A longitudinal study of iron status in children at 12, 24 and 36 months

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Abstract

Objectives: To assess iron status in a sample of clinically well, Caucasian children and explore the complex factors which contribute to iron deficiency during infancy.
Design: Infants recruited at birth and followed longitudinally at 1, 2, 3, 4, 5, 6, 9, 12, 24 and 36 months; feeding practices and socioeconomic data recorded. Iron status assessed using venous blood at 12, 24 and 36 months.
Setting: Baseline data recorded in the maternity unit. Follow-up visits took place in the infants' homes and blood sampling in a paediatric hospital.
Subjects: Subjects comprised a mixed socioeconomic group of healthy children ($n = 121$). Blood samples taken from 85, 72 and 67% at 12, 24 and 36 months, respectively.
Results: Prevalence of anaemia (Hb $< 110\,g\,l^{-1}$) in the longitudinal sample ($n = 76$) increased from 2.6% at age 12 months to 9.2% at 24 months, and at age 36 months ($n = 70$) was 8%. The most significant finding was that at age 12 months, cows' milk consumption was negatively associated with iron status. Other variables also had an influence. At both 24 and 36 months the most significant predictor of iron status was earlier iron status.
Conclusions: Infants born to anaemic mothers or mothers who smoke and infants who consume cows' milk during infancy are at increased risk of developing anaemia. Breast milk is the ideal, but for the infant who is not breast fed an iron fortified formula should be used. Advice to mothers should focus on the importance of introducing nutrient dense complementary foods, such as meat, which contains readily absorbable iron.

Keywords
Anaemia
Infant feeding
Cows' milk

Iron deficiency anaemia of infancy has declined in many countries as a result of improved feeding practices but the condition remains relatively common[1]. The UK National Diet and Nutrition Survey[2] (NDNS) provides cross-sectional data on the iron status of a sample of over 900 children, aged 1.5–4.5 years, of whom two-thirds were aged 1.5–3.5 years. In the sample as a whole, 8% were found to have haemoglobin (Hb) $< 110\,g\,l^{-1}$; this included 12% of the 1.5–2.5 year olds and 6% of those aged 2.5–3.5 years. Twenty-three per cent of 8-month-old Avon infants had Hb $< 110\,g\,l^{-1}$ in another UK study[3].

Increasing evidence suggests that even mild iron deficiency anaemia of greater than 3 months duration can have a long-term detrimental influence on mental and psychomotor development, making the prevention and early treatment of iron deficiency a priority for paediatric health care[4–6]. The factors which predispose to the development of iron deficiency and anaemia, together with the prevalence of the disorder, need to be clearly understood before effective preventative measures can be initiated.

Available studies give much information about the prevalence of anaemia in various paediatric populations but many include hospitalized patients, in whom anaemia may be disease related[7,8], or subjects from disadvantaged communities[9,10] and ethnic minority groups[11,12], who are at increased risk of developing anaemia. Others provide only cross-sectional data, which give no information about the changes which take place in iron status over time[2,3]. In reality, the supply of, and demand for, iron form part of a constantly balancing cycle and iron deficiency develops after a prolonged period of either inadequate supply, increased demand or a combination of the two. Infants have a high requirement for iron as a result of their rapid growth rates.

The influence of milk feeding practices on iron

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supply has been examined in certain subgroups[10,12] but feeding data are often collected retrospectively or at the same time as blood samples[11] whereas earlier feeding practices will have a distinct influence on current iron status. A more comprehensive range of factors which might affect the supply of iron is not usually considered. To our knowledge, no longitudinal studies have reported on factors influencing iron status of a mixed socioeconomic group of community-based children from birth to age 3 years.

This study assesses the prevalence of iron deficiency and iron deficiency anaemia in a longitudinal sample of normal, clinically well, infants at the ages of 12, 24 and 36 months. Nutritional, social and environmental data were recorded prospectively from birth. Relationships between iron status and these variables are examined.

