Iron status of Asian children aged 2 years living in England

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Abstract

Haemoglobin and ferritin values were analysed in blood from 1057 children, aged 2 years, of Asian parents living in England. Children who had thalassaemia trait or a current/recent infection were excluded. Twenty nine per cent of Pakistani, 25% of Bangladeshi, and 20% of Indian children had haemoglobin < 110.0 g/l. The recent national diet and nutrition survey of preschool children found a prevalence of 12% of 2 year olds with haemoglobin < 110.0 g/l. No single factor accounted for more than a small proportion of the variance in haemoglobin and ferritin values, but the most significant factors that had a negative effect on iron status included the amount of cows' milk consumed, the use of a baby bottle, and mother's place of birth being outside of the UK. Taking vitamin or iron supplements was positively associated with iron status in one or more of the three groups.

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Keywords: ethnic origin; Asian children; iron status; ferritin

In the recent national diet and nutrition survey (NDNS) of children aged 1.5 to 4.5 years, iron deficiency anaemia was identified as a common problem.¹ About one in eight children aged between 18 and 30 months who provided a blood sample in the NDNS had haemoglobin concentrations below 110.0 g/l, which is the definition of anaemia suggested by the WHO.² A number of smaller local studies in the UK have shown a much greater proportion of low haemoglobin concentrations among young Asian children with up to half of the children in some studies found to be iron deficient.³

This survey provides national data for the first time on the iron status of young Asian children. The sample for this study was a group of Asian children living in England who took part in a survey of infant feeding in Asian families when they were about 15 months old,⁴ and were followed up when they were about 2 years old. The survey, which was designed to study the early feeding practices and growth of babies born to mothers of Bangladeshi, Indian, or Pakistani origin, was commissioned by the Department of Health and undertaken by the Social Survey Division of the Office for National Statistics.

Methods

SAMPLE DESIGN AND RESPONSE

Full details of recruitment and the characteristics of the sample are published elsewhere.⁴ The sample was drawn from the register of births in 41 local authority areas. These areas covered 95% of the Asian population at the time of the 1991 census. We included all babies born in the relevant local authorities between 15 August and 11 November 1994 to mothers who defined themselves as being of Bangladeshi, Indian, or Pakistani origin. We also included a small sample of babies born to white mothers living in the same geographical areas as the Asian mothers but they were not followed up for this stage of the survey. Mothers were interviewed on four occasions: when the baby was between 6 and 10 weeks old, at 5 months, 9 months, and 15 months. At each stage, anthropometric measurements of the baby were taken. Interviews were achieved when the children were about 15 months old with 71% (2382) of mothers of babies who were originally eligible.

The 1750 children that we followed up for the current study are the Asian children who participated in the survey at 15 months and whose mothers agreed to be interviewed again. Fieldwork was done during October and November 1996. Two thirds of parents or guardians consented to a blood sample being taken from their child. Ethical approval for the study was given by all 43 NHS local research ethics committees covering the 41 local authority areas in the sample and by the research ethics committee of the Great Ormond Street Hospital for Children NHS Trust.

A total of 1280 (73.1%) mothers of eligible children were successfully contacted when their child was about 2 years old and agreed to at least one interview, which updated information already collected in the infant feeding survey and asked specifically about the consumption of foods which are thought to influence iron status.

Phlebotomists obtained venous blood samples from the antecubital fossa of 1057 (60.4%) eligible children. They attempted to collect 4.0 ml blood and 799 samples were sufficiently large to include a clotted blood sample to analyse ferritin concentrations. The phlebotomists visited the child's home accompanied by a trained interviewer from the Office for National Statistics and an interpreter where appropriate. Overall, about a third of interviews were done through an interpreter, ranging from 15% with Indian mothers, 32% with Pakistani mothers, and 64% with Bangladeshi mothers. All documents used in the survey were written in English and Asian languages.

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Table 1 Milk drinking habits at 2 years old by ethnic group

	Bangladeshi	Pakistani	Indian
Given milk in a bottle or cup	92%	97%	97%
Bottle fed	85%	89%	79%
Weighted base = 100% (all children)	316	418	550
Mean (SD) bottles of milk daily	2.6 (1.0)	2.8 (1.3)	2.8 (1.3)
Mean (SD) quantity (ml) of milk daily	487 (236)	615 (313)	607 (315)
Weighted base = 100% (bottle fed children)	270	369	432
Mean (SD) cups of milk daily	1.2 (1.2)	1.5 (1.0)	1.4 (1.2)
Weighted base = 100% (children given milk in a cup)	123	197	353

Pakistani mothers who did not agree to blood being taken from their child were more likely to be better educated. In all groups the proportion of children who were ever breast fed, given vitamins and different types of food and drink at previous stages of the survey was similar among those who gave a blood sample at age 2 and those who did not.

