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Chapter 32

Iron nutritional status during early childhood - the importance of weaning foods to combat iron deficiency

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Summary

Socioeconomic factors, low iron intake with food, delayed introduction of solids, and the early introduction of cow's milk are the main factors contributing to high prevalence of iron deficiency in most industrialized and developing countries. In most European countries, public health measures and food-fortification programmes still need to be improved. Metabolic and clinical studies have shown that iron fortified cereals and baby foods can be alternatives to iron fortified formulas to combat iron deficiency during late infancy.

Epidemiology of iron deficiency and anaemia

Epidemiological data

Data on prevalence of iron deficiency and anaemia related to iron deficiency have been summarized by WHO in 1985⁴ (Table 1). Such data are important since even mild or moderate iron deficiency anaemia in the second 6 months of life and beyond infancy can be associated with delayed mental and motor development and the outcome after appropriate iron treatment is inconsistent^{13,14,19}. It may be that relatively brief periods of iron deficiency during a vulnerable 'age window of risk' can result in long-lasting consequences for behavioural and mental developmental status even in a school population. If this is true, a public health shift from early detection and treatment to primary prevention of iron deficiency anaemia is appropriate for most countries in the world.

Table 1 Prevalence of iron deficiency (0-5) years

Region	No studies	Prevalence	Mean (range)
Africa	45	59	(15-93)
Latin America	35	34	(12-69)
East Asia	5	46	(15-80)
South Asia	43	51	(2-92)
Europe			
Northern	3	5	(0-11)
Western	2	6	(3-9)
Southern	1	34	
Eastern	-	34 (?)	

Source: WHO⁴

Surveys of anaemia world-wide for children between and 5 years of age indicate that⁴ (Table 1) estimated prevalences in less developed countries are generally high. Since the agespan is rather wide, it is impossible to obtain specific information published on infants.

Few studies from European countries are included in the WHO report, but it seems rather evident that the estimated prevalences were lower in the 1970s and 1980s in Europe than in less developed countries. Recent data on the prevalence of iron deficiency and anaemia were collected between 1992 and 1994 as part of the Euro-Growth study. During this longitudinal study to evaluate the interactions between nutrition, health and growth, blood samples of 520 healthy infants from 11 European cities were collected at 12 months of age. Nine point eight per cent had haemoglobin values below 11 g/dl and 23.7 per cent had ferritin values below 12 ng/ml. Six per cent of the infants were anaemic and had signs of iron deficiency (low ferritin and/or low MCV). This indicates that public health measures and food-fortification programmes still need to be improved in most European countries.

Recent data from Canada and the USA are also available. Fullterm infants born between 1990 and 1992 were studied by Zlotkin *et al.*²². Their age at the time of blood sampling was between 8.5 and 15.5 months and infants with acute or chronic diseases were excluded. The laboratory results of 428 infants from four Canadian cities indicate that 8 per cent had haemoglobin levels below 11 g/dl. However, only 1.1 per cent of the infants studied had haemoglobin values below 10 g/dl. One out of three Canadian infants at that age range had depleted iron stores, if 10 ng/ml was considered as the adequate cut-off value. It is of interest that only 4.3 per cent of the infants had both low haemoglobin and ferritin values. Thus in more than 50 per cent of the infants with anaemia there was no biochemical proof of iron deficiency. During this conference Dallman *et al.* (1995) presented preliminary data from the NHANES III from the USA, where the prevalence of iron deficiency anaemia in children between 1 and 2 years of age is now as low as 3.5 per cent, substantially lower than in Canada and Europe.

Factors contributing to anaemia

Infection, genetic and socioeconomic factors, and low iron intake play important roles in the development of hypochromic anaemia during early childhood. Evidence suggests that the prevalence of iron deficiency anaemia in young British children varies greatly according to social circumstances and has been shown to approach 30 per cent in the most disadvantaged groups (Stevens 1991). Preliminary data from the NHANES III¹ indicate that iron intake in the US is higher than in Austria, a member country of the European Union (Table 2). This is probably related to the general use of iron fortified formulas and the higher iron-fortification level of infant formulas in the USA. Indeed, it seems that the prevalence of iron deficiency during late infancy is lower in the USA than in Europe.