Subjects and methods

The protocol was approved by the ethics committee of the Federated Dublin Voluntary Hospitals. A sample of 121 consecutive, normal, healthy infants was recruited at birth from the Coombe Women's Hospital, Dublin, one of three major maternity units in the city, with approximately 7000 births per annum. Infants were excluded if the mother had diabetes, epilepsy or any condition which required her to take medication on a regular basis, if birth weight was < 2500 g, gestational age < 37 weeks or unknown or if the infant had any congenital malformations, chronic or inherited metabolic disease, or any illness that required hospitalization for more than 7 days. Pregnancies resulting from non-natural insemination were excluded as were those infants whose fathers were unknown. Only singleton infants were included in the sample, which included those from public (60%), private (30%) and semi-private (10%) wards. During the recruitment period 31 mothers refused to participate. Baseline characteristics were recorded for these mother–infant pairs.

In the immediate postnatal period birth weight, length, head circumference, choice of feeding method and socioeconomic data were recorded. Maternal Hb concentration during pregnancy was taken from hospital records. Usually only one Hb measurement, recorded at the booking visit, was available. If the Hb measurement was repeated, the lower of the values was used. Follow-up visits were organized in the infants' homes, monthly for the first 6 months and at the ages of 9, 12, 18, 24, 30 and 36 months. At each visit anthropometric measurements were taken and a questionnaire, which recorded the type of milk feeding used, the frequency of feeding, the volume of formula or cows' milk consumed, the age of weaning to solid foods and the various foods used, was completed by one investigator. Type of milk feeding was categorized as either breast feeding (exclusive or partial), infant formula (all available infant formula is iron fortified), follow-on formula or cows' milk. The age of introduction of cows' milk was derived from the longitudinal data. The quantity of milk consumed daily was the usual daily intake as reported by the carer, who was generally the mother. The mother was asked whether the child was feeding from a bottle or a cup or both. The number of drinks taken daily from a bottle and the volume of each and the number of drinks taken from a cup and the volume of each were recorded. The quantity of cows' milk consumed during the first year of life was calculated from usual daily consumption, which was recorded at the ages of 1, 2, 3, 4, 5, 6, 9 and 12 months. If the infant had been transferred from one milk to another in the interim period between visits the calculation took account of this. At the ages of 12, 24 and 36 months venous blood samples were taken from 92 (85%), 78 (72%) and 70 (67%) infants, respectively. The longitudinal samples comprised 76 infants (12–24 months) and 70 infants (24–36 months).

Analyses for haemoglobin (Hb), haematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular Hb (MCH), mean corpuscular Hb concentration (MCHC) and red cell distribution width (RDW) were completed using Coulter counter (model STKS). Serum was analysed for serum ferritin (SF) by radioimmunoassay (FER-CTRIA, CIS Bio International, France); total iron binding capacity (TIBC) calculated from transferrin using immunodiffusion (NORPartigen, Behring) and serum iron (Kodak Ektachem clinical chemistry slide).

Differences between mean values for haematological variables measured at the ages of 12, 24 and 36 months were assessed using paired student's *t*-tests. Multivariate regression analysis was performed to explain iron status from other variables. At age 12 months, independent variables included in the regression were gestational age, birth weight, sex, level of education of the mother, smoking habits of the mother during pregnancy, milk feeding method and the quantity of cows' milk consumed during the first year of life, the age of introduction of meat, the infant's use of supplemental iron and markers of maternal iron status. At the ages of 24 and 36 months, markers of earlier iron status of the infant were included in the regression model as independent variables. Dependent variables examined were Hb, MCV and SF.

Results

There were no significant differences between participants and non-participants for birth weight, maternal age, maternal height or the percentage of urban or rural families included. A trend for participating mothers

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Table 1 Characteristics of the longitudinal sample at 12 and 24 months ($n = 76$) and of remaining infants ($n = 45$). Mean values are given with standard deviations in parentheses

	Longitudinal sample ($n = 76$)	Remaining infants ($n = 45$)
Birth weight (g)	3573 (425)	3654 (457)
Birth length (cm)	50.8 (1.7)	52.4 (2.1)
Age of mothers (years)	29 (5)	29 (5)
Age of fathers (years)	31 (6)	28 (6)
Age mothers' education stopped (years)	17 (4)	17 (4)
Age fathers' education stopped (years)	17 (6)	14 (8)
% Boys	55	43
% Families with both parents unemployed	14.5	15.8
% Families with neither parent unemployed	48.7	30.7
% Families with no central heating	22.0	32.8
% Mothers who took medicinal iron during pregnancy	76	65

to have a higher level of education did not reach statistical significance.