BLOOD ANALYSIS

Children who were found to have β thalassaemia trait (0.3–2.7%) or haemoglobin E trait (0–7%) were excluded from the haemoglobin and red cell analyses. Full blood counts were done on the day of receipt of the sample using a Bayer H3 analyser; serum ferritin assays were done on the Abbott IMX analyser. External quality assessment was by the National External Quality Assessment Scheme, which runs monthly.

Table 2 How often children are given different types of drinks at 2 years old by ethnic group

Frequency	Bangladeshi (%)	Pakistani (%)	Indian (%)
Other milk drinks*			
At least once a day	9	9	10
At least once a week	14	20	13
Less than once a week	4	8	10
Never	74	63	66
Pure fruit juice			
At least once a day	46	57	55
At least once a week	30	28	26
Less than once a week	4	3	7
Never	19	11	12
Ribena, baby, or toddler drinks			
At least once a day	41	52	44
At least once a week	24	17	18
Less than once a week	2	2	6
Never	32	29	32
Weighted base = 100%	316	418	550

*Not in table 1.

Table 3 How often children are given different types of food at 2 years old by ethnic group

Frequency	Bangladeshi (%)	Pakistani (%)	Indian (%)
Breakfast cereal			
At least once a day	62	67	72
At least once a week	25	22	16
Less than once a week	1	1	2
Never	12	10	9
Bread, chapati, or naan			
At least once a day	46	93	91
At least once a week	39	5	8
Less than once a week	3	0	0
Never	12	1	1
Chicken, turkey, or other meat			
At least once a day	31	8	5
At least once a week	66	88	63
Less than once a week	1	1	4
Never	2	3	28
Fish			
At least once a day	22	1	2
At least once a week	58	75	51
Less than once a week	6	12	12
Never	14	12	36
Weighted base = 100%	316	418	550

Results

We considered results separately for each of the three ethnic groups because, as described in the report of the survey, the characteristics of the groups were quite different from each other.⁴

DIETARY AND LIFESTYLE QUESTIONNAIRE

Tables 1–3 present data obtained at the two year interview. Socioeconomic factors and data on feeding practices, diet, and growth have been brought forward from the previous stages of the infant feeding survey and used in the analysis described in this paper. The full results of the first four interviews are published in the report of that survey.⁴

Table 1 shows the milk drinking habits of the group at 2 years of age: 97% of Indian and Pakistani children and 92% of Bangladeshi children were given milk; 89% of Pakistani, 85% of Bangladeshi, and 79% of Indian children still drank milk from a bottle, even if only occasionally. Most children who were given milk in a bottle or a cup received whole milk, but 8% of Indian and Bangladeshi and 7% of Pakistani children were given semi-skimmed milk (compared with 14% in the NDNS). One per cent or less in any group were given skimmed milk. Table 2 shows consumption of other drinks such as juices.

Table 3 shows how often children ate selected foods. Seventy two per cent of Indian children, 67% of Pakistani, and 62% of Bangladeshi children ate breakfast cereals daily. More than 90% of Indian and Pakistani children ate bread, naan, or chapati daily. Bangladeshi children ate them less frequently: 46% at least once a day, but 85% at least once a week. Twenty eight per cent of Indian children never ate meat. Bangladeshi children were the most likely (31%) to eat meat every day. Although Pakistani children did not eat meat as frequently as this, 96% ate meat at least once a week. Twenty two per cent of Bangladeshi children ate fish at least once a day. Only 1% of Pakistani and 2% of Indian children ate fish that frequently, but 75% of Pakistani and about 50% of the Indian children ate fish at least once a week. Thirty six per cent of Indian, 14% of Bangladeshi, and 12% of Pakistani children never ate fish.

At age 2 years, 46% of Indian, 43% of Bangladeshi, and 38% of Pakistani children were given vitamin or iron supplements. Three per cent of Pakistani and 2% of Indian and Bangladeshi children were given iron supplements. About a quarter of children in all groups were given Department of Health vitamin drops containing vitamins A, D, and C.

