Predictors of iron status in well-nourished 4-y-old children¹–³

Inger Öhlund, Torbjörn Lind, Agneta Hörnell, and Olle Hernell

ABSTRACT

Background: Iron status in childhood is influenced by diet. Other factors affecting iron status at that age are unclear.

Objectives: The objectives of the study were to evaluate iron status in 4-y-old children, to track that status from infancy to childhood, and to examine the associations of iron status with dietary factors, growth, and heredity.

Design: This study consisted of a longitudinal follow-up at age 4 y of children (n = 127) from the cohort of a study that began at age 6 mo. Blood samples and anthropometry were assessed in both children and their parents; food records were collected from children only.

Results: Dietary intake was not significantly correlated with hemoglobin concentrations, whereas the consumption of meat products had a positive effect on serum ferritin concentrations and mean corpuscular volume in boys (P = 0.015 and 0.04, respectively). The prevalences of anemia and iron deficiency were low, affecting 2 (1.8%) and 3 (2.8%) children, respectively; no child had iron deficiency anemia. There was significant within-subject tracking of hemoglobin and mean corpuscular volume from age 6 mo to 4 y. The mother’s but not the father’s hemoglobin correlated with the child’s hemoglobin over time.

Conclusions: Food choices had little effect on iron status. Hemoglobin concentrations and mean corpuscular volume were tracked from infancy to childhood. In healthy, well-nourished children with a low prevalence of iron deficiency, the mother’s hemoglobin was significantly associated with that of her child, but the underlying mechanism is unclear.  Am J Clin Nutr 2008;87:839–45.

INTRODUCTION

A person’s iron status is greatly influenced by diet. The bioavailability of iron in the diet is influenced by the type of iron, as well as by inhibitors and promoters of iron absorption. For example, calcium and phytate decrease absorption, whereas meat enhances absorption (1). Cow milk is low in iron but rich in calcium, which results in low bioavailability of the iron. Many studies have shown a negative association between cow milk intake and iron status during childhood (2, 3). Therefore, many nations and the World Health Organization recommend that cow milk should not be consumed until age 1 y, and milk intake after 1 y should be limited to ≈500 mL/d (1, 4–6).

Whether calcium is an inhibitor of iron uptake is debated. The association between high calcium intake and low iron absorption has been shown in single-meal experiments and short-term studies, but it has not been confirmed in long-term studies (7–10). Another inhibitor of absorption, phytate, is found in cereals and other weaning foods such as milk-based cereal drinks (MCDs) and porridge. A previous randomized intervention study by our group (11) investigated the effect of the phytate content in complementary food on iron status during infancy. That intervention was conducted while the infants were between 6 and 12 mo of age; it showed that a reduction of the phytate content of weaning cereals had little long-term effect on iron status, probably because the inhibitory effect was compensated for by high ascorbic acid content in the commercial products.

For infants, sex-related differences in iron status are thought to result from both biological differences and differences in iron intake (12, 13). In infants and preschool-age children, growth rates seem positively correlated to iron status (14, 15). In contrast, iron supplementation to iron-replete infants may have a negative effect on growth (16–19). Furthermore, an association between a mother’s iron status and that of her child has been described in areas with poor nutritional status where iron deficiency (ID) is prevalent (20, 21).

The aims of the present study were to evaluate hemoglobin and iron status in 4-y-old children, to evaluate the association of those factors with dietary factors, body growth, and heredity and to examine possible tracking of iron status variables from infancy to childhood. At the age of 4 y, children are in a relatively stable phase of life with respect to growth and eating pattern, and, in Sweden, all 4-y-old children undergo a routine check-up in well-baby clinics.

SUBJECTS AND METHODS

Study cohort

The baseline double-blind intervention study of children from 6–12 mo of age investigated the effect of the phytate content in complementary food on iron status during infancy, but little long-term effect on iron status was found (11). Three hundred healthy, term infants were recruited from well-baby clinics in

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Umeå, Sweden, from December 1995 to June 1998. Of these 300 children, 234 (80%) completed monthly dietary and anthropometrical registrations from age 6 mo to age 18 mo. Starting in 2001, these children were invited to participate in this longitudinal follow-up study at 4 y of age.

