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Factors associated with Hb concentration in children aged 6–59 months in the State of Pernambuco, Brazil

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In 1997, the prevalence of anaemia was 40·9 % among children aged 6–59 months in the State of Pernambuco, north-east Brazil. Using the same sample of children, we have investigated possible reasons for this high prevalence. A representative sample was selected through a three-stage process: proportional systematic random sampling of municipalities in the State, systematic random sampling of census sectors within these municipalities, and finally, simple random sampling of households with children aged 6–59 months to obtain the sample of 650 children. Data collection included demographic, environmental, socio-economic and maternal variables, and nutritional status and dietary intakes of the children. Multiple linear regression analysis was based on a hierarchical model of factors associated with Hb concentration. The mean Hb concentration of children aged 6–23 months was 10 g/l lower than that of older children. In the regression analysis, child age explained 8·3 % of the variance in Hb concentration. The intake of bioavailable Fe explained a further 3·3, serum retinol 2·7, diarrhoea 2·4, water treatment 1·7, sanitation 1·3 and low birth-weight 0·5 %. The final model explained 23·4 % of the variance in Hb concentration. We conclude that child age, bioavailable-Fe intake, serum retinol concentration, diarrhoea, water treatment, sanitation and low birth-weight are independently associated with Hb concentration. In north-east Brazil, anaemia prevention programmes among children should focus on those aged <2 years and should consider feasible strategies to improve intakes of bioavailable Fe and vitamin A, and reduce infection. Supplemental Fe should be given to low birth-weight infants.

Anaemia in Brazil: Haemoglobin concentration: Bioavailable iron intake: Pre-school child

Fe-deficiency anaemia is a major nutritional problem throughout the world and more than 2 billion people are estimated to be anaemic (United Nations International Children's Emergency Fund, 1998). Young children and pregnant women are most affected. In 1997, in a State-wide survey of anaemia prevalence among children aged 6–59 months in Pernambuco, north-east Brazil, the prevalence was 61·8 % at 6–23 months and 31·0 % at 24–59 months, with an overall prevalence of 40·9 % (Osório *et al.* 2001). We now explore possible reasons for this high prevalence by building a multiple regression model of biological, socio-economic, nutritional and other factors associated with Hb concentration in a representative sample of young children in the State of Pernambuco.

Subjects and methods

Location

The present study was carried out in Pernambuco, north-east Brazil. This State covers approximately 100 000 km^2 and has an estimated population of >7 million, of which 10 % are children <5 years old (Instituto Brasileiro de Geografia e Estatística, 2001). Most of the population reside in and around the capital (Recife) or in small towns in the interior. Along the eastern seaboard, the climate is predominantly hot and humid, with sugar cane constituting the main crop. To the west, the climate becomes increasingly dry and most families are subsistence farmers living in harsh conditions. In Pernambuco, infant mortality during 1999 was 58·2 per 1000 live births, 24·7 % of the population aged ≥15 years were illiterate and 74·5 % of families with children <6 years old earned one minimum wage or less *per caput* (Instituto Brasileiro de Geografia e Estatística, 2001). One minimum wage is approximately US $80 per month.

Study design

The data are from a cross-sectional survey undertaken during February–May 1997 in a representative sample of households in Pernambuco.

Abbreviations: EF, enhancing factor; IQR, interquartile range.

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Subject selection

Sampling was carried out in three stages. The first stage was proportional systematic random sampling in which eighteen out of a total of 178 municipalities were selected to reflect the population distribution of the State. For the second stage, systematic random sampling of the census sectors within these municipalities was carried out and a total of forty-five sectors (out of 2655) were selected. Each census sector had approximately 200 households. Finally, households in each selected sector were visited to identify children aged 6–59 months. The starting point in each sector was randomly determined from the census map, selecting one block at random and then one corner of that block, also at random. Then in a clockwise direction, households were visited one by one, taking all eligible children, until the required sample of 650 children was selected. On average, fourteen children per sector were selected.

Socio-economic, demographic, breast-feeding and child morbidity characteristics

Information about area of residence (metropolitan region of Recife, urban interior, rural interior), household environment (water supply, water treatment, sanitation, garbage collection), family income (in minimum wages *per caput*), maternal education, maternal age, paid maternal work and antenatal care was collected at home by structured questionnaires. For the index children the variables were age, gender, duration of breast-feeding, diarrhoea in the last 2 weeks, and cough in the last week.