Table 4 Haemoglobin concentration by ethnic group excluding children with β thalassaemia or HbE trait

Haemoglobin concentration (g/l)	Bangladeshi (%)	Pakistani (%)	Indian (%)	NDNS 1.5–2.5 years
< 100.0	13	14	9	2
< 105.0	16	19	13	4
< 110.0	25	29	20	12
< 120.0	58	59	58	51
< 130.0	87	91	91	84
< 140.0	98	99	99	99
All	100	100	100	100
Weighted base	239	311	430	310
Mean	116	114	116	120
Median	118	117	118	119
Lower 2.5 centile	84	80	90	102
Upper 2.5 centile	140	137	136	137
SE	0.9	0.8	0.5	0.5
SD	14.5	14.1	10.9	9.2

NDNS, National Diet and Nutrition Survey: children aged 1.5–4.5 years.¹ Data for children aged 1.5–2.5 years.

Table 5 Serum ferritin concentration by ethnic group

Serum ferritin (μ g/l)	Bangladeshi (%)	Pakistani (%)	Indian (%)	NDNS 1.5–2.5 years
< 5.0	8	13	7	9
< 10.0	39	45	41	28
< 20.0	74	75	76	60
< 30.0	92	90	89	77
Weighted base	197	252	350	300
Mean (average value)	15.0	13.9	15.7	21.0
Median	11.0	10.0	12.0	16.0
Lower 2.5 centile	3.0	3.0	3.0	4.0
Upper 2.5 centile	49.2	42.3	57.7	78.0
SE	0.82	0.69	0.76	1.10
SD	11.48	10.98	14.20	18.70

NDNS, National Diet and Nutrition Survey: children aged 1.5–4.5 years.¹ Data for children aged 1.5–2.5 years.

Table 6 Factors found by bivariate analysis to be related to haemoglobin < 110.0 g/l

	Bangladeshi	Pakistani	Indian
Bottle fed from birth	NS	Yes	NS
Bottle fed—mainly casein formula at 5 months	NS	NS	Yes
Bottle fed—mainly cows' milk at 9 months	Yes	Yes	NS
Milk in bottle or cup—mainly cows' milk at 15 months	NS	NS	Yes
Bottle fed at age 2—600 ml or more of cows' milk daily	NS	Yes	NS
Bottle fed at age 2—700 ml or more of cows' milk daily	NS	NS	Yes
Among those with the fastest rate of growth from birth to 15 months	Yes	NS	NS
Second or later baby	NS	Yes	NS

Yes, significant at the 95% confidence interval.

BLOOD RESULTS

The mean haemoglobin values for Bangladeshi and Indian children was 116.0 g/l and for Pakistani children 114.0 g/l, compared with a mean of 120.0 g/l for children aged 1.5 to 2.5 in the NDNS. Twenty nine per cent of Pakistani children, 25% of Bangladeshi, and 20% of Indian children had haemoglobin concentrations below 110.0 g/l compared with the NDNS results of 12% below 110.0 g/l (table 4).

Table 7 Factors found by bivariate analysis to be related to ferritin < 10.0 μ g/l

	Bangladeshi	Pakistani	Indian
Bottle fed—mainly casein formula at 5 months	Yes	NS	NS
Bottle fed—mainly cows' milk at 9 months	Yes	Yes	NS
Milk in bottle or cup—mainly cows' milk at 15 months	NS	NS	Yes
Bottle fed at age 2—500 ml or more of cows' milk daily	Yes	NS	NS
Bottle fed at age 2—700 ml or more of cows' milk daily	NS	Yes	Yes
Does not eat meat daily	Yes	NS	NS
Among those with the fastest rate of growth to 15 months	Yes	NS	NS
Not given vitamins at age 2	NS	NS	Yes
Second or later baby	NS	NS	Yes
Number of children in the family	NS	Yes	NS
Mother not born in UK	NS	Yes	NS
Mother has little or no understanding of English	NS	Yes	NS

Yes, significant at the 95% confidence interval.

The mean ferritin concentrations were 15.7 μ g/l for Indian, 15.0 μ g/l for Bangladeshi, and 13.9 μ g/l for Pakistani children. The mean concentrations for children in the NDNS was 21.0 μ g/l. If the lower limit of the normal range is taken as 10.0 μ g/l,⁵ then 45% of Pakistani, 41% of Indian, and 39% of Bangladeshi children had values below this compared with 28% of children from the NDNS (table 5).