Does prolonged exclusive breast-feeding contribute to poor iron-nutritional status? It is well established that iron concentration in breast-milk declines during the course of lactation¹⁷. Studies on exclusively breast-fed infants in different countries show that iron deficiency is virtually absent at 6 months of age but may become evident in a small percentage of infants at 9–12 months of age^{10,11,16}. Another factor contributing to iron deficiency in industrialized and developing countries is the early introduction of cow's milk into the infants diet. Consumption of cow's milk as the liquid part of the infants diet results in low iron intake, can cause gastrointestinal blood loss, and negatively interacts with iron absorption because of the high protein and calcium concentrations in cow's milk^{7,21}. Both the Canadian²³ and the Euro-Growth¹⁶ studies confirm the negative influence of early introduction of cow's milk on iron nutritional status of older infants.

Table 2. Mean iron intake (g/day) between 2 and 24 months

Month	NHANES III, USA 1988–91	Austria 1988
< 11	15.5	4.8 ^a 10.3 ^b
12–24	9.5	7.4

^aNon-fortified formula ^bIron fortified formula

Iron deficiency anaemia

and socioeconomic factors, play important roles in the aetiology of chronic iron deficiency anaemia during early childhood. Evidence suggests that the prevalence of iron deficiency anaemia in young children is greatly increased according to socioeconomic status and has been shown to apply to the most disadvantaged children (Table 2). Preliminary data from Austria, a member country of the WHO (Table 2). This is probably due to the general use of iron fortified infant formula in the USA. Indeed, it seems that iron deficiency during early childhood in the USA is more prevalent than in Europe. What is the nutritional status of infants who are exclusively breast-fed during the course of lactation? Iron deficiency is virtually absent in breast-fed infants in industrialized countries up to 12 months of age but may be present in 10-15 per cent of infants in developing countries.^{11,16} Another factor contributing to iron deficiency in industrialized and developing countries is the early introduction of a solid diet. Consumption of a diet high in protein and low in iron, such as that of the infants in the Euro-Growth¹⁶ studies, can cause gastrointestinal problems and negatively interacts with the absorption of iron from cow's milk.^{7,21} Both the Euro-Growth¹⁶ studies and the influence of early introduction of a solid diet on iron nutritional status

(Table 2) between 2 and 24 months

ES III, 1988-91	Austria 1988
15.5	4.8 ^a 10.3 ^b
9.5	7.4

Iron fortified formula

Weaning foods to combat iron deficiency**Cereals**

There are several reasons for selecting iron fortified infant cereals as a vehicle to combat iron deficiency. Cereal products are relatively inexpensive and have a long shelf life. Moreover, they are distributed through infant feeding programmes in industrialized and developing countries. Although they have been on the market since the 1950s, their effectiveness in preventing iron deficiency is still under discussion. A major disadvantage of infant cereal as the main source of iron is that the amount consumed varies substantially from infant to infant.

Iron absorption from infant cereals

The first data in 4-6 month-old infants were published by Rios¹⁷, who used iron-59 as an extrinsic label to calculate the absorption of fortification iron from rice cereal and infant formula in 4-6 month-old infants. Geometric mean absorption was 0.7 per cent for ferric orthophosphate, 1 per cent for sodium iron pyrophosphate, 2.7 per cent for ferrous sulfate, and 4 per cent for electrolytic iron powder. Absorption of electrolytic iron from cereal was about 4 per cent, which was similar to the percentage iron absorption from infant formulas fortified with ferrous sulfate. However, if added to dry infant cereals, ferrous sulfate would promote oxidative rancidity and the electrolytic iron powder studied¹⁷ was of considerably smaller particle size than that used in commercial fortification of infant cereals. Ferrous fumarate has been suggested as an attractive iron preparation for cereal fortification¹². The stable isotope technique⁷ showed that mean erythrocyte incorporation of iron from rice-based cereal meals fortified with ferrous sulfate and ferrous fumarate in 4-6-month-old infants was 4.4 per cent and 4.0 per cent of intake, respectively. Recently it has been shown that the addition of ascorbic acid to a whole-wheat breakfast cereal test meal increases mean erythrocyte incorporation of iron from 3.1 to 7.5 per cent of intake¹⁵.

Clinical data

The results of clinical studies on iron nutritional status of infants receiving iron fortified cereals are conflicting²⁰. Comparisons between iron