Mothers who were willing to allow blood samples to be taken from their children comprised 85, 72 and 67% of participants at the ages of 12, 24 and 36 months, respectively. Table 1 summarizes the characteristics of those who were included in the longitudinal sample at 12 and 24 months ($n = 76$) and of those who were not ($n = 45$). Milk feeding practices of those included in the longitudinal sample at 12 and 24 months ($n = 76$) are shown in Fig. 1. Formula milks were far the most popular up to age 9 months but cows' milk was commonly used at age 12 months. Infants were being fed cows' milk from as early as 2 months, 9% receiving cows' milk by age 4 months. Table 2 shows mean volumes of cows' milk ($ml\,day^{-1}$) being consumed during the first year. The percentage of infants who were breast fed was low, falling from 25% at 1 month to 11% at 6 months and 6% at 12 months. Commercially produced, iron fortified infant cereals were most frequently used as first weaning foods. By age 12 months, about 85% of infants were eating meat, fish or chicken daily. Most others consumed meat, fish or chicken on a regular, but less frequent, basis. No vegetarian children were included.

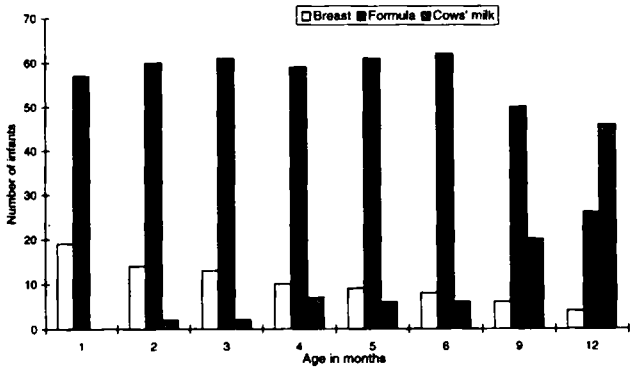

Fig. 1 Milk feeding during the first year of life in the longitudinal sample ($n = 76$)

At age 12 months, mean Hb in the total sample was $122.5\,g\,l^{-1}$ (SD 7.9). Of the 92 infants, three (3.2%) had Hb $< 110\,g\,l^{-1}$. For one infant (Hb $109\,g\,l^{-1}$), all other haematological parameters were within the appropriate reference ranges. The other two showed further haematological evidence of iron deficiency (SF < 1 and $3\,\mu g\,l^{-1}$; TIBC 525 and $574\,\mu g\,dl^{-1}$), had been introduced to cows' milk from the age of 2 months and had inadequate intakes of heme iron. Meat, fish or chicken was being eaten by them during only two of the eight interview periods during the first year of life, by one child at ages 4 and 5 months and by the other, irregularly at age 9 months, and at age 12 months. Mothers of both infants who were anaemic at age 12 months had been severely anaemic (Hb $< 85\,g\,l^{-1}$) during their pregnancies. The mean Hb in those mothers for whom data was available ($n = 51$) was $116\,g\,l^{-1}$ and no other mother recorded a Hb $< 90\,g\,l^{-1}$.

Mean (SD) for a range of haematological variables in the longitudinal samples at ages 12, 24 and 36 months are presented in Tables 3 and 4. By age 24 months mean Hb had fallen slightly to $120.2\,g\,l^{-1}$, but this decrease was not statistically significant, and seven infants (9.2%) had Hb $< 110\,g\,l^{-1}$. All seven had SF $< 10\,\mu g\,l^{-1}$. Mean Hb at age 36 months was $120\,g\,l^{-1}$ and 8% had Hb $< 110\,g\,l^{-1}$. Together with this fall in the percentage found to be anaemic, mean MCV, RDW and TIBC showed significant improvement during the third year (Table 4).

