Public Health Nutrition: 16(10), 1751–1759 doi:10.1017/S1368980012005617

Anaemia and iron deficiency between 2003 and 2007 in Amazonian children under 2 years of age: trends and associated factors

Fernanda Serra Granado[1], Rosangela Aparecida Augusto[1], Pascoal Torres Muniz[2] and Marly Augusto Cardoso[1,*], the ACTION Study Team

[1]Department of Nutrition, School of Public Health, University of São Paulo, Av. Dr Arnaldo 715, São Paulo, SP 01246-904, Brazil: [2]Department of Health Sciences, Federal University of Acre, Rio Branco, Brazil

Submitted 29 June 2012: Final revision received 6 November 2012: Accepted 6 December 2012: First published online 1 February 2013

Abstract

Objective: To describe trends in the prevalence of anaemia and Fe deficiency in children under 2 years of age living in a town in western Brazilian Amazonia.

Design: Temporal analysis of two cross-sectional population-based surveys. Information on socio-economic status, morbidity and breast-feeding was obtained using a structured questionnaire. Child weight and length were measured for anthropometric evaluation. Concentrations of blood Hb, plasma ferritin and soluble transferrin receptor were measured.

Setting: The town of Acrelândia, state of Acre, north-west Brazil.

Subjects: A total of 170 and 224 participants of the 2003 and 2007 surveys, respectively.

Results: Comparison between the 2003 and 2007 surveys revealed no statistically significant differences in the prevalence of anaemia (48 (95 % CI 39, 56) % to 40 (95 % CI 33, 47) %) or Fe-deficiency anaemia (39 (95 % CI 30, 48) % to 37 (95 % CI 30, 45) %), respectively. However, an increase in the overall prevalence of Fe deficiency from 62 (95 % CI 51, 68) % to 81 (95 % CI 75, 86) % was observed (χ^2 test, $P \leq 0{\cdot}001$). In age- and sex-adjusted analyses for risk of Fe deficiency, only early introduction of cow's milk (<90 d) was associated with Fe deficiency in 2003 (prevalence ratio (PR) = 0·76; 95 % CI 0·57, 1·01), while caesarean section (PR = 1·18; 95 % CI 1·03, 1·35) and birth weight <3500 g (PR = 1·15; 95 % CI 1·00, 1·34) were associated with Fe deficiency in 2007.

Conclusions: No improvements were observed in the prevalence of anaemia, exposing a worrying scenario for public health, while a significant increase was found in the prevalence of Fe deficiency in the studied infants and toddlers.

Keywords
Breast-feeding
Anaemia
Iron deficiency
Child health
Amazon

Iron deficiency (ID) is the most common and widespread nutritional deficiency in the world. ID affects both industrialized and developing nations and has been identified as the main determinant in cases of anaemia among infants under 2 years of age[1]. According to the WHO, nutritional anaemia is considered a public health problem in 76 % of all countries, predominantly affecting children. Estimates show that between 66 % and 80 % of the world's population is Fe deficient while 30 % is anaemic, corresponding to about two billion individuals[2].

In Brazil, according to figures from the 2006 National Demographic and Health Survey (PNDS)[3], about 50 % of children under the age of 5 years are anaemic, a prevalence which rises further in infants under 2 years of age or from low-income families. This situation is highly worrying since ID and anaemia are linked to greater infant mortality and morbidity, stunting, retardation of motor and cognitive development, as well as reduced intellectual capacity, and often have irreversible effects[1].

Children under 2 years old, particularly those residing in poorer regions, are at greater risk of ID since the higher requirement for the mineral for growth in this group is often not met due to low body reserves of Fe at birth, inadequate intake characterized by low quantity and bioavailability of Fe in complementary foods, and as a result of more frequent infections[1,4,5].

In order to ensure better nutrition in the first years of life and prevent nutritional deficiencies, the WHO[6] recommends that infants be exclusively breast-fed until 6 months old and continue to receive breast milk, together with nutritionally safe and suitable complementary food, up to 2 years of age or older. Despite these recommendations, the practice of early weaning and inadequate complementation of breast-feeding is common in many parts of the world.