Written informed consent was obtained from the parents of all of the children. The study was approved by the local Ethics Committee of the faculty of medicine, Umeå University, Sweden.

Dietary assessment

We assessed dietary intake in the children by using 5-d food records. Household measures were used for quantities, but the parents (and day-care center staff when applicable) also used photographs from a booklet that had been used to estimate quantities in the baseline study (11). The parents were instructed by a trained dietitian (IO) in filling out the food record. When the child started at a day-care center, the dietitian went there to inform the staff. The food records were checked by the same dietitian. Energy and nutrient intakes were calculated with the use of MAT software (version S-406; Rudans Lättdata, Västerås, Sweden). This program uses a food composition database (version 2.00) from the Swedish National Food Administration, which was complemented in the present study with special products for children and products not included in the original database. Calcium was analyzed in terms of total intake and as intake from dairy products. Macronutrients were described as percentages of energy intake (EI). The nutrient intake data are reported on the basis of foods, and supplements were analyzed as a separate variable. To evaluate the accuracy of the reported EIs, we calculated the ratios of EIs to basal metabolic rate [(BMR) EI:BMR] (22) in girls and boys.

Anthropometric measures and biochemical analyses

Venous blood samples were collected from the children at 6, 12, and 18 mo of age in the baseline study and in the follow-up from the children at age 4 y and from their parents. Hematologic indexes and serum ferritin (S-Ft) were analyzed at the Department of Clinical Chemistry, Umeå University Hospital, by using a Sysmex SE 9000 Autoanalyzer (Tillqvist, Kista, Sweden). The hemoglobin concentration was analyzed by using a Sysmex Sulfolyzer automated hemoglobin reagent (Toa Medical Electronics Co, Los Alamitos, CA), and mean corpuscular volume (MCV) was automatically calculated from the erythrocyte particle concentration. S-Ft was analyzed by using an immunoturbidometric technique (BM/Hitachi 704/717/911; Boehringer Mannheim, Mannheim, Germany) calibrated against World Health Organization standard 80–602. We analyzed hemoglobin, MCV, and S-Ft in the children and hemoglobin and MCV in the parents.

In the 4-y-old children, height to the nearest millimeter was measured by using a portable stadiometer (CMS Weighing Equipment LTD, London, United Kingdom). Weight was measured to the nearest 100 g in both children and parents by using a digital adult scale (model 835; Seca, Hamburg, Germany). From the baseline study, we extracted data on infant length and weight at age 12 mo. Growth was expressed as absolute length gain (cm) and weight gain (kg) between age 12 mo and age 4 y as well as the percentage increment in body length and weight from age 12 mo to age 4 y.

Statistical analysis

Statistical analyses were performed with SPSS software (version 15.0; SPSS Inc, Chicago, IL). Means ± SD and ranges were used to describe anthropometrics, iron status indexes, and nutrient and food intakes. Because the distribution of S-Ft was skewed, it was log transformed in all calculations. Sex difference was analyzed by t test. Pearson’s correlations were used for the associations between child iron status indexes at different ages and parental iron status. Linear regression was used to analyze associations between variables with possible relevance to iron status: growth, parents’ hemoglobin values, and the intakes of dietary iron, meat products, ascorbic acid, calcium, milk, milk-based fortified cereals (MFCs), MCDs, and porridge. Factors associated with a univariate P < 0.05 were then included in multivariate analyses, and collinearity diagnostics were used.

RESULTS

Subjects

A total of 127 children (63 girls and 64 boys) and their parents participated in this follow-up. Of the children, 86 (47 girls and 39 boys) had complete data sets, 122 had data on weight and height (61 girls and 61 boys), 106 had data on biochemical analyses (57 girls and 49 boys), and 99 (52 girls and 47 boys) had data on dietary intake. From the 127 pairs of parents, biochemical data were obtained from 119 mothers and 114 fathers. Weight and height data were obtained from 122 mothers and 118 fathers. Of the nonparticipating children, 12 were sick at follow-up, and 16 had moved from the area; for the remainder, the parents declined to participate, without explanation. A comparison of 12-mo data on iron intake and iron status showed no differences between the nonparticipating and the participating children.