Table 2 Cows' milk consumption ($ml\,day^{-1}$) during the first year of life (n max. = 92)

Age (months)	n	Mean	SD	Minimum	Maximum
1	0	—	—	—	—
2	2	881	40	852	909
3	2	853	241	682	1023
4	7	763	268	426	1136
5	6	885	239	540	1136
6	6	838	285	398	1136
9	26	580	284	114	1023
12	63	524	242	21	1193

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Table 3 Mean (SD) of haematological variables in the longitudinal sample ($n = 76$) at ages 12 and 24 months

	Hb ($g l^{-1}$)	S. ferritin ($\mu g l^{-1}$)	Hct ratio	MCV (fl)	RDW	TIBC ($\mu g dl^{-1}$)	Ts%
12 months	121.9 (7.7)	16.8 (12.2)	0.357 (0.023)	77.1 (3.8)	13.8 (1.2)	398 (53)	23 (17)
24 months	120.1 (9.0)	10.1 (5.8)	0.352 (0.023)	76.4 (5.6)	14.0 (1.5)	409 (61)	19 (11)
P	NS	<0.0001	NS	NS	NS	NS	NS

Hb = haemoglobin; S. ferritin = serum ferritin; Hct = haematocrit; MCV = mean corpuscular volume; RDW = red cell distribution width; TIBC = total iron binding capacity; Ts% = percentage saturation of transferrin; *P* = difference between 12-month and 24-month values.

Mean SF was $17.5 \mu g l^{-1}$ (SD 12.3) at age 12 months. Twenty-three per cent of the total and 8% of those fed iron fortified formula throughout the first year appeared iron deficient (SF $< 10 \mu g l^{-1}$). However, the lower limit of the normal reference range for SF is poorly defined in infant populations. The distribution of ferritin in infants is positively skewed, as it is in adults[13], so a small shift in the lower limit would result in a considerable number of infants being categorized differently. In this case 43% of infants who had SF $< 10 \mu g l^{-1}$ would not have been categorized as iron deficient if the lower reference limit was $7 \mu g l^{-1}$. The maximum ferritin value fell from $61 \mu g l^{-1}$ to $26 \mu g l^{-1}$ between the ages of 12 and 24 months. In the longitudinal sample ($n = 76$) mean SF fell from $16.8 \mu g l^{-1}$ at age 12 months to $10.1 \mu g l^{-1}$ at age 24 months and this decrease was statistically significant ($P < 0.0001$) (see Table 3). At age 2 years, 38 infants (50%) had SF $< 10 \mu g l^{-1}$ and 24 (31%) had SF $< 7 \mu g l^{-1}$. In the 3-year-old children mean SF was $12.3 \mu g l^{-1}$ (SD 9.2); 46% had SF $< 10 \mu g l^{-1}$ and 26% $< 7 \mu g l^{-1}$. In the 8% who were anaemic at age 36 months, mean SF was $8.8 \mu g l^{-1}$ (range $1-21 \mu g l^{-1}$). Correlations were found between Hb and SF at both 12 and 24 months but not at 36 months ($r = 0.26$, $P = 0.023$ at age 12 months and $r = 0.66$, $P = 0.000$ at 24 months).

Multivariate regression analysis (Table 5) showed that the quantity of cows' milk consumed during the first year was negatively associated with Hb ($r = -0.36$; $P < 0.000$), MCV ($r = -0.42$; $P < 0.026$) and SF ($r = -0.42$; $P < 0.001$). If the age of introduction, rather than the quantity, of cows' milk was used in the regression model a similar, significant, but less strong association was found. Haematological variables recorded at 12 and 24 months were included in the regression model to explain later iron status and each dependent variable was found to be significantly influenced by its value 12 months earlier. Smoking during pregnancy negatively influenced iron status indicators at the ages 12 and 24 months. The possible confounding effect of other socioeconomic variables on this association was examined, but none was found to be significant.