*Corresponding author: Email marlyac@usp.br

Brazilian strategies for the prevention of ID include government adoption of the National Program for Iron Supplementation (PNSF)[7] aimed at infants aged 6–18 months, pregnant or puerperal women; and since 2004, a programme of compulsory fortification of wheat and corn flours with 4·2 mg of Fe and 150 μg of folic acid per 100 g[8]. In addition to the combined interventions of Fe supplementation and compulsory flour fortification for the prevention of ID[7,8], in recent years Brazil has seen a major expansion in the Family Health Program (FHP), created to reach individuals from the most impoverished regions of the country[9]. However, few studies assessing the effectiveness of these actions for reducing ID in young infants are available, particularly in the Amazon region. The WHO[4] recommends regular population-based surveys to examine the prevalence and associated factors for anaemia and ID, in order to help guide future government actions. In spite of these recommendations, many developing countries have no data available assessing the magnitude of ID in childhood or its evolution in recent years in the presence of prevailing public health programmes and policies[1].

The present study reports a temporal series of two cross-sectional population-based surveys conducted in 2003 and 2007 in a town in western Brazilian Amazonia, to assess trends in the prevalences of anaemia and ID in children under 2 years old. Studies of this nature are scarce in Brazil and also in other developing countries[4]. No national estimates of ID in the general population or among at-risk subgroups are available.

Materials and methods

Study design and population

A temporal analysis was performed involving two population-based studies conducted in January 2003 and December 2007, respectively, in Acrelândia, a town situated 100 km from Rio Branco, the capital of Acre State. In January 2003, we conducted a population-based cross-sectional study in Acrelândia with the assistance of local teams of the FHP of the Brazilian Ministry of Health[10]. All households from this urban area with children aged <5 years were identified and invited to participate (*n* 334), and only two declined participation. Data were collected from 332 households (99·4 %) involving a total of 477 children. In December 2007, using registers from the FHP in the town, a total of 749 households with 1225 children aged <10 years were identified. Of this total, 1151 children took part in the study (94·0 % of those eligible), as reported elsewhere[11]. The present analyses included all children under the age of 2 years assessed in the 2003 survey (*n* 170) and the 2007 survey (*n* 224). Sampling strategies and additional information on the two surveys can be found in earlier publications[12,13].

The field research team comprised researchers involved in the study from the University of São Paulo and the Federal University of Acre (including physicians and nutritionists), community health workers and health professionals from the FHP. Socio-economic, demographic and health data were collected using a structured questionnaire. Anthropometric measurements, dietary intake data and maternal breast-feeding practices were obtained through the application of clinical, biochemical and parasitological examinations. Diarrhoea (defined as three or more liquid evacuations within a 24 h period) during the 15 d leading up to the survey was recorded. Community health workers were trained by the study researchers to carry out household interviews by introducing themselves, explaining the objectives of the survey, and requesting voluntary participation and signing of the Free and Informed Consent Form by children's parents or guardians. The study was approved by the Research Ethics Committee of the Public Health Faculty of the University of São Paulo (under research protocol no. 2166).

Measures

Anthropometric measurements

Length and weight were measured by trained research assistants employing standardized procedures on calibrated equipment[14]. Length was measured with children in the dorsal decubitus position using a portable wooden infantometer, accurate to the nearest 0·1 cm, on a flat surface. Children were placed barefoot in a central standing position in the stadiometer, with head, shoulders, buttocks and heels pressed against the wall. Weight measurements were taken on an electronic scale (model HS-302; Tanita, Tokyo, Japan) and recorded to the nearest 100 g. Each measurement was repeated and the mean value calculated. Birth date was recorded directly from birth certificates or child health cards. Length-for-age *Z*-scores were calculated where the cut-off for stunting (<−2) was defined according to WHO child growth standards[15].

Laboratory measurements

Fasting venous blood samples were collected by trained nursing assistants. At the field laboratory in Acrelândia, Hb concentrations were measured on a portable haemoglobin photometer (HemoCue AB, Angelholm, Sweden), recommended by the WHO for use in epidemiological studies[16]. A separate blood sample was centrifuged within 1 h of collection; plasma samples were shipped to São Paulo on dry ice and frozen at −70°C until further analysis. In São Paulo, plasma ferritin (PF) and soluble transferrin receptor (sTfR) concentrations were measured using commercially available enzyme immunoassays (Ramco, Houston, TX, USA). Anaemia, ID and iron-deficiency anaemia (IDA) were defined according to Hb, PF and sTfR concentrations as follows[17,18]: anaemia was defined as Hb concentration <110·0 g/l (for children >6 months of age); ID was defined when PF concentration was low (<12 μg/l) or sTfR

https://doi.org/10.1017/S1368980012005617 Published online by Cambridge University Press

concentration was high (>8·3 mg/l); IDA was defined when ID occurred in anaemic children.