At 4 y of age, children with incomplete data sets did not differ from those with complete data sets with respect to measures of dietary intake at age 12 mo and hemoglobin, S-Ft, body weight, and body mass index (in kg/m²) at age 4 y. Nearly all of the children were living with both parents, a minority of whom were smokers (Table 1).

Iron status

Iron status improved from age 6 mo to age 4 y (Table 2). According to the standards used in this study, at 4 y old, 2 children (1.8%) had anemia (hemoglobin < 110 g/L) and 3 (2.8%) had iron deficiency (S-Ft < 12 µg/L), but no child had iron deficiency anemia (IDA; hemoglobin < 110 g/L and either S-Ft < 12 µg/L or MCV < 72 fl). No significant differences were found in hemoglobin or S-Ft between boys and girls, but MCV was significantly higher in girls (Table 2).

Both hemoglobin and MCV were significantly associated with previous hemoglobin concentrations and MCVs; that is, they were tracked from age 6 mo to ages 12 mo, 18 mo, and 4 y. S-Ft also was tracked during infancy but not to age 4 y (data for infancy not shown). The children’s hemoglobin concentrations at ages 12 mo, 18 mo, and 4 y were significantly associated with the mothers’ hemoglobin measured when the children were 4 y old (Table 3). No associations were found between the father’s and child’s hemoglobin values or between the child’s S-Ft and the parents’ hemoglobin (data not shown).
Hemoglobin (g/L) 114.9

Main source of calcium in both groups was dairy products. The source of dietary iron (meat products were the main source. Meat had a significantly higher intake of calcium than did the latter compared with 6.3 iron intake than did the group not consuming MFCs (8.9 group consuming MFCs had a significantly higher mean daily intake of 232 compared with 666 mL. The intake of milk was negatively associated with the intake of MFCs (r = −0.23, P = 0.020), but it was not associated with iron intake (r = −0.09, P = 0.37) or the intake of other foods (data not shown).

Associations between dietary intake and iron status

There were no associations between hemoglobin and mean daily intake of iron, meat, MFCs, ascorbic acid, calcium, or dairy products in the children. In boys, but not in girls, S-Ft concentrations had a small but significant positive association with meat intake (Table 5). Nor did we find a significant association between cow milk intake and S-Ft concentrations (r = −0.07, P = 0.5).

Growth

Girls grew faster than boys between ages 12 mo and 4 y. The relative increment in linear growth from age 12 mo to age 4 y was 39% in girls and 36% in boys (P < 0.001). The relative linear growth was positively associated with hemoglobin at 4 y (r = 0.23, P = 0.016), but, for S-Ft, an association with linear growth was seen only in boys (r = 0.33, P = 0.02). Weight gain and body mass index were not significantly associated with any measure of iron status (data not shown).

TABLE 2

Indicators of iron status in children and their parents

<table>
<thead>
<tr>
<th></th>
<th>6 mo old</th>
<th>12 mo old</th>
<th>18 mo old</th>
<th>4 y old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Girls</td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
</tr>
<tr>
<td></td>
<td>(n = 57)</td>
<td>(n = 48)</td>
<td>(n = 57)</td>
<td>(n = 48)</td>
</tr>
<tr>
<td>Hemoglobin (g/L)</td>
<td>114.9 ± 8</td>
<td>115 ± 7.9</td>
<td>118.3 ± 9.2</td>
<td>119.5 ± 9.1</td>
</tr>
<tr>
<td>Serum ferritin (µg/L)</td>
<td>55.6²</td>
<td>35.04²</td>
<td>25.8</td>
<td>22.4</td>
</tr>
<tr>
<td>MCV (fL)</td>
<td>76.5 ± 2.9</td>
<td>75.3 ± 2.2</td>
<td>76.5 ± 3.3</td>
<td>75.7 ± 2.6</td>
</tr>
<tr>
<td>Anemia (%)</td>
<td>18</td>
<td>14</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Iron-deficient (%)</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