fortified rice cereal and unfortified rice cereal were made in infants who were exclusively breast-fed for more than 4 months, and with iron fortified formula in infants who were weaned to formula before 4 months of age. The infants were followed from 4 to 15 months of age. The cumulative percentages of infants excluded from the study until 15 months of age on the basis of a low haemoglobin value (<105 g/l) were 4 per cent, 8 per cent, and 24 per cent in the groups fed the fortified formula, fortified cereal, and non-fortified food, respectively. The authors concluded that iron fortified infant cereal can play a significant role in prevention of iron deficiency anaemia but iron fortified formulas presented a slight advantage. Fuchs *et al.*⁸ prospectively studied infants from 4-6 to 12 months of age who were randomly assigned to receive whole cow's milk plus iron fortified cereal, one of two iron fortified follow-up formulas, or an iron fortified infant formula. By 12 months of age, mean serum ferritin (Fig. 1) and mean corpuscular volume of the erythrocytes were lower in the group fed cow's milk and the iron fortified cereal. Moreover, 29 per cent of the infants in that group had serum ferritin values below 12 ng/ml and 24 per cent MCV below 70 fl. In the three groups fed the iron fortified formulas, low ferritin values were found in 0-4 per cent only and low MCV in 0-7 per cent. It remains uncertain whether poor bioavailability of iron from cereal and/or feeding of cow's milk was the main factor contributing to poorer iron nutritional status than in the other groups at 12 months of age.

Other weaning foods

Commercially prepared baby foods fortified with ferrous sulfate and ascorbic acid are available in many European countries. If meat is also present, the iron in these foods is assumed to be of high bioavailability because meat and ascorbic acid^{2,5} enhance the bioavailability of non-haem (i.e. fortification) iron. In a prospective study, healthy term infants received non-fortified formula and iron mainly from fortification iron in baby foods from 4 to 12 months of age⁸. Their mean iron intake was only 0.42-0.65 mg/kg/day between 274 and 365 days of age, which is substantially below the estimated requirements⁷. However, none of the infants had a

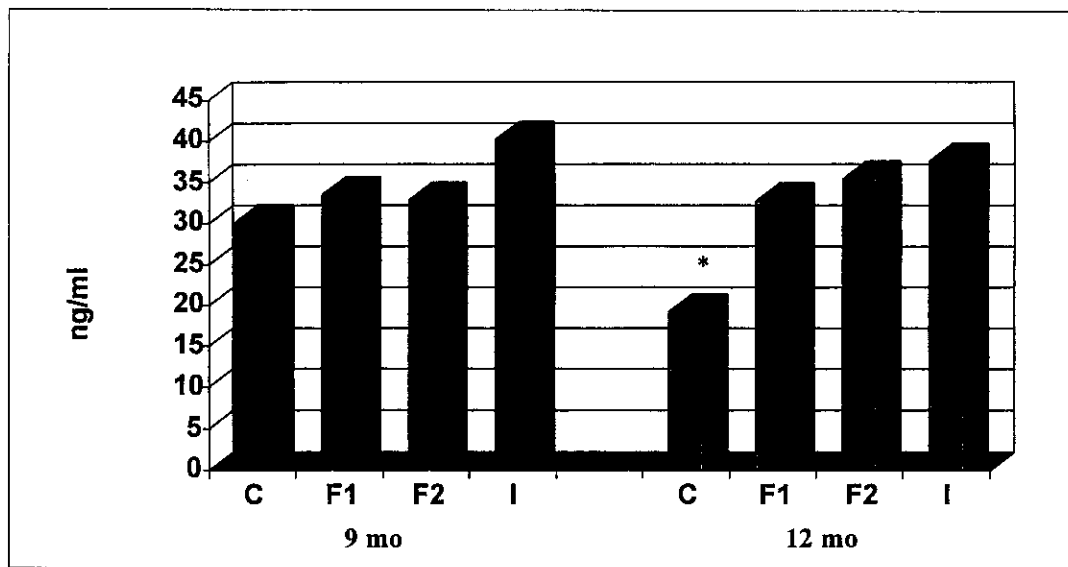


Fig. 1. Serum ferritin of infants fed iron fortified cereal + cow's milk (C), iron fortified follow-up formulas (F1, F2), or iron fortified infant formula (I). * Indicates $p < 0.05$ compared to F1, F2, and I. (Data from Fuchs et al.,⁸)

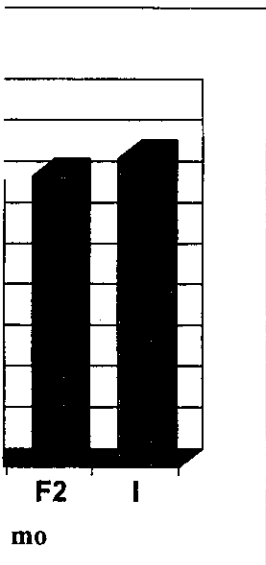
haemoglobin value below 100 g/l and only 8 per cent had ferritin below 10 ng/ml at 12 months of age. This indicates that regular feeding of such baby foods may be a convenient and effective

way of providing iron to infants who are breast-fed or receive cow's milk between 6 and 12 months of age.

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