FACTORS AFFECTING HAEMOGLOBIN AND FERRITIN CONCENTRATIONS

Table 6 shows the characteristics of children with a haemoglobin concentration < 110.0 g/l and table 7 shows the characteristics of children with a ferritin concentration < 10 μ g/l, which proved to be significant in bivariate analysis. Some of these factors may be interrelated. By using a modelling analysis (multiple regression) it is possible to identify the factors that have the greatest impact on, for example, the child's haemoglobin concentration and those that have no significant impact when the main factors have been taken into account. The variables included in the analysis are those that might be expected from the bivariate analysis of data from this study or from previous studies (see discussion) to have a significant effect on the concentration of haemoglobin or ferritin. The distribution of ferritin was skewed so a log transformation was done.

Table 8 shows variables significant for at least one ethnic group in predicting haemoglobin and ferritin concentrations. Table 9 shows characteristics associated with haemoglobin concentration at age 2 years, and table 10 shows characteristics associated with ferritin concentration at this age. As only two thirds of the samples collected were sufficiently large to include a ferritin estimation, the model to analyse the characteristics associated with ferritin are based on a smaller sample than that described for haemoglobin.

The two most significant factors affecting haemoglobin concentrations of Bangladeshi and Pakistani children were a negative association between haemoglobin at age 2 and weight gain from birth to 15 months and whether they were mainly given cows' milk at 9 months. The haemoglobin values of Pakistani children were also negatively related to the number of children in the family. Among Bangladeshi children, the amount of cows' milk consumed in a bottle at 2 years of age was also a significant factor. Bivariate analysis showed that Bangladeshi children who were anaemic were significantly more likely to be bottle fed and consumed on average 600 ml or more of cows' milk daily.

The significant factors affecting haemoglobin concentrations of Indian children differed from other groups. They were more likely to have a lower haemoglobin concentration if they were mainly given cows' milk at 15 months or their mother was Muslim. Indian children were likely to have higher haemoglobin concentrations if they received a vitamin supplement or ate cereal at 2 years of age.

Among children in all groups, the two most significant factors that affected the concentra-

Table 8 Variables included in multiple regression to predict haemoglobin and ferritin concentrations

	Haemoglobin	Ferritin
<i>Variables significant for at least one ethnic group</i>		
Fed cows' milk at 9 months	Yes	Yes
Fed cows' milk at 15 months	Yes	Yes
Amount of cows' milk drunk at 2 years	Yes	Yes
Weight gain—birth to 15 months	Yes	Yes
Whether given vitamins at 2 years	Yes	Yes
Whether eats cereal daily	Yes	NS
Number of siblings	Yes	NS
Mother's country of birth	NS	Yes
Mother's religion—Muslim	Yes	NS
<i>Variables not significant for any group</i>		
Bottle fed from birth		
Fed casein formula at 9 weeks		
Fed casein formula at 5 months		
Age first ate solid food		
Whether family received income support		
Mother's understanding of English		
Whether ate meat or fish daily at 2 years		
Whether weaning problems reported at 15 months		
Birth weight		
Birth order		

Yes, significant at the 95% confidence interval.

tion of ferritin at 2 years old were whether they were mainly given cows' milk at 15 months and the amount of cows' milk consumed in a bottle at 2 years of age. Pakistani children were also likely to have a lower concentration of ferritin if they were mainly given cows' milk at 9 months.

Although the models indicate factors that affect haemoglobin and ferritin values, a large proportion of the variance is still unexplained. The proportion of the variance explained by the models to predict haemoglobin was 9–10% and those to predict ferritin levels was 11–17%. While these figures are not unusual for this type of modelling, the results should be used with care.