At age 12 months all breast fed infants had Hb $> 115 g l^{-1}$ and SF ranged from 5 to $12 \mu g l^{-1}$; three of the five infants had SF $< 10 \mu g l^{-1}$ (5, 8 and $9 \mu g l^{-1}$). All three were eating meat, fish or chicken daily. Although breast feeding was associated with 'low' SF, the relationship was weak and there was a significant correlation between breast feeding and later introduction of solids, excluding meat and fruit ($r = 0.46$, $P = 0.000$). Low SF is taken to be synonymous with poor iron status, but no further evidence to support this view can be seen in the breast fed baby with the lowest SF level. The full haematological profile of this infant was as follows: SF $5 \mu g l^{-1}$; Hb $12 g dl^{-1}$; Hct ratio 0.344; MCV 75.9 fl; MCH 26.5 pg; MCHC $34.9 g dl^{-1}$; RDW 13.4; TIBC $423 \mu g dl^{-1}$; Ts 16%.

Discussion

Mean Hb ($122 g l^{-1}$) in this sample at age 12 months compares favourably with that recorded by Burman who found a mean of $117.5 g l^{-1}$ (SD 10.8) in a sample of 105 1-year-old infants who had been given no medicinal iron[14] and is the same as the median value reported from the white 1–2 year olds ($n = 98$) who were included in the Second National Health and

Table 4 Mean (SD) of haematological variables in the longitudinal sample ($n = 70$) at ages 24 and 36 months

	Hb ($g l^{-1}$)	S. ferritin ($\mu g l^{-1}$)	Hct ratio	MCV (fl)	RDW	TIBC ($\mu g dl^{-1}$)	Ts%
24 months	120.0 (0.92)	9.9 (5.8)	0.352 (0.023)	76.4 (5.6)	14.1 (1.5)	409 (59)	18.7 (11.2)
36 months	120.0 (0.8)	12.3 (9.2)	0.349 (0.021)	78.3 (5.0)	13.5 (1.3)	377 (55)	19.8 (11.4)
P	NS	NS	NS	0.03	0.01	0.001	NS

Hb = haemoglobin; S. ferritin = serum ferritin; Hct = haematocrit; MCV = mean corpuscular volume; RDW = red cell distribution width; TIBC = total iron binding capacity; Ts% = percentage saturation of transferrin; *P* = differences between 12-month and 24-month values.

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Table 5 Regression analyses: iron status at the ages of 12 ($n = 92$), 24 ($n = 76$) and 36 ($n = 70$) months

Dependent variable	Independent variable§	r	P	Adjusted r^2
Age 12 months				
Hb	Cows' milk*	−0.36	0.000	
	Iron supplement	0.21	0.001	
	Gestational age	−0.27	0.034	0.206
MCV	Cows' milk*	−0.42	0.026	
	Maternal MCV	0.30	0.001	
	Smoking DP†	−0.40	0.002	
	Follow-up milk	0.19	0.038	0.337
Log ferritin	Cows' milk*	−0.42	0.001	
	Smoking DP†	−0.40	0.009	
	Breast feeding	−0.11	0.041	0.264
Age 24 months				
Hb	Hb 1‡	0.50	0.001	
	Log ferritin 1	0.53	0.005	
	Smoking DP†	−0.44	0.027	0.372
MCV	MCV 1‡	0.73	0.000	
	Log ferritin 1	0.54	0.021	0.558
Log ferritin	Cows' milk*	−0.53	0.000	
	Log ferritin 1	0.50	0.022	0.310
Age 36 months				
Hb	Hb 1	0.59	0.002	
	Hb 2‡	0.78	0.000	0.657
MCV	MCV 2	0.89	0.000	0.791
Log ferritin	Log ferritin 2	0.55	0.000	
	Hb 2	0.47	0.015	0.337

*The quantity of cows' milk consumed during the first year.
†Number of cigarettes smoked daily during pregnancy.
‡Hb, MCV and log ferritin 1 and 2 are the values of these variables at 12 and 24 months, respectively.
§Of the independent variables used in the multivariate regression analyses (gestational age, birth weight, level of education of the mother, smoking habits of mother during pregnancy, milk feeding method, quantity of cows' milk consumed during the first year, age of introduction of meat, supplemental iron, iron status of mother during pregnancy, and (at 24 and 36 months) markers of earlier infant iron status) only those reaching statistical significance are given in the table.