Blood collection

Blood was collected from an antecubital vein by trained fieldworkers after obtaining permission of the mother or custodian. Hb concentration was measured with a portable haemoglobinometer (HemoCue Limited, Sheffield, Yorks., UK), following the manufacturer's instructions.

Serum retinol

After centrifuging the blood, serum samples were protected from light and transported in dry ice to the Biochemical Laboratory of the Federal University of Pernambuco, where they were analysed by the method of Araújo & Flores (1978).

Anthropometric measurements

Children were weighed on a spring balance (Itac Co., Silver Spring, MD, USA; 25 kg × 100 g). Length or height were measured to the nearest 1 mm with a locally manufactured stadiometer. Children <2 years old were measured lying down and older children were measured standing. All children were measured without shoes and wearing lightweight shorts, using standard techniques (World Health Organization, 1983). Two measurements were taken and the mean value was used. Birth weight was obtained from each child's health record.

Iron intake and iron bioavailability

Food consumption of the index children was estimated by 24 h recall. Recipes were obtained for composite dishes and amounts were reported in household measures (small, medium or large spoons, cups, etc.). Breast-milk intake was estimated from the number of breast-feeds, using average volumes according to child age (Virtual-Nutri software, version 1.0 for Windows, Philippi *et al.* 1996). Amounts of food and breast milk consumed were converted to nutrients using national food composition tables (Instituto Brasileiro de Geografia e Estatística, 1977) and the corresponding software (Virtual-Nutri software, Philippi *et al.* 1996). For missing items the Instituto de Nutrición de Centro América y Panamá/Comité Interdepartamental de Nutrición para la Defensa Nacional (1970) food composition tables were used. For each meal and snack, the intakes of ascorbic acid, and of haem and non-haem Fe, were calculated.

The algorithm of Monsen & Balinfy (1982) was used to calculate the % absorption of non-haem Fe, taking into account the quantity of enhancing factors (EF) present in each meal, where 1 EF is equivalent to 1 mg ascorbic acid or 1 g cooked meat, fish or poultry. In this method, the absorption of non-haem Fe ranges from 3 (no EF present) to 8 (≥75 EF present) %. When ΣEF is <75, the % absorption $= 3 + 8{\cdot}931 \quad \log((\text{EF} + 100)/100)$. For each meal and snack, the % absorption of non-haem Fe was calculated, and then the intake of bioavailable non-haem Fe was obtained. Haem Fe absorption is relatively unaffected by other constituents in the meal and its absorption was assumed to be 23 % (Monsen *et al.* 1978; Monsen & Balinfy, 1982). Bioavailable Fe intakes were then summed to obtain the 24 h intake.

Ethical permission

The present study had the approval of the Ethical Committee of the Federal University of Pernambuco. Children diagnosed with anaemia were treated with 3 mg elemental Fe (as $FeSO_4$)/kg per week for 6 months and advised to go to their local clinic for follow-up.

Data analysis

The questionnaires were checked daily for accuracy, consistency and completeness. Double data entry was conducted by two data clerks independently and verified using Epi-info 6·04 (1994). Height-for-age, weight-for-age and weight-for-height Z-scores were calculated with the Epinut software (Epi-info 6·04, 1994). A correlation matrix indicated that there was no multi-collinearity among the variables since the correlation coefficients were <0·36, except for weight-for-age *v.* height-for-age (0·70).