¹ NA, not available; MCV, mean corpuscular volume. All values are ± SD.
² Sex differences were analyzed by t test (P < 0.05).
³ Geometric ± SD.
⁴ Hemoglobin <110 g/L in children, <120 g/L in mothers, and <130 g/L in fathers.
⁵ Serum ferritin <12 µg/L.
that the variables were highly correlated, and therefore, in the present study in northern Sweden, only 1.8% of the participating children had hemoglobin values < 110 g/L, and no one had IDA (hemoglobin < 110 g/L and either S-Ft < 12 μg/L or MCV < 72 fL).

**DISCUSSION**

The main findings of this study were the tracking of hemoglobin values in children (at ages 6, 12, and 18 mo and 4 y) and the correlations between the mother’s hemoglobin, recorded when the child was 4 y old, and the child’s hemoglobin. The strength of the present study is that it is based on prospective longitudinal data for both biochemical variables and dietary intake of the children (11, 24).

Tracking of iron status from infancy to childhood has been reported in other studies but from areas with a higher prevalence of ID (15, 20). In a study aimed at identifying risk factors for ID in Chile, lower hemoglobin at age 6 mo was the strongest predictor for ID at age 12 mo (25).

In the present study group, made up of well-nourished children and their parents, we found an association between the child’s and the mother’s hemoglobin values. Children’s hemoglobin values at ages 12 mo, 18 mo, and 4 y were significantly correlated with their mother’s but not their father’s hemoglobin values. Such an association has been reported from South Africa in an area with a high prevalence of childhood malnutrition and also from Ireland in mothers with poor nutritional status (20, 21). The hemoglobin value in 5-y-old Finnish children was found to be associated with the hemoglobin values of both parents (26). In that study, parents and children were given oral iron drops and were rendered iron-replete at examination. The reasons behind these associations in the present study are unclear, because neither dietary data from the parents nor specific tests were available to make it possible to explain the underlying mechanism.

The prevalence of IDA in infants and preschool-age children varies in well-nourished populations (3, 20, 27–30). In the present study in northern Sweden, only 1.8% of the participating children had hemoglobin values < 110 g/L, and no one had IDA (hemoglobin < 110 g/L and either S-Ft < 12 μg/L or MCV < 72 fL).

**Multivariate analyses**

Factors that were significantly (P < 0.05) associated with iron status indexes (ie, hemoglobin, S-Ft, and MCV) at age 4 y in the univariate analysis were entered into a multivariate regression model (Table 5). Hemoglobin in infancy and early childhood was the strongest predictor of hemoglobin at 4 y, although both the mother’s hemoglobin and the child’s relative length gain contributed significantly (Tables 3 and 5). There was a high degree of collinearity between hemoglobin values in infancy and the mother’s hemoglobin (data not shown). When several hemoglobin values from infancy were entered into the model, we found that the variables were highly correlated, and therefore, in the final model, only the hemoglobin value at age 18 mo was included. Intake of meat products and relative length gain remained significant contributors to S-Ft only in boys. Similarly, MCV was associated with the intake of meat products only in boys.

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**TABLE 3**

Tracking of iron status indexes from age 6, 12, and 18 mo until age 4 y in children and the association between the mother’s and the child’s hemoglobin values.

