly assigned to one of five groups: (a) a plain multivitamin tablet (MV), (b) the same multivitamin with 12 mg of iron (MV + iron), (c) a multivitamin with iron and 8 mg of zinc (MV + minerals), (d) a multivitamin with 8 mg of zinc (MV + zinc), or (e) a placebo. The sup-

TABLE 2. Feeding practices and supplemental iron needs in term infants

	0-3 months	4-6 months	7-9 months	10-12 months
Breast milk	-	-	+	+
Cow's milk formula	-	-	+	+
(low iron)	-	+	-	-
Iron enriched	-	-	-	-
Soy formula	-	+	+	+
Cow milk	-	+	+	+

Plus sign indicates the need for supplemental iron.

plements were provided in two batches of 100 tablets each, and compliance was assessed by counting the remaining pills at the 3- and 6-month visits. Families were instructed to provide one tablet daily, and follow-up visits were scheduled 3 and 6 months after the start of the study.

At the first visit, after anthropometric measurements were obtained, the child was tested with the Bayley Scales of Infant Development, and the caregivers were instructed to keep diet records. A venipuncture was attempted, and if it was successful, the following assays were performed: plasma zinc, hematological panel with indices (CBC), zinc protoporphyrin (ZPP), and serum ferritin. With small volumes, only ZPP, CBC, and plasma zinc levels were measured. If venipuncture failed, or if the parents objected, a capillary finger stick was used to obtain a hematological panel.

At the 3- and 6-month visits, anthropometric tests, developmental tests, and diet record collection were repeated. Venipuncture was repeated at the end of the 6-month study.

With regard to the laboratory assays, normal values included a hemoglobin concentration greater than 11.2 g/dl, zinc protoporphyrin levels less than 40 µg/dl, serum ferritin greater than 20 ng/ml, and mean corpuscular volume greater than 70 fl. Iron depletion was considered if serum ferritin levels alone were decreased. Iron deficiency can manifest itself by biochemical changes including microcytosis before anemia appears. In iron deficiency with anemia, hemoglobin levels are decreased, zinc protoporphyrin concentrations are elevated, and serum ferritin levels are low.

Seventy-two-hour diet record collection was also part of this study, and at the initial interview, the caregivers were instructed on proper methods of keeping diet records. The records were examined for completeness and accuracy first by a child health associate and later by a nutritionist. The actual analysis was performed by graduate students in nutrition from Cornell University under the supervision of Dr. Divya Sanjur. Complete food records were provided by 78 subjects, while an additional 12 provided at least one record from each study period. A total of 793 records from 90 subjects were the basis for the final analysis, for 72% of the total 1,104 diet records obtained during the investigation.

DEMOGRAPHIC AND SOCIOECONOMIC CHARACTERISTICS OF THE DENVER TODDLERS

Of 90 children, 67% were Hispanic, 31% were white, and 2% were black. Although yearly income ranged from \$3,264 to \$35,000, 34% of the participant families had incomes of less than \$5,000 a year (Table 3), and 73% of the families fell below poverty limits. Educational levels of the mothers are summarized in Table 3. Regarding maternal occupations, 66 mothers were homemakers (72%), 20 were clerical, sales, manual, or skilled work-

ers, and 4 were students. The mean family size was three members; only 10 families had more than five, and 30 had fewer than three members. Male heads of household were excluded from the computation of family size.

Of the first 190 subjects, hemoglobin levels were obtained on 179 children, and 12 had concentrations below 11.2 g/dl. Zinc protoporphyrin levels in excess of 40 µg/dl were present in 44 of 153 subjects, and serum ferritin levels were low in 39 of 140 samples. Because of problems with blood collection, sample size, and clotting, some assays were not done on all subjects.

Further analysis of these biochemical criteria provided a better definition of the iron nutritional status of the population upon entry to the study. Twenty-eight subjects had iron depletion alone with low serum ferritin levels, 42 had biochemical evidence of iron deficiency manifested by increases in zinc protoporphyrin concentration, and two subjects had iron deficiency with anemia. Ten subjects had infection-induced anemia, in which zinc protoporphyrin and serum ferritin levels were normal and the situation corrected spontaneously. There was no evidence of lead toxicity in the subjects with zinc protoporphyrin levels greater than 50 µg/dl. Hence, laboratory evidence of inadequate iron status was present in 72 of 190 (38%) of the participants at the beginning of the study.