Multiple linear regression analysis was based on a hierarchical model according to the logical or theoretical relationships between biological and social factors, and consideration of potential confounding (Victora *et al.* 1997). According to this technique, each explanatory variable is assessed in terms of what it adds to the equation at its own point of entry. The degree of association between the outcome and the explanatory variables is reassessed at each step of the hierarchy (Tabachnik & Fidel, 1996). All variables with $P<0{\cdot}2$ in the bivariate analyses (except geographic area) were selected for initial inclusion and each was then entered stepwise, following the hierarchical model. Those with $P<0{\cdot}05$ were retained for the multiple regression analysis. A five-stage process was used for model selection. In the first model, family income, maternal education, maternal paid work and environmental factors were assessed, and in model 2 maternal age and antenatal visits were added. Although these factors do not directly influence Hb concentration, they may affect the proximal factors. Model 3 showed the effect of breast-feeding duration and bioavailable Fe intake after controlling for socio-economic and maternal variables. In model 4, diarrhoea, cough and nutritional status indicators were included. Finally, in model 5, child age and sex were added, adjusting for all the variables in this model. R^2 adjusted indicates the multiple correlation coefficient of the explanatory variables on Hb concentration in the final model. The change in R^2 defines the contribution of each variable to the coefficient of determination (i.e. the difference after entering each variable).

Statistical analyses were undertaken with the statistical package STATA, version 5.0 (1999; Stata Corporation, College Station, TX, USA). The standard *t* test was used to compare differences between two mean values. One-way ANOVA was used for more than two mean values. Statistical significance was taken as $P\leq 0{\cdot}05$.

Results

Dietary pattern

The staple adult diet in Pernambuco is rice and beans, with meat or fish whenever the family can afford. Vegetables are not widely consumed apart from onions and tomatoes, which are used for flavouring or as a relish. Fruit consumption tends to be low in the dry interior and among poor urban families. Among the children studied, cereal porridge with added milk and sugar was the main food eaten by those aged 6–23 months, and foods with a high Fe content (meat, beans, leafy vegetables) were consumed by few children at this age (Table 1). Milk, when consumed, was typically processed dried milk. Fresh milk was rarely used. Older children had a more varied diet, although fish was rarely eaten and meat intakes tended to be small (median value 30 g/d). The median intake of vitamin C was 29 mg/d, and varied little with child age.

Table 1. Comparison of foods eaten by children aged 6–23 months and 24–59 months (selected items from 24 h recall)

	Children eating (%)	
Food	6–23 months	24–59 months
Beans	32·6	63·5
Meat	28·5	54·1
Fish	1·0	3·5
Leafy vegetables	16·2	23·4
Fruit	56·3	62·5
Fe-fortified milk and cereal	48·8	33·0

For details of subjects, see p. 308.

Iron intake

Fig. 1 shows a comparison of the intakes of haem and non-haem Fe by child age. Intakes of haem Fe were negligible in children aged 6–23 months and low in older children with a median of 0·5 (interquartile range (IQR) 0·0, 1·7) mg/d. Intakes of non-haem Fe increased progressively with age, with a median intake at 24–59 months of 6·2 (IQR 4·0, 8·6) mg/d. Intakes of bioavailable Fe by age group are shown in Table 2 and compared with the requirement for absorbed Fe (Food and Agricultural Organization/ World Health Organization, 1988, 2002). A very pronounced shortfall between Fe intake and requirement is apparent among children aged 6–23 months. Children in the rural interior, where anaemia prevalence is highest, had the lowest intakes of bioavailable Fe, the median at 6–23 months being 0·24 (IQR 0·14, 0·51) and at 24–59 months 0·46 (IQR 0·25, 0·87) mg/d.

Bivariate analyses

Tables 3 and 4 show that all the socio-economic, maternal and child variables examined were associated with Hb concentration except maternal work, breast-feeding duration, cough and gender of child. The lowest mean Hb concentrations were associated with rural residence, low family income, no indoor piped water, untreated drinking water, no sanitation or garbage collection, fewer years of maternal schooling, younger mothers and no antenatal care. Of the child-related variables, the lowest mean Hb concentrations were associated with age 6–23 months, low birth-weight, low weight-for-age and length-for-age, lower serum retinol concentration, diarrhoea in the last 2 weeks and low Fe intake.

Regression analysis

Results of the multiple regression analysis for each of the five models are shown in Table 5. Seven variables remained significant after adjusting for other variables in the model. These were (% of the variance): child age 8·3, bioavailable Fe intake 3·3, serum retinol 2·7, diarrhoea 2·4, water treatment 1·7, sanitation 1·3, low birth-weight 0·5. Overall, the final model explained 23·4 % of the variance in Hb concentration.