<table>
<thead>
<tr>
<th>Tracking</th>
<th>r²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin (n = 105)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 mo–4 y</td>
<td>0.37</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>12 mo–4 y</td>
<td>0.48</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>18 mo–4 y</td>
<td>0.44</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Serum ferritin (n = 105)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 mo–4 y</td>
<td>-0.06</td>
<td>0.52</td>
</tr>
<tr>
<td>12 mo–4 y</td>
<td>-0.04</td>
<td>0.7</td>
</tr>
<tr>
<td>18 mo–4 y</td>
<td>0.07</td>
<td>0.47</td>
</tr>
<tr>
<td>MCV (n = 104)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 mo–4 y</td>
<td>0.63</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>12 mo–4 y</td>
<td>0.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>18 mo–4 y</td>
<td>0.71</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Correlation between the mother’s and the child’s hemoglobin:

| 12 mo (n = 119) | 0.26 | <0.001 |
| 18 mo (n = 118) | 0.2 | 0.03 |
| 4 y (n = 119) | 0.31 | <0.001 |

1 MCV, mean corpuscular volume.
2 Pearson correlation coefficient; there were no significant differences in the r values across the age groups.
3 The mother’s hemoglobin concentration was measured when the child was 4 y old.

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**TABLE 4**

Reported daily dietary intakes of energy and nutrients in 4-y-olds.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Reported intake/d</th>
<th>Recommended intake</th>
<th>EAR</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake in girls (MJ)</td>
<td>5.7 ± 0.96 (3.7–8)</td>
<td>5.3</td>
<td>5.7 ± 0.7</td>
<td>52</td>
</tr>
<tr>
<td>Energy intake in boys (MJ)</td>
<td>6.1 ± 1.01 (4.4–8.6)</td>
<td>5.7</td>
<td>5.8 ± 0.8</td>
<td>47</td>
</tr>
<tr>
<td>Carbohydrate (% of energy)</td>
<td>52.2 ± 4.4 (40.4–60.5)</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (% of energy)</td>
<td>13.3 ± 1.7 (10.3–19.5)</td>
<td>15 (10–20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (% of energy)</td>
<td>33.3 ± 4 (26.2–44.1)</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>8.2 ± 3.5 (2.8–22.5)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>6.8 ± 2.9 (3.5–31.8)</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascorbic acid (mg)</td>
<td>73 ± 39 (16–180)</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>842 ± 263 (244–1713)</td>
<td>600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium from dairy products (mg)</td>
<td>479 ± 238 (7–1268)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 EAR, estimated average daily energy requirements; MJ = megajoule; NA, not available. Sex differences were analyzed by t-test. There were no significant sex differences.
2 According to the Nordic Nutrition Recommendations (22).
3 Girls, 320 kJ/kg; boys, 330 kJ/kg (22).
4 ± SD; range in parentheses (all such values).
Differences in the reported prevalence of IDA between populations may be related to differences in the definition of IDA in different age groups (27, 31) as well as to differences in choices of weaning products and dietary habits. In Sweden, children consume iron-fortified complementary foods such as MCDs and porridge during infancy and childhood, whereas, in other settings, cow milk and iron-nonfortified products are more commonly consumed during the second half of infancy. Another factor that may lead to the lower prevalence of IDA in Sweden is the quality of meals in day-care centers. In Sweden, many 4-y-olds eat most of their meals at day-care centers, where guidelines stipulate the quality and composition of the foods (32).

The reported EI for the children in the present study was in accord with the Nordic Nutrition Recommendations 2004 (22). The method used for measuring dietary intakes has been validated for adolescents (33) but not for infants or small children. To evaluate the accuracy of the reported EIs in the present study, we calculated EI:BMR (22) in girls and boys separately. We found a mean value of 1.61 in both girls and boys, which is close to measured EI:BMR values for the age group (34, 35). Thus, the validity of the data in the present study is deemed good. Our food intake data (not shown) are similar to those in other studies (36–38). One reason for the high mean EI:BMR may be that the parents in the present study were well trained in completing food diaries through their participation in the baseline study, which included monthly food records. In the baseline and follow-up studies, the food records were checked by the research dietitian; any questions or missing data were discussed with the parents, and the record was corrected as needed. Nearly all of the children in the present study were living with both parents, which also may have increased the reliability of the data.