Stool samples were collected in plastic containers containing a preservative solution (10% w/v formalin). Since variable volumes of faeces were mixed with formalin for preservation, no attempt was made to perform egg counts. The stool samples were examined for parasite ova, cysts and larvae as described elsewhere[19].

Children with anaemia or intestinal parasites detected during the surveys received free treatment prescribed by research clinicians.

Breast-feeding indicators

Based on current information on breast-feeding and the introduction of water, tea infusions or foods, the children were considered to be exclusively breast-fed when consuming only breast milk without other foods, water and/or tea infusions, but in use of drops and/or syrups. This information was used to determine the age at introduction of cow's milk, considered early introduction when given to infants before the age of 90 d based on the median age for weaning observed in our study population.

Statistical analysis

Nutritional deficiencies, socio-economic situation and health status of the children were expressed in terms of proportion of the sample and the respective 95% confidence interval, while means and standard deviations were also provided for some characteristics. For both surveys, it was checked whether the prevalence of ID differed according to the characteristics of the children studied. The ID prevalence in 2003 and 2007 was also compared according to children's characteristics. Comparisons were made using Pearson's χ^2 test for categorical variables and Student's t test for continuous variables. Then, crude analyses were first conducted using Poisson regression models between the dependent variable of interest (ID) and the explanatory variables. Adjusted prevalence ratios (PR) and 95% confidence intervals were obtained for the factors associated with ID using multiple Poisson regression models with robust variance. At each level of determination, covariates were retained in the model if they were associated with the outcome or if their inclusion in the model changed the PR by 10% or more. Missing observations were included in the multiple models by creating missing-value categories. All analyses were performed using the Stata statistical software package version 11·0. The level of significance adopted was $P \leq 0{\cdot}05$ for all analyses.

Results

Table 1 depicts the general characteristics of the children studied based on the data from the two surveys. Children were evenly distributed by gender and age in both surveys.

Table 1 General characteristics of children under 2 years of age and maternal health-care assistance according to the 2003 and 2007 surveys in Acrelândia, Acre State, north-west Brazil

	2003 (*n* 170)		2007 (*n* 224)	
Variable	%	*n*/total†	%	*n*/total†
Gender				
Male	48·8	83/170	49·1	110/224
Female	51·2	87/170	50·9	114/224
Age group (months)				
0–6	18·2	31/170	13·8	31/224
6–12	30·6	52/170	25·9	58/224
12–18	27·1	46/170	30·0	67/224
18–25	24·1	41/170	30·4	68/224
First prenatal visit*				
First trimester	28·3	39/138	53·5	106/198
Second trimester	63·0	87/138	40·4	80/198
Third trimester	8·7	12/138	6·1	12/198
Prenatal visits*				
<6 visits	32·9	45/137	19·3	39/202
≥6 visits	67·2	92/137	80·7	163/202
Type of delivery**				
Vaginal	75·0	114/152	62·1	128/206
Caesarean section	25·0	38/152	37·9	78/206
Low birth weight (<2500 g)	8·4	14/166	6·7	14/210
Immunization coverage*	85·3	145/170	92·9	208/224
Presence of parasite in stool sample	18·0	25/139	22·8	44/193
Diarrhoea in the 15 d before survey	37·9	64/169	43·7	97/222
Treated water supply coverage	50·0	83/167	58·6	130/222
Father's schooling*				
<5 years	51·0	76/149	34·3	62/181
≥5 years	49·0	73/149	65·8	119/181

*$P \leq 0{\cdot}05$, **$P \leq 0{\cdot}01$ for difference between 2003 and 2007.
†Totals differ from the total number of study children due to missing values.

https://doi.org/10.1017/S1368980012005617 Published online by Cambridge University Press

Table 2 Nutritional characteristics and breast-feeding practices of children under 2 years of age according to the 2003 and 2007 surveys in Acrelândia, Acre State, north-west Brazil