Discussion

In this State-wide representative sample of children, Fe intakes of infants aged 6–11 months were grossly inadequate in all three geographic regions and failed to meet requirements by a substantial margin. Intakes were worst in the rural interior, where the prevalence of anaemia at 6–11 months old was 79 % (Osório *et al.* 2001). In this age group, porridge was the main food, meat and fish were not consumed, and few infants were breast-fed (9 %) and thus failed to benefit from the enhancing effect of breast milk on Fe absorption. Studies of attitudes to young

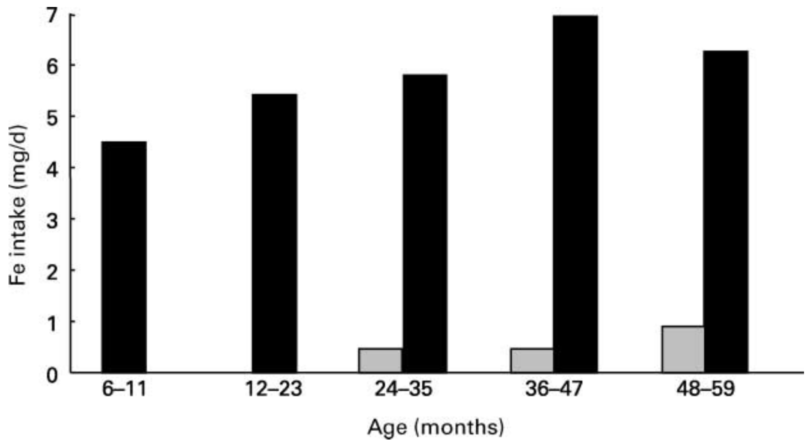

Fig. 1. Intakes of haem (□) and non-haem iron (■) by age group of children from the State of Pernambuco, Brazil. Values are medians. For details of subjects and procedures, see p. 308.

child-feeding in north-east Brazil show a strong reluctance among mothers to introduce meat, fish, beans and green leaves before the second year of life (Monte & Sá, 1998). Intakes of bioavailable Fe showed some improvement in children aged 12–23 months, but were still substantially below requirements. Children in the rural interior were again the worst affected. Fe intakes of young children could be improved by earlier introduction of family foods following existing recommendations (Monte & Sá, 1998; Brazil Ministry of Health, 2002).

By 24–47 months old, median bioavailable Fe intakes approximated to the median requirement, except for children in the rural interior where a substantial shortfall remained. By 48–59 months old, median Fe intakes exceeded requirements except for the rural interior. The Monsen & Balinfy (1982) algorithm does not take into account factors that inhibit non-haem Fe absorption such as phytates and polyphenols, and from 24–59 months old most children were consuming beans and 18 % drank coffee, both of which inhibit non-haem Fe absorption. Intakes of absorbed Fe in this age group may thus be overestimates. Although the algorithm is widely used for children (Zive *et al.* 1995; Tseng *et al.* 1997; Kohlmeier *et al.* 1998), its appropriateness is not known.

Children aged 6–23 months had on average 10 g Hb/l less than older children and in the regression analysis, the main determinant of Hb concentration was child age. In the final model, Hb concentration increased by 0·3 g/l for each month of age. Other researchers have found an effect of child age, but other factors were not controlled (Viteri *et al.* 1972; Brault-Dubuc *et al.* 1983; Sherriff *et al.* 1999). The independent effect of child age can be explained by the higher physiological requirement for Fe at younger ages (Table 2), because of faster rates of growth. The higher Fe requirement of young children is particularly problematic, because their energy requirements are lower than those of older children. Thus, the diet of younger children needs to provide more Fe per unit of energy intake than the diet of older children.

The intake of bioavailable Fe had a significant effect on Hb concentration and when first entered into the regression analysis the ß coefficient was 6 g/l for each 1 mg increase in bioavailable Fe intake. Its effect was greatly attenuated, however, when child age (reflecting Fe requirement) was introduced into the final model, at which point the deficit between intake and requirement assumed greater explanatory power on Hb concentration than intake alone. In the final model, bioavailable Fe intake explained only 3·3 % of the variance. Its explanatory power, however, will have been reduced if the values are imprecise or unrepresentative; this is likely, as dietary factors that inhibit Fe absorption were not considered and intakes were assessed by 24 h recall.