Mean values for serum ferritin, before and after supplementation, are shown in Fig. 1. These results are grouped according to the supplement received. In the MV + iron group, mean serum ferritin levels appear to be increased after 6 months of supplementation; however, because of the variability in results, these differences were not significant. Since this was a longitudinal study, it provided the opportunity to compare differences in serum ferritin levels before and after 6 months of supplementation. In Fig. 2, these paired differences are summarized according to the various supple-

TABLE 3. Annual household income and years of education of mothers of 90 children from low-income Denver families

Annual household income (\$)	Number (N = 90)	Percent of sample
< 5,000	31	34
5,000-11,000	35	39
11,001-15,000	12	19
15,001-20,000	7	8
> 20,000	5	6
Education of mothers (years)		
College graduate (16)	4	5
Junior college (partial: 14)	15	17
High school graduate (12)	40	44
Some high school (10)	31	34

mentation groups. Positive mean differences in serum ferritin levels (ferritin at 6 months - ferritin at onset) were found only in the subjects receiving some form of iron supplement. Negative mean differences in serum ferritin occurred in the other three groups. There were significant differences in the paired mean changes in ferritin between the MV + iron group and three other groups (plain MV, MV + zinc, and placebo). There also was a trend toward significance between the MV + minerals and the plain MV, the MV + zinc, and placebo groups. No differences were evident between the MV + iron and the MV + minerals groups.

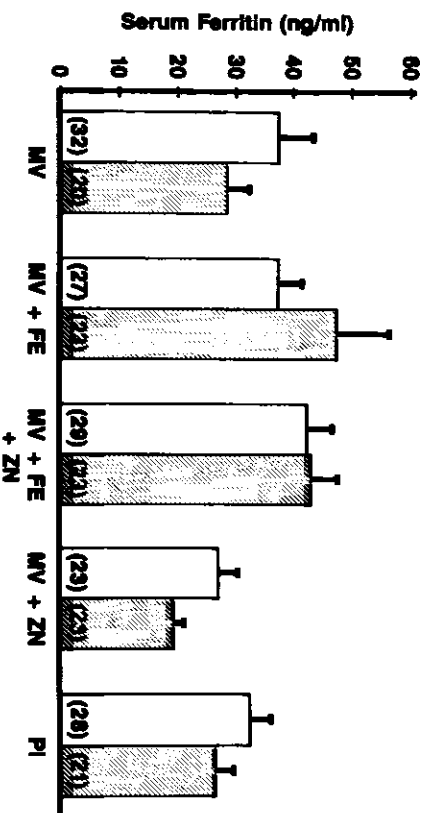


FIG. 1. Mean (SEM) serum ferritin concentrations before (open boxes) and after (hatched boxes) 6 months of supplementation with multivitamins or placebo. Sample size is indicated by numbers in parentheses within each bar.

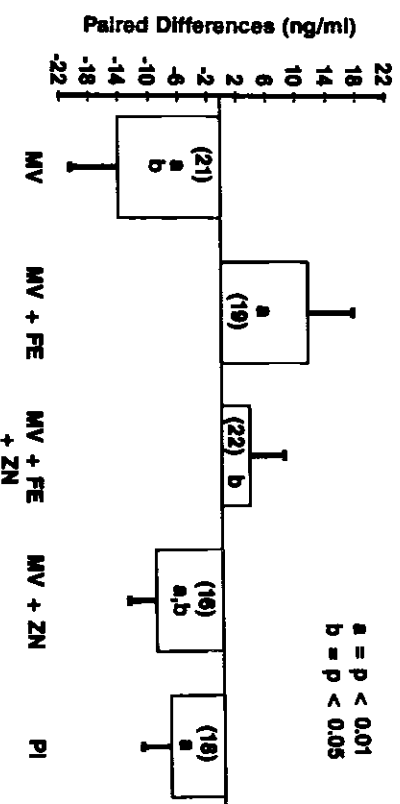


FIG. 2. Mean (SEM) paired differences in serum ferritin concentrations after 6 months of multivitamin or placebo supplementation. Number of subjects for whom paired samples were obtained is indicated in parentheses within each bar.

NUTRIENT AND ENERGY INTAKES OF CHILDREN IN THE DENVER STUDY

In general, nutrient and energy intakes were adequate (Table 4), and intakes of vitamin A, thiamine, riboflavin, and niacin (not included in Table 4) were all at or above the Recommended Dietary Allowances (12). Because of its potentiating effect on iron absorption, the daily intake of ascorbic acid was particularly critical. With regard to distribution of energy, protein intake averaged 15.3%, fat 34.3%, and carbohydrate 50.4% of total caloric intake. Iron was the most limiting nutrient, with a mean daily intake of 7.6 mg, which is 51% of the recommendation for this age group. The dietary intakes of magnesium (59% of RDA) and calcium (85% of RDA) were also inadequate. Of concern also were excessive intakes of potassium and sodium.