Nutrition Examination Survey[15]. Burman emphasized the major physiological changes which occur in Hb levels during the first 12 months of life with a standardized range (±2 SD) from 96 to 143 $g\,l^{-1}$, and highlighted the persistent haemodynamic state which exists during infancy[16]. A UK study of 8-month-old infants found a mean Hb of 117 $g\,l^{-1}$, somewhat lower than in the 12-month-old Irish children[3]. In the NDNS[2] mean Hb in the 1.5–2.5 and 2.5–3.5 year old children were 120 $g\,l^{-1}$ and 122 $g\,l^{-1}$, respectively, similar to values in the present groups.

The prevalence of anaemia (2.6%) in this sample of apparently normal, clinically well infants at age 12 months is significantly lower than that reported in UK studies[7,11,12], increases to 9.2% during the second year of life and decreases again to 8% in the third year. Duggan *et al.* similarly found that the highest prevalence of anaemia was between 21 and 24 months[11]. The earlier UK studies included sample populations which differ from the present mixed socioeconomic group of Caucasian children. Results can more appropriately be compared with the NDNS[2] in which 12% of those aged 1.5–2.5 years, 6% of 2.5–3.5 year olds and 8% of all children aged 1.5–4.5 years had Hb < 110 $g\,l^{-1}$. NDNS subjects were a representative sample selected from private households in England, Scotland and Wales. Blood samples were taken from 54% of the responding sample. Because the age groups are not matched with those in the present study, and in the knowledge that there are major physiological changes in iron status during infancy and early childhood, it is not possible to make precise comparisons between the groups. However, both studies were carried out during the same time period and it appears that a similar level of anaemia exists in the two populations at the age of 24 months. Improved iron status is also seen in both populations during the third year. The somewhat higher prevalence of anaemia in the UK children aged 1.5–2.5 years may be the result of inclusion in the sample of non-Caucasian subjects, with feeding patterns which differ from the Caucasian population. This possibility is suggested by the fact that it is reported that only about 50% of the NDNS children aged 1.5–4.5 years consumed meat during the 4-day interview period, although no information is given on the percentage of vegetarian children

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included. However, the wider age groups may also be a factor. Twenty-three per cent of 8-month-old infants in Avon[3] had Hb < 110 g l^{-1} compared with only 2.6% of the present 1 year olds but the Avon authors conclude that the cut-off point of 110 g l^{-1} may be inappropriate for Hb estimated from capillary blood, which can become diluted with serum during the sampling procedure. Hb and red cell mass are gradually increasing at this point, and iron stores are being utilized to sustain the increases. This would explain the apparent contradictions found in Avon in relation to correlations with weight at age 8 months. Weight gain correlated positively with Hb but negatively with SF. As the infant grows the reserves of iron are mobilized to sustain the expansion in blood volume and red cell mass which is associated with growth[16]. A similar dynamic, associated with pubertal growth, has been shown in Finnish boys[17].

Iron deficiency at age 12 months was strongly related to the early introduction of cows' milk. This finding is not surprising as the contribution of cows' milk to iron deficiency in infancy is well documented[18,19]. Milk intakes were recorded frequently during the first year of life and are deemed to be an accurate estimate of consumption. Age of introduction could be used in the regression model interchangeably with quantity of cows' milk to confirm the validity of the results. Furthermore, these data supply information about milk intakes during a period preceding blood sampling and should, therefore, give a more accurate picture of the influence of milk consumption on iron status. The recommendation to avoid cows' milk as the primary milk drink until age 12 months is now widely publicised. However, cows' milk has traditionally been used at an earlier age and, while the majority of mothers delayed its introduction until 9 months, by age 12 months cows' milk was commonly the main milk consumed. Cows' milk was more frequently used at an early age in the present sample, with 7% consuming cows' milk by age 6 months compared with 3% of those in the NDNS[2]. However, approximately 27% of infants in both groups were reported to be drinking cows' milk by age 9 months.

Severe maternal anaemia during pregnancy was found to be present in the mothers of both infants who were anaemic at age 12 months. Although no postnatal blood samples were taken, it is known that severe maternal iron deficiency compromises the level of iron laid down by the fetus *in utero*, hastening the infant's dependence on dietary iron. A recent Danish study has shown significant tracking for SF between the ages of 2 and 9 months, suggesting a close relationship between postnatal iron status and iron status in later infancy[20] and a number of studies have confirmed the relationship between maternal and infant ferritin levels, particularly when maternal iron stores are low [21,22].