Serum retinol was significantly associated with Hb concentration ($P<0{\cdot}001$). Vitamin A is known to play an

Table 2. Median intakes of bioavailable iron (mg/d) by study children in comparison with requirements (median range and 95th centile) according to child age*

Age group (months)	Median intake of absorbable Fe (mg/d)	Median requirement of absorbable Fe (mg/d)†	95th centile requirement of absorbable Fe (mg/d)†
6–11	0·29	0·72	0·93
12–23	0·46	0·50	0·62
24–35	0·58	0·52	0·65
36–47	0·64	0·55	0·69
48–59	0·80	0·59	0·74

† The method set out by the Food and Agricultural Organization/World Health Organization (1988, 2002) was used to calculate the requirements for each age group.
* For details of subjects and procedures, see p. 308.

Table 3. Bivariate analyses of socio-economic and maternal variables and child Hb concentration (g/dl)*
(Mean values and 95 % confidence intervals)

Variable	*n*	Hb (g/dl)	95 % CI	Statistical significance of effect
Geographic area				
Rural interior	210	10·7	10·5, 10·9	$F_{(2,647)}$ 7·78, $P<0·001$
Metropolitan region of Recife	236	11·1	10·9, 11·3	
Urban interior	204	11·3	11·1, 11·5	
Family income (minimum wage per caput)				
<0·25	206	10·8	10·5, 11·0	$F_{(2,639)}$ 8·42, $P<0·001$
0·25–0·49	303	11·0	10·9, 11·2	
≥0·50	133	11·5	11·2, 11·7	
Water supply inside house				
No	232	10·7	10·6, 11·0	$t_{(650)}$ −3·46, $P<0·001$
Yes	418	11·2	11·0, 11·3	
Treatment of drinking water				
No	281	10·7	10·5, 10·9	$t_{(650)}$ 5·26, $P<0·001$
Yes	369	11·3	11·2, 11·5	
Sanitation				
None	260	10·8	10·6, 11·0	$F_{(2,647)}$ 12·93, $P<0·001$
Latrine	226	11·0	10·7, 11·1	
Flush toilet	164	11·6	11·3, 11·8	
Garbage disposal				
None	261	10·7	10·6, 11·0	$F_{(2,647)}$ 10·04, $P<0·001$
Burnt and/or buried	59	10·8	10·4, 11·2	
Collected	330	11·3	11·2, 11·5	
Maternal schooling (years)				
0–4	360	10·8	10·6, 11·0	$F_{(2,646)}$ 9·59, $P<0·001$
5–8	169	11·2	10·9, 11·4	
≥9	120	11·5	11·2, 11·8	
Maternal work outside home				
No	460	11·0	10·8, 11·1	$t_{(647)}$ −1·85, $P=0·064$
Yes	187	11·2	11·0, 11·4	
Maternal age (years)				
<20	44	10·6	10·2, 11·0	$F_{(3,643)}$ 3·76, $P=0·011$
20–24	191	10·8	10·6, 11·1	
25–29	173	11·3	11·1, 11·5	
≥30	239	11·2	10·9, 11·4	
Antenatal visits				
None	142	10·8	10·5, 11·1	$F_{(2,627)}$ 4·37, $P=0·013$
1–4	136	10·9	10·6, 11·1	
≥5	352	11·2	11·0, 11·4	

* For details of subjects and procedures, see p. 308.

important role in haematopoiesis and it is thought that it is involved in the mobilisation of stored Fe and its utilisation (Mejía *et al.* 1977; Bloem *et al.* 1989; Lynch, 1997). Vitamin A also affects susceptibility to infection, which impairs Fe absorption (Beresford *et al.* 1971; De Vizia *et al.* 1992). Provision of vitamin A has been shown to benefit Fe status (Mejía & Chew, 1988; Bloem *et al.* 1990); Bloem (1995) has advocated provision of vitamin A together with Fe in anaemia-control programmes in areas where vitamin A deficiency is endemic. High-dose vitamin A supplementation every 6 months to children <5 years old is health policy in Brazil, but is not implemented routinely in the north-east region. The findings of the present study suggest that improved coverage will help reduce childhood anaemia in this region.