Discussion

IRON DEFICIENCY IN ETHNIC GROUPS

This is the first large, nationally representative survey of Asian children covering most areas with an Asian community in England. The

prevalence of anaemia (20–29%) concords with the local smaller studies done in the past 10 years, which have described a high prevalence of anaemia (defined as haemoglobin < 110.0 g/l) in young Asian children compared with white children living in the same areas: Ehrhardt surveyed children aged between 6 months and 4 years admitted to hospital in Bradford and found a prevalence of 28% with a low haemoglobin concentration in 225 Asian children (mainly Pakistani) compared with 12% in 373 non-Asian children⁶; 68% of a sample of 55 Asian 2 year olds had a haemoglobin < 120.0 g/l in a study in Rochdale compared with 23% of a similar sample size of white children of the same age⁷; a study of 51 1 year old infants in London found a prevalence of 26% in Asian children (mainly Bangladeshi) and 12% in non-Asians⁸; a later study also in east London screened children aged 8 months to 2 years and found a prevalence of anaemia of 16% in Asian (mainly Pakistani) and 9% in white children (sample size 62 and 52 respectively)⁹; Marder *et al* found a prevalence of 39% anaemia in 44 Asian children from inner city Nottingham aged 15 months to 2 years and 16% in white children.¹⁰ A number of studies that did not include a white comparison group have described a high prevalence of haemoglobin < 110.0 g/l: Grindulis *et al* studied 135 Asian children aged 22 months in Birmingham and described a prevalence of 31% anaemia¹¹; a prevalence of 24% was described in 138 Asian children in Sheffield aged 12 months to 2 years.¹²

FERRITIN

Serum ferritin is reduced in iron deficiency, and in adults correlates with the quantity of storage iron in the body.¹³ It would be expected to decrease before erythropoiesis would be affected, although this did not seem to be the case in these groups, as indicators of iron deficient erythropoiesis were detected in many more children than the 8–13% who had low ferritin values. Most studies where a high prevalence of haemoglobin < 110.0 g/l has been found also describe a high prevalence of ferritin values below 10 µg/l for Asian and white children; in the most recent study, 48% of children had low ferritin values and 24% also had low haemoglobin concentrations¹²; other studies in children have described a prevalence of low ferritin values of approximately double the prevalence of low haemoglobin values.^{6–8} In the NDNS for children aged 1.5 to 2.5 years a correlation between haemoglobin concentration and ferritin of 0.12 ($p < 0.05$) was found. Twenty eight per cent of children had low ferritin values compared with 12% with low haemoglobin values. A significant correlation of 0.37 (Bangladeshi), 0.32 (Pakistani), 0.21 (Indian) ($p < 0.01$) was found between haemoglobin and ferritin in this study, although we find it difficult to explain the unexpectedly high proportion who had normal ferritin concentrations. Infection is known to increase serum ferritin values, and it may be that the Asian children in this study had more infections than their white counterparts in the

Table 9 Characteristics associated with haemoglobin concentration at 2 years old

	Bangladeshi	Pakistani	Indian
All children†			
Constant: base haemoglobin (g/l)	135.8	130.8	118.0
Weight gain: birth to 15 months	-2.14**	-1.62**	NS
Cows' milk at 9 months	-6.11**	-7.30**	NS
Amount of cows' milk at 2 years	-0.008*	NS	NS
Number of siblings	NS	-1.40*	NS
Given vitamins at 2 years	NS	NS	4.00**
Cows' milk at 15 months	NS	NS	-5.31**
Eats cereal daily	NS	NS	2.43*
Muslim	NS	NS	-2.83*
Percentage of variance explained by model	10	9	9

* $p < 0.05$; ** $p < 0.01$.

†Children with β thalassaemia or haemoglobin E trait excluded.

Table 10 Characteristics associated with concentration of ferritin (log values) at 2 years old

	Bangladeshi	Pakistani	Indian
Constant: base ferritin (µg/l)	3.96	3.78	2.93
Cows' milk at 15 months	-0.42**	-0.37**	-0.46**
Amount of cows' milk at 2 years	-0.0005**	-0.0004**	-0.0003**
Weight gain: birth to 15 months	-0.13**	-0.08*	NS
Mother not born in UK	NS	-0.25*	NS
Cows' milk at 9 months	NS	-0.38**	NS
Given vitamins at 2 years	NS	NS	0.21**
Percentage of variance explained by model	16	17	11

* $p < 0.05$; ** $p < 0.01$.