Analysis of iron intake by food group is shown in Fig. 3. The cereal group was the largest contributor (40.4%), presumably because of fortification of breakfast cereals; the meat group (20.6%) and fruits (12.0%) also provided fair amounts of iron. According to the formulation of Monsen and colleagues (13), an easily absorbable iron level is 0.5 mg daily. Whenever cereals and dairy products contribute 50% or more of total energy intake, they become potential inhibitors of iron absorption. Thus, it is not surprising that iron depletion is a frequent finding in infancy.

OTHER STUDIES OF IRON NUTRITURE IN CHILDREN 18 TO 36 MONTHS OF AGE

A number of reports on iron nutriture among children 18 to 36 months of age have been carried out in the last 15 years (Table 5). Brault-Dubuc and colleagues in 1983 (14) presented an extensive report on iron intake in

TABLE 4. Dietary intakes of 90 children from low-income Denver families (mean: \pm SD)

Nutrient	Intake	Range	% RDA
Energy (kcal)	1142 \pm 327	483-2239	95
Protein (g)	45 \pm 14	16-91	193
Fat (g)	45 \pm 15	12-87	—
Carbohydrate (g)	146 \pm 50	42-323	—
Iron (mg)	7.6 \pm 2.6	3-16	51
Vitamin C (mg)	52 \pm 42	2-136	117
Calcium (mg)	680 \pm 379	145-2137	85
Magnesium (mg)	89 \pm 42	7-206	59
Phosphorus (mg)	822 \pm 420	261-2126	103
Sodium (mg)	1344 \pm 507	523-2681	207
Potassium (mg)	1583 \pm 542	427-3064	288

RDA, Recommended Dietary Allowance.

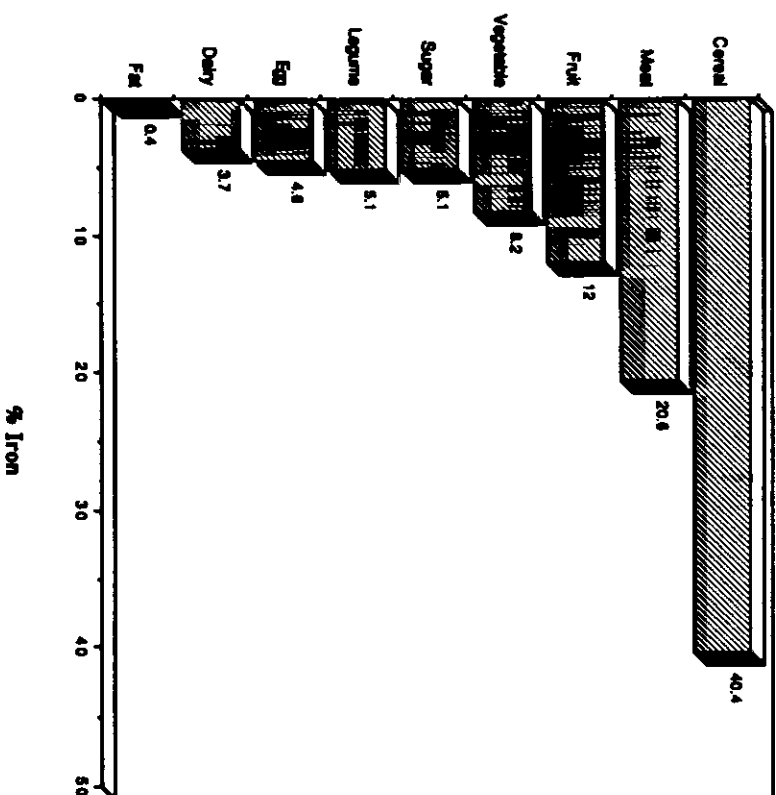


FIG. 3. Mean contribution of various food groups to the daily dietary iron intake of 90 toddlers from low-income Denver families.

TABLE 5. Dietary iron intake of children 18-36 months of age in seven worldwide studies

City/country (ref.)	Mean intake (mg)			Income/area	Age (months)	Year of study
	All	Boys	Girls			
Denver (U.S.) ^a	7.6			Low/urban	18-24	Ongoing
Solis (Mex) (16)	11.2			Low/rural	18-30	1980
Great Britain (19)		7.0	6.5	Mixed/mixed	24	1981
Manitoba (15)	7.9			Low/rural	35	1981
Montreal (14)		7.9	7.5	Medium/urban	24	1983
Finland (17)		10.0	9.0	Medium/mixed	36	1985
Sweden (18)		11.2	10.9	Medium/mixed	24	1986

^aPresent report.