Family income is considered an important determinant of anaemia and many studies have found, as in Brazil, that anaemia prevalence is worse in poor families (Sichieri, 1987; Sargent *et al.* 1996; Monteiro *et al.* 2000). We found, however, that income lost its significance when more proximal variables were added in the model. This does not mean that income is not important, but rather that it influences other variables such as sanitation, treatment of drinking water, morbidity, dietary intake and birth weight. Similarly, maternal schooling, which explained 2·5 % of the variance in Hb concentration, lost its significance when more proximal determinants were added to the model.

Sanitation and treatment of drinking water explained 3·0 % of the variance in Hb concentration. Poor public services are a feature of the rural interior and in the most recent survey of households, 66 % had no sanitation (Instituto Nacional de Alimentação e Nutrição/Ministério da Saúde, 1998). Sanitation is also poor in the *favelas* of metropolitan Recife. Poor sanitation and untreated drinking water increase the risk of oral–faecal transmission of diarrhoeal pathogens and intestinal parasites. Stool examination was not possible in the present study. Monteiro *et al.* (2000) have reported low infestation rates of helminths (5 %) and Giardia (6 %) in a large random sample of children <5 years in Sao Paulo, and it is possible that low prevalences would likewise be found in metropolitan Recife and in the urban interior. In 1989, in four small villages in rural Pernambuco, 80 % of inhabitants >1

Table 4. Bivariate analyses of child age, nutritional status, morbidity and iron intake and Hb concentration (g/dl)* (Mean values and 95 % confidence intervals)

Variable	*n*	Hb (g/dl)	95 % CI	Statistical significance of effect
Age group (months)				
6–23	249	10·4	10·2, 10·6	$t_{(650)}$ −8·86, $P<0·001$
24–59	401	11·4	11·3, 11·6	
Gender				
Male	334	11·2	11·0, 11·3	$t_{(650)}$ 1·76, $P=0·078$
Female	316	10·9	10·8, 11·1	
Birth weight (g)				
<2500	53	10·5	10·0, 11·0	$t_{(607)}$ −2·54, $P=0·011$
≥2500	554	11·1	11·0, 11·2	
Weight-for-age (Z-score)				
<−2	34	10·1	9·5, 10·7	$F_{(2,643)}$ 11·86, $P<0·001$
−2–<−1	134	10·8	10·4, 11·0	
≥1	478	11·2	11·1, 11·3	
Height-for-age (Z-score)				
<−2	80	10·4	10·0, 10·8	$F_{(2,642)}$ 15·96, $P<0·001$
−2–<−1	163	10·8	10·5, 11·0	
≥−1	402	11·3	11·2, 11·4	
Serum retinol (μg/dl)				
<20	87	10·6	10·3, 10·9	$t_{(483)}$ −3·40, $P<0·001$
≥20	396	11·2	11·1, 11·4	
Diarrhoea in last 2 weeks				
Yes	141	10·6	10·3, 10·8	$t_{(648)}$ −4·18, $P<0·001$
No	507	11·2	11·0, 11·3	
Cough in last week				
Yes	317	11·0	10·8, 11·1	$t_{(650)}$ −1·56, $P=0·119$
No	333	11·2	11·0, 11·3	
Breast feeding (months)				
<4	316	10·9	10·8, 11·1	$t_{(650)}$ −1·82, $P=0·069$
≥4	334	11·2	11·0, 11·3	
Total Fe intake (terciles)				
P<33	186	10·6	10·3, 10·8	$F_{(2,606)}$ 16·43, $P<0·001$
P33–<P66	215	11·1	10·9, 11·3	
≥P66	208	11·4	11·3, 11·6	
Haem Fe intake (terciles)				
<P66	383	10·8	10·6, 10·9	$t_{(609)}$ −6·61, $P<0·001$
≥P66	226	11·6	11·4, 11·8	
Non-haem Fe intake (terciles)				
P<33	192	10·6	10·4, 10·9	$F_{(2,504)}$ 11·32, $P<0·001$
P33–<P66	210	11·2	10·9, 11·4	
≥P66	207	11·4	11·2, 11·6	
Bioavailable Fe intake (terciles)				
<P33	185	10·6	10·4, 10·8	$F_{(2,606)}$ 17·42, $P<0·001$
P33–<P66	209	11·0	10·8, 11·2	
≥P66	215	11·5	11·3, 11·7	

* For details of subjects and procedures, see p. 308.