The most significant determinant of iron status at the ages of 24 and 36 months is earlier iron status, so it appears that the tracking effect seen in infancy continues into the second and third years and that determinants of early iron status continue to have an influence. The deterioration in iron status between the ages of 12 and 24 months is also due to the change from a fortified to an unfortified diet and a failure to replace the fortification iron with food iron. Iron intake in infants aged 9–12 months has been shown to be lower than in 6–9 month olds as a result of the decreased reliance on fortified foods[23]. In the present sample, diet is failing to provide sufficient iron to support erythropoesis in almost one in ten children at age 24 months. The improvement in the third year may be a reflection of the fact that the infants are reaching an equilibrium in terms of iron turnover. In early childhood, when there is a high demand for dietary iron but a relatively low energy intake, the provision of a nutrient dense diet is essential to meeting the nutritional needs of the child. Cereals were found to be the major energy provider in the NDNS, with biscuits, buns, cakes and pastries providing a greater proportion of the energy derived from cereal than either bread or breakfast cereals[2]. The excessive use of foods which do not provide essential nutrients increases the risk that deficiencies will develop. This is particularly true of iron deficiency. The demand for iron is high, absorption of iron is relatively poor, especially from foods containing non-heme iron, and heme iron, found only in meat, fish or chicken, is not widely dispersed in the diet.

A lower range (5–12 μg l^{-1}) for SF at age 12 months, was seen in the small number of breast fed infants in the present sample, but breast feeding should not be interpreted as a risk factor for iron deficiency anaemia. The extensive health benefits of breast feeding are well documented and no child who was breast fed became anaemic. Differences in iron storage levels in late infancy are likely to result from high intakes of supplemental iron by formula fed infants[24] rather than from an inadequate supply of iron in the diets of those who are breast fed. As a result, the breast fed baby does not experience the dietary iron deficit which results from the change to an unfortified from a fortified milk and, given an adequate intake of iron from complementary foods, lower levels of storage iron stimulate increased absorption of iron, to maintain iron homoeostasis. Levels of breast feeding in Ireland are low, so a National Breastfeeding Policy has been designed to improve both the uptake and duration of breast feeding[25]. Higher levels of breast feeding have been reported in the UK and Scotland[2,23,26] and should be a realistic objective in our similar population.

For the infant who is not breast fed, formula milk can

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provide a substantial proportion of the iron required during the first year of life and it is vital that the use of cows' milk as the main milk drink should continue to be discouraged. However, iron fortification of formula still presents some difficulties. The optimal level of fortification remains unclear[27, 28] and a recent study has shown that ascorbic acid supplementation of formula, designed to enhance iron absorption, causes the formation of free radicals *in vitro*[29]. In addition, there is some danger that over reliance on bottle feeding will prevent the initiation of weaning on to a good variety of solid foods. Mothers tend to discontinue the use of iron fortified formula towards the end of the first year when the resulting deficit in dietary iron should be met by the foods consumed. If an equivalent volume of cows' milk is substituted in place of formula it may provide adequate energy, but the requirement for other nutrients, including iron, will not be met.

Meat, fish and poultry, which are generally available in developed countries, contain the most bio-available form of iron, heme iron. Recent studies have confirmed that meat intake influences iron status in infants and young children[20,30]. A report on infant feeding 'Weaning and the Weaning Diet' recommends the inclusion of meat from the age 4–6 months[31]. This recommendation is of particular relevance given the significant increase in anaemia which is found in the second year of life. All infants and young children should be encouraged to eat a wide variety of nutrient dense foods, including meat, in the knowledge that they have a high requirement for iron. By tackling the problem from a dietary perspective, the development of good eating habits, which will continue to provide for the nutrient needs of the growing child, is encouraged. This, and not increasing reliance on greater fortification of formula, should be the cornerstone of the prevention of anaemia and iron deficiency of late infancy and childhood in the future.

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