Montreal infants from 3 to 36 months of age. In this longitudinal follow-up study of French Canadian middle-income families, the data collected between 1975 and 1979 included dietary intakes and laboratory assays of iron nutrition at quarterly intervals for children up to 24 months and again at 36 months of age. At 24 months, the median iron intake of the boys was 7.7 mg, ranging from 5.2 to 12.5 mg, or the 10th and 90th percentiles, respectively. Iron intakes of the female toddlers were slightly lower. Serum ferritin concentrations below 10 ng/ml, indicative of very poor reserves, were found in 7.8%, and low ferritin levels (10–20 ng/ml) occurred in 51.2% of the 166 2-year-old infants. At 24 months, the total incidence of hypoferritinemia was 59%, which decreased to 28.1% by 3 years of age.

In another Canadian study, toddlers from two isolated Indian villages in Manitoba were surveyed during the Winter, Spring, and Fall of 1974 (15). At a mean age of 35 months, more than one-half of the children were consuming less than the 7 to 9 mg of iron recommended by the Canadian Dietary Standards (15). Mean intakes in Winter and Spring approximated 8 mg/day and were lower than the mean intake in the fall, which reached 11 mg. In these villages, 33% to 42% of the ingested iron came from meat and alternative products, including fish, eggs, and legumes.

In a recent project, Allen and colleagues (L. H. Allen, personal communication) studied iron intake in toddlers (18–36 months) in the town of Solis, Mexico. The mean iron intake averaged 12.2 mg/day with a range from 6.7 to 20 mg, although only 0.2 mg was from animal sources. Heme iron ranged from 0.02 to 1.08 mg, compared to a mean intake of 1.85 of heme iron in NHANES II. Allen's observations are based on measurements performed 2 days/month over a 12-month period. Blood samples were collected in 39 children, and iron deficiency was present in one-third (16).

Two large nutritional surveys have recently been published from Scandinavia, where dietary records were generally collected between 1980 and 1981. Rasanen and colleagues (17) reported the results of the Finnish surveys compiled in 5 university cities and 12 surrounding rural communities. The mean iron intake for a group of 281 3-year-old children was 10 mg for the boys and 9 mg for the girls (SD of 4 mg). The relative contributions of meat products and cereals to the daily iron intake were 22% and 53%, respectively.

From Sweden, Hagman and colleagues (18) published the results of their childhood nutrient survey. Data were collected in Uppsala and Umea, two university and administrative centers and two rural areas. The mean intake of 2-year-old toddlers was 11.2 mg, with a range of 7.0 to 18 mg. Twenty-two percent of the Swedish toddlers were receiving less than 60% of the RDA. The contributions of meat products and cereals to the iron intake of the Swedish infants were 29% and 30%, respectively.

As Table 5 shows, the Denver toddlers were in the low ranges for dietary iron. The levels were similar to those documented in Great Britain, where

mean iron intakes of 6.5–7 mg were found in a survey of 2-year-olds during the previous decade (19). Erhardt, however, recently documented iron deficiency anemia in 7% of white children and 21% of Asian children in Bradford (20); he suggested the need for a community-based preventive program. The Montreal study found a progressive increase in serum ferritin levels between 24 and 36 months in middle-class children. No such trend was present in the Denver study, since at completion of the 6-month observation period, 30% of the children still had ferritin levels less than 20 ng/ml.

Furthermore, in 56 subjects who received a multivitamin product containing iron and for whom we have initial and final hemoglobin levels, 10 increased their hemoglobin concentrations by more than 1 g/dl. Whether this relates to the supplemental iron, to lessened infection, or both remains to be determined, but it does appear that iron nutrition remains less than satisfactory in this low-income group.

In high-risk populations, a second screening of iron status should be performed in the toddler years, with the inclusion of zinc protoporphyrin levels to detect early iron deficiency. Another alternative would be to offer a 6-month period of low-dose iron supplementation if this can be done safely. The formulation used in the Denver study contained 1,200 mg of iron/bottle, which could be a dangerous dose if all of the tablets were consumed at once. Lesser risk would incur if chewable products containing iron supplements for children were provided in bottles holding only 30 or 50 tablets. In toddlers from disadvantaged families, improvements of iron nutrition should remain an objective of the medical and nutritional communities.