Table 5. Multiple regression models of Hb concentration (g/dl) and its explanatory factors (β-coefficients) in the State of Pernambuco, Brazil†

	Models						
Variables	1	2	3	4	5	R^2 (adjusted)	Change in R^2
Family income per caput (≥0·25‡ *v.*<0·25)	−0·12	−0·12	−0·07	−0·09	−0·12	0·013	0·013
Maternal schooling (≥5‡ *v.*<5 years)	−0·12	−0·12	−0·04	0·00	0·03	0·025	0·012
Water treatment (yes‡ *v.* no)	−0·43**	−0·42**	−0·39**	−0·26	−0·35*	0·042	0·017
Sanitation (yes‡ *v.* no)	−0·46**	−0·43**	−0·37**	−0·42**	−0·43**	0·055	0·013
Maternal age (≥25‡ *v.* <25 years)		−0·33**	−0·33**	−0·26	−0·17	0·062	0·007
Intake bioavailable Fe (mg)			0·60***	0·47***	0·31**	0·095	0·033
Diarrhoea (no‡ *v.* yes)				−0·44**	−0·21**	0·119	0·024
Birth weight (≥2500‡ *v.* <2500 g)				−0·71**	−0·64**	0·124	0·005
Serum retinol (μg)				0·02***	0·02***	0·151	0·027
Age (months)					0·03***	0·234	0·083

Levels of significance (two-tailed test): *$P<0·05$, **$P<0·01$, ***$P<0·001$.
† For details of subjects and procedures, see p. 308.
‡ Reference category.

year old had hookworm and 70 % had *Trichuris* (Gonçalves *et al.* 1990), These parasites cause blood and Fe to be lost, and if still prevalent in the rural interior can be expected to influence Hb concentration. There are no routine deworming programmes in Pernambuco, although deworming has been shown to be an effective anaemia prevention measure elsewhere (Guyatt *et al.* 2001). In Pernambuco, deworming may be more feasible in the short-term than improving sanitation. Promotion of drinking water treatment should be considered through, for example, solar disinfection, which is effective and has minimal cost.

Diarrhoea in the last 2 weeks remained in the final model as a determinant of Hb concentration after controlling for all other variables. Diarrhoea can lead to blood loss from the gut and recent diarrhoea may be a marker for more frequent or persistent episodes. Fever was not recorded in our present study, but infections markedly impair Fe absorption (Beresford *et al.* 1971): even mild infections in infants aged 9–12 months have been found to be associated with lowered Hb concentration (Reeves *et al.* 1984). Reducing morbidity in communities with a high burden of disease can be expected to reduce anaemia. Malaria is not found in this region.

Low birth-weight had a significant and independent effect on Hb concentration. In this region both preterm delivery and intra-uterine growth retardation contribute to low birth-weight. Fe is transferred to the fetus late in pregnancy, so preterm infants start postnatal life with poor Fe reserves. Intra-uterine growth-retarded infants have small livers and also have poor Fe reserves (Cook *et al.* 1994). With accelerated postnatal growth, Fe stores are quickly depleted. The WHO advocates that all low birth-weight infants be given Fe-containing drops from 2 months of age (World Health Organization, 2001). In Pernambuco, the prevalence of low birth-weight is 8 %, but there is no supplementation policy. Most babies are born in hospital and weighed at birth, so identifying low-birth-weight infants is feasible and implementing a supplementation policy should not be too difficult.

The prevention and control of childhood anaemia is a high priority in many national nutrition programmes, particularly because of concern regarding its adverse functional effects on neuro-cognitive development and school achievement. The variables studied explain 23·4 % of the variance in Hb concentration in children aged 6–59 months. Normal variation in Hb concentration is likely to account for a substantial proportion of the remaining variance. The main strength of the present study is that the sample was representative of the State, and that bioavailable Fe intake was assessed. Omission of intestinal parasites is a weakness, as mentioned earlier. Several policy actions are suggested by the results. These include strategies to improve intakes of bioavailable Fe and vitamin A, and reduce infection. Further research is needed to determine if intestinal parasites are a public health problem in this region.

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