	2003 (*n* 170)			2007 (*n* 224)		
Variable	%	*n*/total†	95 % CI	%	*n*/total†	95 % CI
ID*	61·8	84/136	51·4, 68·2	80·7	167/207	74·6, 85·8
Anaemia‡	47·5	66/139	39·0, 56·1	39·7	75/189	32·7, 47·0
IDA	38·9	49/126	30·3, 48·0	37·2	68/183	30·1, 44·6
Exclusive breast-feeding in children <6 months old	22·6	7/31	9·6, 41·1	16·1	5/31	5·5, 33·7
Early introduction of cow's milk (<90 d)	37·6	62/165	30·2, 45·4	29·0	65/224	23·2, 35·4
Stunting	8·9	15/169	5·1, 14·2	11·4	25/219	7·5, 16·4

ID, iron deficiency; IDA, iron-deficiency anaemia.
*$P \leq 0{\cdot}001$ for difference between 2003 and 2007.
†Totals differ from the total number of study children due to missing values.
‡Only for children ≥6 months old.

Children's mean age was 12·0 (SD 6·5) months in the 2003 survey and 13·8 (SD 6·4) months in the 2007 survey. Regarding general characteristics of the children studied, between 2003 and 2007, no statistically significant improvements were found in rates of low birth weight, use of vitamin and/or mineral supplements, infection by intestinal parasites, or occurrence of diarrhoea. No increase in coverage of treated water supply was evident while the absence of sewage treatment and collection in the region remained. Statistically significant improvements in prenatal care were noted, where attendance during the first trimester of pregnancy virtually doubled from 28·3 % to 53·5 %. Similarly, a greater percentage of mothers attended a higher number of consultations (≥6 visits). However, in contrast, there was a statistically significant increase (about 50 %) in the number of caesarean sections in 2007. Some positive findings were an increase in immunization coverage, reaching almost 100 % of children surveyed in 2007, and longer paternal schooling period with an average increase from 5 to 7 years of schooling.

With regard to nutritional indicators, between 2003 and 2007, no reduction in the prevalence of anaemia, stunting or breast-feeding indicators was evident, where this latter parameter was marked by low prevalence of exclusive breast-feeding and high frequency of early introduction of cow's milk. In addition to the absence of nutritional improvements, a significant increase in the prevalence of ID was observed, which rose by 30 % and affected 80·7 % of children in 2007 (Table 2).

In a stratified analysis of the prevalence of ID by child characteristics, ID prevalence in 2007 was significantly higher among children under 12 months of age, among boys, in infants delivered by caesarean section and in those with a birth weight of <3500 g (Table 3). The analysis of ID increase by child characteristics between 2003 and 2007 showed a significant overall rise of about 30 %, a 65 % increase in children aged younger than 12 months and a 38 % increase in neonates with a birth weight of <3500 g. A higher prevalence of ID was also detected according to type of delivery (a 23 % increase for normal deliveries *v.* 27 % for caesarean deliveries). In 2003, only early introduction of cow's milk was retained in age- and sex-adjusted multiple regression models for ID risk. In 2007 though, after adjusting for sex and age groups, caesarean section and birth weight <3500 g remained positively associated with ID (Table 3).

Discussion

Acrelândia is a frontier town situated 112 km east of Rio Branco, the capital of Acre State, in western Brazilian Amazonia. The urban inhabitants are mainly migrants from south-east and south Brazil who are engaged in commercial agriculture and raising cattle. Infant mortality in Acrelândia, estimated at 70·7/1000 live births in 2000, is substantially higher than the country average (27·7/1000 live births)[20]. The scenario exposed in the present study is of great concern, revealing no improvements in terms of basic sanitation over the period spanned by the two studies. Additionally, persistence in stunting among under-2 s of about 11 % was noted, four times the level expected in a well-nourished population[21], along with a high rate of anaemia of about 40 % representing a major public health problem[4]. Importantly, results after 4 years showed a significant increase of about 30 % in the prevalence of ID in 2007 compared with 2003 levels, with ID affecting 80 % of children under 2 years of age. Despite the great advances in the Brazilian economy over recent years, now ranked among the top ten globally, the high prevalences of anaemia and ID found in Acrelândia are akin to those seen in more impoverished regions such as Africa and South-East Asia[4]. This situation points to an urgent need for more effective health and nutrition actions, particularly in poorer regions such as the Amazon.