ACKNOWLEDGMENTS

This project was generously supported by a grant from the Mead Johnson Nutritionals. The encouragement and support of Dr. Angel Cordano and Dr. Duvi Carrera were much appreciated. The dietary data were analyzed by Ruth Aguilar, Alicia Garcia, and Molly Mort, nutrition students from Cornell University under the supervision of Dr. Diva Sanjur. Finally, this project could not have been completed without the help of the clerical, nursing, and clinical staff of the pediatric section at the Westside Health Center in Denver.

REFERENCES

1. Stines, M. A., Salmempena, L., and Perhentupa, J. (1984): Exclusive breast-feeding for nine months: risk of iron deficiency. *J. Pediatr.*, 104:196–199.
2. Sadovitz, P. D., and Oski, F. A. (1983): Iron status and infant feeding practices in an urban ambulatory center. *Pediatrics*, 72:33–36.
3. American Academy of Pediatrics Committee on Nutrition (1983): The use of whole cow's milk in infancy. *Pediatrics*, 72:253–255.

4. Tunnessen, W. W., and Oski, F. A. (1987): Consequences of starting whole cow milk at six months of age. *J. Pediatr.*, 111:813-816.
5. Nelson, S. E., Ziegler, E. E., Copeland, A. M., Edwards, B. B., and Fomon, S. J. (1988): Lack of adverse reactions to iron-fortified formula. *Pediatrics*, 81:360-364.
6. Herranpfi, E., Cayazzo, M., Pizarro, F., and Steckel, A. (1986): Bioavailability of iron in soy-based formula and its effect on iron nutrition in infancy. *Pediatrics*, 78:640-645.
7. Rees, J. M., Morsen, E. R., and Merrill, J. E. (1985): Iron fortification of infant foods. A decade of change. *Clin. Pediatr.*, 24:707-710.
8. Vazquez-Seoane, P., Windom, R., and Pearson, H. A. (1985): Disappearance of iron-deficiency anemia in a high-risk infant population given supplemental iron. *N. Engl. J. Med.*, 213:1239-1240.
9. Miller, V., Swaney, S., and Delnard, A. (1985): Impact of the WIC program on the iron status of infants. *Pediatrics*, 75:100-105.
10. Dallman, P. R. (1986): Iron deficiency in the weanling: a nutritional problem on the way to resolu-tion. *Acta Pediatr. Scand.*, 323 (suppl):50-67.
11. Dallman, P. R. (1988): Nutritional anemia of infancy: iron, folic acid, and vitamin B12. In: *Nutrition During Infancy*, edited by R. C. Tsang and B. F. Nichols. Hanley & Belfus, Philadelphia, p. 225.
12. Food and Nutrition Board, National Research Council (1980): *Recommended Dietary Allowances*. National Academy of Sciences, Washington, D.C.
13. Morsen, E. R., Hallberg, L., Lavyisse, M., Hegsted, D. M., Cook, J. D., and Mertz, W. (1978): Estimation of available dietary iron. *Am. J. Clin. Nutr.*, 31:134-141.
14. Brault-Dubuc, M., Nadeau, M., and Dickie, J. (1983): Iron status of French-Canadian children: a three-year follow-up. *Hum. Nutr. Appl. Nutr.*, 37A:210-221.
15. Ellestad-Sayet, J. J., Haworth, J. C., Coodin, F. J., and Dilling, L. A. (1981): Growth and nutrition of preschool Indian children in Manitoba: II. Nutrient intakes. *Can. J. Publ. Health*, 72:127-133.
16. Black, A. K., Allen, L. H., Mata, M., and Pello, G. H. (1988): Dietary correlates of hematological status in Mexican preschoolers. *FASEB J.* 2:A1204.
17. Rasanen, L., Ahola, M., Kara, R., and Uhart, M. (1985): Atherosclerosis precursors in Finnish children and adolescents. VIII. Food consumption and nutrient intakes. *Acta Paediatr. Scand.*, 318(suppl):135-153.
18. Hagman, U., Bruce, A., Persson, L. A., Samuelson, G., and Sjolin, S. (1986): Food habits and nutrient intake in childhood in relation to health and socioeconomic conditions. A Swedish multicen-tre study 1980-81. *Acta Paediatr. Scand.*, 328(suppl):4-56.
19. Darke, S., Dissectduff, M., and Try, G. (1980): Frequency distributions of mean daily intakes of food energy and selected nutrients obtained during nutrition surveys of different groups of people in Great Britain between 1968 and 1971. *Br. J. Nutr.*, 44:243-252.
20. Ehrhardt, P. (1986): Iron deficiency in young Bradford children from different ethnic groups. *Br. Med. J.*, 292:90-93.