NDNS study, although children with a current or recent infection were not asked to give a blood sample. It has been noted in a previous study that Asian parents reported more infections in their children during their first year compared with white children.⁷

DIET

A number of dietary practices that may predispose to iron deficiency have been described in Asian populations in the UK. Compared with white mothers, Asian mothers tend to introduce solid foods later,^{7 8 14 15} and although we confirmed this finding,⁴ more than 90% of children from all groups were receiving some solids by 4 months of age. Asian children are reported to receive more sweet desserts and fewer savoury and meat based foods than white children during infancy,^{7 15} although Thomas and Avery showed that only Bangladeshi children ate desserts more frequently than white children.⁴ In the current study, meat consumption at 2 years of age was not found to be significantly associated with iron status. The Asian children consumed meat less frequently at 15 months than did white children; 53% of Bangladeshi, 30% of Pakistani, and 21% of Indian children ate meat daily compared with 69% of white children. Twenty two per cent of Indian households were vegetarian.

Apart from milk, the only food that was significantly associated with iron status was seen in Indian children, where those who ate breakfast cereal daily at 2 years of age were less likely to be anaemic. Data on iron content of cereals was not documented, but the majority of breakfast cereals in the UK are fortified with iron.

Although there appears to be no correlation between dietary iron intake and iron status,⁹ iron intake in Asian children has been described as being similar to,⁷ or lower than,^{9 12 13} similar samples of white children. Some attempts have been made to make a more general assessment of diet,¹⁶ and in a mainly white sample of children in Montreal, iron deficiency was associated with a "poor diet".¹⁷ In our study, white children at 15 months ate a greater variety of foods in their diet than any of the Asian groups.⁴

A characteristic of Asian weaning diets is the emphasis and value put on cows' milk as a staple food for young children. Asian mothers tend to introduce cows' milk as a main drink earlier than white families do and encourage young children to drink larger quantities, with up to 60% of energy intake at 18 months derived from milk.¹² Several studies have described an increased risk of poor iron status in children who received cows' milk as their main drink before 1 year of age. Most have found that the introduction of cows' milk at 6 months of age results in a poorer iron status between 1 and 2 years of age compared with children who received an iron fortified formula until the age of 1,^{8 18 19} and one study showed that continuing with an iron fortified formula until 18 months had an advantage in terms of iron status at age two years.²⁰ Two studies have not shown any association between age of

introduction of cows' milk and subsequent iron status.^{11 12} Mills described an effect of cows' milk on iron status after introduction at 8 months of age.⁹ In our study, the introduction of cows' milk at 9 months increased the risk of iron deficiency in Bangladeshi and Pakistani children. The iron status of Indian children was only affected if cows' milk was given at age 15 months. This study endorses the recommendation by the Department of Health that cows' milk should not be used as a main drink before the age of 1.²¹

The quantity of cows' milk was shown to be negatively associated with iron status; Bangladeshi and Pakistani children who consumed more than 600 ml daily and Indian children who consumed more than 700 ml daily were found to be at greater risk of iron deficiency. These quantities are considerably smaller than the volumes associated with poor iron status in some earlier studies. Morton suggested that an intake of 900 ml was a risk factor for iron deficiency,⁸ although Kim found that as little as 500 ml at 6 months had an effect.¹⁹ Mills found no direct correlation between volume of milk consumed and haemoglobin concentrations but did report that iron deficiency was more common in Asian children consuming more than 1000 ml daily.⁹ The use of feeding bottles after the age of 1 was associated with higher milk consumption,⁴ and previous studies have described prolonged use of feeding bottles in Asian children.^{7 14 15} We found that at 15 months at least 90% of Asian children were still bottle fed, if only partially, compared with 75% of white children; 67% of white children drank milk from a cup at this age compared with 50% of Indian, 41% of Pakistani, and 26% of Bangladeshi children.⁴ The addition of cereal or sugar is more common among Asian mothers¹⁴; in the current survey approximately a third of Bangladeshi mothers added something to the milk of their 15 month old child: mainly rusk, baby rice, or other cereal; 10% of Pakistani mothers added sugar. It is likely that sweetening the milk and the use of a baby bottle compared with a cup is likely to encourage a high consumption of milk to the detriment of other foods. Milk is a valuable food for children and 600 ml is commonly recommended as being a suitable volume; further work needs to be done on the optimum quantity of milk for young children.