In Sweden, it is common practice to give children MFCs (37), and, in the present study, those products were important sources of iron and calcium, contributing $\frac{1}{5}0.51$ and $\frac{1}{5}0.51$ of mean iron and mean calcium intake, respectively. Not surprisingly, children with a higher intake of fortified cereals had significantly higher intakes of iron and calcium than did the other children. However, we were surprised to find that fortified cereals were the main source of iron in such a large proportion of the children in the age group studied here. Although MFCs were responsible for a large part of the iron intake and contributed to a higher total iron intake, iron status did not differ between children who consumed MFCs and those who did not. We found, both in this follow-up and at lower ages, that MCD consumption did not compromise iron status. Therefore, we suggest that iron-fortified milk cereals should be further studied in populations with a low intake of meat products.

Even if dietary intake was positively associated with hemoglobin during infancy (24), the associations between iron status and food or nutrient intake were weak or nonexistent at ages 18 mo and 4 y. Other studies (28, 39, 40) have reported negative associations between intake of cow milk and iron status, but we found no such relation between the intake of dairy products or calcium and iron status. A high intake of cow milk is thought to reduce the intake of other foods, thereby reducing iron intake. The absence of such a relation in the present study may be due to the children’s high iron intake and relatively low milk intake (<500 mL/d in more than half of the children). Similar results were reported from a study of infants in Chile. The median intake

![FIGURE 1. Pie charts showing the proportional sources of dietary iron in the subjects consuming (left) and those not consuming (right) milk-based fortified cereals.](https://academic.oup.com/ajcn/article-abstract/87/4/839/4633332)

**TABLE 5**

Multiple linear regression analyses of factors associated with iron status at 4 y of age.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variable</th>
<th>$R^2$</th>
<th>$R$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin</td>
<td>All children</td>
<td>0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>At 18 mo old</td>
<td>0.37</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In the mothers</td>
<td>0.17</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Relative length gain (%)</td>
<td>0.4</td>
<td>0.041</td>
<td></td>
</tr>
<tr>
<td>Serum ferritin</td>
<td>Boys</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meat products</td>
<td>0.19</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>MCV</td>
<td>Boys</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meat products</td>
<td>0.02</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

1 MCV, mean corpuscular volume. In the analysis, serum ferritin was log transformed.
2 Independent variables were entered into the regression model for hemoglobin: the mother’s hemoglobin, the child’s hemoglobin at age 18 mo, and relative length gain from age 12 mo to 4 y, adjusted for sex.
3 Concentrations were recorded when the child was 4 y old.
4 Independent variables for serum ferritin: relative length gain and meat products.
5 Independent variables for MCV: meat products.
of cow milk was 432 mL/d at age 12 mo, and 25% of the participants consumed > 500 mL/d, but that intake did not relate to iron status when other factors were considered (25). In 6-y-old Icelandic children, calcium intake was not significantly associated with iron status, although, at earlier ages, the intake of cow milk was negatively associated with all indexes of iron status (ie, hemoglobin, S-Ft, and MCV) (2, 40).

In the present study, meat products were an important source of iron. Although intake did not differ as much as it did for MFCs, there was a small but significant association between the intake of meat products and S-Ft concentrations and MCV in boys. This finding is similar to that in the Icelandic study, although the mean daily intake of iron was higher in the Icelandic children than in the children in the present study (10.2 ± 4.1 compared with 8.2 ± 3.5 mg) (15). It is interesting that we found a positive association between iron status and growth, even in these well-nourished children.

In conclusion, we found the strongest predictors of hemoglobin at 4 y of age to be the mother’s hemoglobin value and the child’s hemoglobin value earlier in life. This suggests that familial factors are important in determining the hemoglobin values in healthy well-nourished children. However, the lack of associations between dietary intake and the child’s hemoglobin implicates other shared exposures, but the underlying mechanism is unclear.

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The authors’ responsibilities were as follows—IO: wrote the draft of the manuscript and participated in the planning of the study and collection and analysis of the food data; OH and TL: contributed to study planning, data analysis, and manuscript writing; and AH: contributed to data analysis and manuscript. None of the authors had a personal or financial conflict of interest.

REFERENCES