GROWTH AND IRON STATUS

Birth weight and growth velocity are considered to be major influences on iron status during 6–12 months of age. Faster growing children are theoretically at greater risk of deficiency; evidence is conflicting, although most studies have considered a younger age group than those in this study. No correlation was found between growth and iron status up to 1 year of age in one study,²² while Morton found that iron deficiency at 1 year of age was significantly correlated with a greater weight gain.⁸ Two studies of white children in Europe have described a negative effect of growth velocity on iron stores although not on haemoglobin values. In one study, infants were measured at

1 year,²³ whereas the other study examined older children with a mean age of 7.1 years.²⁴ In our study, we found no relation between weight gain up to 15 months and haemoglobin values, but ferritin values showed a significant relation with weight gain between birth and 15 months in the Bangladeshi group. We find this difficult to explain because Bangladeshi children were smaller than white children and children from the other Asian groups at 15 months of age,⁴ and although their increases in length and weight from birth to 15 months were larger than for the white group, the increase was still smaller than that seen in the two other Asian groups.

SOCIOECONOMIC AND ETHNIC FACTORS

We examined socioeconomic factors such as family size, income, education, and birthplace of mother. None of these factors showed an association with iron status for any of the Asian groups. The iron status of Pakistani children was negatively associated with the number of siblings in the family. Among Bangladeshi and Pakistani children, iron status was negatively associated with the mother being born outside of the UK; in addition, Bangladeshi children tended to have poorer iron status if their mother did not have a good understanding of English. Indian children were more likely to have poorer iron status if their mother's religion was Muslim; this may reflect the socioeconomic characteristics of Indian Muslims who, in our study, tended to be less well educated than other Indian mothers.

We have difficulty in explaining the reason for different factors being associated with iron status in the three groups who all originated from the same sub-continent; the higher prevalence of iron deficiency in the Pakistani children is puzzling also because Pakistanis have usually been established in the UK for longer than Bangladeshis, who tend to be among the more recent immigrants. In the current study, 68% of Bangladeshi, 56% of Pakistani, and 50% of Indian mothers had arrived in the UK within the past 10 years.⁴ Differences in red cell indices between Afro-Caribbean and white ethnic groups has recently been reported.²⁵ Wharton questions the possibility of a genetic influence on the expression of transferrin and transferrin receptors.²⁶ The prevalence of iron deficiency is higher for children in Africa and southern Asia than in other areas of the developing world.²⁷ It may be that there are racial differences, and our data require further analysis to determine whether it is appropriate to compare Asian children directly with white children.

CONCLUSIONS

There is considerable evidence of an association between iron deficiency and impaired mental and motor function in childhood in various ethnic groups,²⁸ although a causative effect of iron deficiency has been questioned.²⁹ We are concerned that our large national study has confirmed that up to one third of children from three different Asian groups in the UK have haemoglobin concentrations that may be

associated with delayed development. The downward trend in the prevalence of iron deficiency seen in the United States during the 1970s seems not to have occurred here³⁰; it is interesting to note that this trend appears to have reached a plateau with a prevalence of iron deficiency among children aged 1 to 2 years in the United States that is slightly lower (9%) than the NDNS study.³¹ No single factor or, indeed, no model using a number of factors explains more than a small proportion of the variance in the current study. The causes of low haemoglobin values in this group remain largely unexplained; further work needs to be done to determine appropriate normal values of indicators of iron status in populations of non-white children: whether there are differences in iron absorption in young Asian children and what are the specific effects of poverty and infection on iron status. A number of prevention strategies have been suggested,³² but before such strategies can be successful, more evidence is needed about the mechanisms underlying iron deficiency in young children.

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- Gregory JR, Collins DL, Davies PS, *et al.* National diet and nutrition survey: children aged 1.5 to 4.5 years. Vol 1. *Report of the diet and nutrition survey*. London: HMSO, 1995.
- WHO. Nutritional anaemias. *WHO technical report series no 503*. Geneva: WHO, 1972.
- Lawson M. Iron in infancy and childhood. In: *British nutrition foundation. Iron. Nutritional and physiological significance*. London: Chapman and Hall, 1995:93–105.
- Thomas M, Avery V. *Infant feeding in Asian families*. London: The Stationery Office, 1997.
- Dallman PR, Looker AC, Johnson CL, *et al.* Influence of age on laboratory criteria for the diagnosis of iron deficiency anaemia and iron deficiency in infants and children. In: Hallberg L, Asp NG, eds. *Iron nutrition in health and disease*. London: John Libbey, 1996:65–76.
- Erhardt P. Iron deficiency in young Bradford children from different ethnic groups. *BMJ* 1986;**292**:90–3.
- Warrington S, Storey DM. Comparative studies on Asian and Caucasian children 1: growth; 2: nutrition, feeding practices, and health. *Eur J Clin Nutr* 1988;**42**:61–7, 69–80.
- Morton RE, Nysenbaum A, Price K. Iron status in the first year of life. *J Pediatr Gastroenterol Nutr* 1988;**7**:707–12.
- Mills AF. Surveillance for anaemia: risk factors in patterns of milk intake. *Arch Dis Child* 1990;**65**:428–31.
- Marder E, Nicoll A, Polnay L, *et al.* Discovering anaemia at child health clinics. *Arch Dis Child* 1990;**65**:892–4.
- Grindulis H, Scott PH, Belton NR, *et al.* Combined deficiency of iron and vitamin D in Asian toddlers. *Arch Dis Child* 1986;**61**:843–8.
- Duggan MB, Steel G, Elwys G, *et al.* Iron status, energy intake, and nutritional status of healthy young Asian children. *Arch Dis Child* 1991;**66**:1386–9.
- Worwood M. Mechanisms of cellular iron status. *British Nutrition Foundation. Iron. Nutritional and physiological significance*. London: Chapman and Hall, 1995:17–22.
- Williams SA, Sahota P, Fairpo CG. Infant feeding practices within white and Asian communities in inner city Leeds. *J Hum Nutr and Diet* 1989;**2**:325–38.
- Williams SA, Sahota P. An enquiry into the attitudes of Muslim Asian mothers regarding infant feeding practices and dental health. *J Hum Nutr Diet* 1990;**3**:393–401.
- Boutry M, Needham R. Use of diet history in the screening of iron deficiency. *Pediatrics* 1996;**9**:1138–41.
- Lehman F, Gray Donald K, Mongeon M, *et al.* Iron deficiency anaemia in 1 year old children of disadvantaged families in Montreal. *Can Med Assoc J* 1992;**146**:1571–7.
- Tunessen WW Jr, Oski FA. Consequences of starting whole cows' milk at 6 months of age. *J Paediatr* 1987;**111**:813–16.
- Kim SK, Cheong WS, Jun YH, *et al.* Red blood cell indices and iron status according to feeding practices in infants and young children. *Acta Paediatr* 1996;**85**:139–44.
- Daley A, MacDonald A, Aukett A, *et al.* Prevention of anaemia in inner city toddlers by an iron supplemented cows' milk formula. *Arch Dis Child* 1996;**75**:9–16.

- 21 Department of Health. Weaning and the weaning diet. *Report on health and social subjects No 45*. London: HMSO, 1994.
- 22 Hasckhe F, Vanura H, Male C, *et al*. Iron nutrition and growth of breast and formula fed infants during the first 9 months of life. *J Pediatr Gastroenterol Nutr* 1993;**16**:151–6.
- 23 Micaelson KF. Nutrition and growth during infancy. *Acta Paediatr* 1997;**86**(suppl):420.
- 24 Vihervuori E, Cook JD, Siimes MA. Iron status of children with short stature during accelerated growth due to growth hormone treatment. *Acta Paediatr* 1997;**86**:588–93.
- 25 Himes JH, Walker SP, Williams S, *et al*. A method to estimate the prevalence of iron deficiency in adolescent Jamaican girls. *Am J Clin Nutr* 1977;**65**:831–6.
- 26 Wharton BA. Iron nutrition in childhood: the interplay of genes, development and environment. *Acta Paediatr Scand* 1989;**36**(suppl):5–11.
- 27 De-Maeyar E, Adiels Tegnman M. The prevalence of anaemia in the world. *World Health Stat Q* 1985;**38**:302–16.
- 28 Walter T. Effect of iron deficiency anaemia on cognitive skills in infancy and childhood. In: Hallenberg L, Asp NG, eds. *Iron nutrition in health and disease*. London: John Libbey, 1996:219–29.
- 29 Logan S. Commentary on iron deficiency anaemia in infancy and early childhood. *Arch Dis Child* 1997;**76**:553–4.
- 30 Yip B, Binkin NJ, Fleshood L, *et al*. Declining prevalence of anaemia among low income children in the United States 1987;**258**:1619–23.
- 31 Looker AC, Dallman PR, Carroll MD, *et al*. Prevalence of iron deficiency in the United States. *JAMA* 1997;**277**:973–6.
- 32 Booth IW, Aukett MA. Iron deficiency anaemia in infancy and early childhood. *Arch Dis Child* 1997;**76**:549–54.