The nutritional status of children under 2 years of age in the Brazilian Amazon, as well as in many other poorer regions in the world, has been largely attributed to a set of interrelated factors. Primarily, factors implicated include the mother–child binomial, with intergenerational transfer of low Fe reserves associated with gestational and delivery characteristics (low quality of prenatal care, poor adherence to use of mineral and vitamin supplements

Table 3 Prevalence of ID and PR for risk of ID according to characteristics of children under 2 years of age in the 2003 and 2007 surveys in Acrelândia, Acra State, north-west Brazil

	2003						2007					
	ID		Crude		Adjusted		ID		Crude		Adjusted	
Variable	%	*n*/total†	PR	95 % CI	PR	95 % CI	%	*n*/total†	PR	95 % CI	PR	95 % CI
Sex												
Female	56·9	41/72	1·00	Ref.	1·00	Ref.	74·5*	76/102	1·00	Ref.	1·00	Ref.
Male	67·2	43/64	1·18	0·91, 1·54	1·15	0·90, 1·50	86·7*	91/105	1·16	1·01, 1·33	1·18	1·02, 1·34
Age group (months)												
<12	45·5	25/55	1·00	Ref.	1·00	Ref.	75·0*	57/76	1·00	Ref.	1·00	Ref.
12–25	72·8	59/84	1·60	1·16, 2·21	1·59	1·15, 2·19	84·0	110/167	1·12	0·96, 1·30	1·14	0·98, 1·31
Wealth index												
1st tertile (lower)	69·6	32/46	1·00	Ref.	–	–	81·8	54/66	1·00	Ref.	–	–
2nd tertile	60·0	24/40	0·86	0.67, 1.19	–	–	81·8	54/66	1·00	0·85, 1·17	–	–
3rd tertile (higher)	55·3	26/47	0·80	0·58, 1·10	–	–	78·7	59/75	0·96	0·82, 1·13	–	–
Father's schooling												
<5 years	60·7	34/56	1·00	Ref.	–	–	89·9	45/53	1·00	Ref.	–	–
≥5 years	61·7	37/60	1·02	0·80, 1·36	–	–	78·9	90/114	0·93	0·80, 1·08	–	–
Type of delivery												
Vaginal	60·0	54/90	1·00	Ref.	–	–	73·7*	87/118	1·00	Ref.	1·00	Ref.
Caesarean section	70·0	21/30	1·17	0·87, 1·56	–	–	88·9*	64/72	1·21	1·05, 1·38	1·18	1·03, 1·35
Early introduction of cow's milk (<90 d)												
No	68·2	58/85	1·00	Ref.	1·00	Ref.	83·0	122/147	1·00	Ref.	–	–
Yes	54·4	25/46	0·80	0·59, 1·08	0·76	0·57, 1·01	75·0	45/60	0·90	0·77, 1·06	–	–
Birth weight (g)												
≥3500	62·0	31/50	1·00	Ref.	–	–	75·0*	60/80	1·00	Ref.	1·00	Ref.
<3500	62·2	51/82	1·00	0·76, 1·32	–	–	86·0*	98/114	1·16	0·99, 1·35	1·15	1·00, 1·34

ID, iron deficiency; PR, prevalence ratio; Ref., reference category.
*$P \leq 0{\cdot}05$ for difference between 2003 and 2007.
†Totals differ from the total number of study children due to missing values.

during pregnancy, gestational anaemia, teenage pregnancies, shorter interval between births, early clamping of the umbilical cord) influencing the nutritional status of the child at birth (low weight, prematurity, low Fe reserves)[22,23]. A study conducted by Sharmanov[24] in Central Asia reported that 68% of infants under 3 years born to anaemic mothers also exhibited anaemia. By contrast, the problem was identified in only 24% of infants born to non-anaemic mothers. Employing standardized methods, the large study examined clusters of three countries and involved 11 750 mothers and their infants. Three other studies, from Spain, Jordan and Indonesia[25–27], demonstrated a higher incidence of ID or IDA in infants born to mothers with IDA during pregnancy, as compared with infants born to mothers with adequate Fe status.

In the present study, the information collected for the two periods precludes an assessment of the evolution of gestational status and its relationship with ID in the children. However, the cross-sectional analysis of the 2007 survey data[11] assessing factors linked to anaemia in children showed a 55% greater prevalence of anaemia in children under 2 years born to mothers who had more than three gestations.

In an effort to propose hypotheses explaining the high prevalence of ID and anaemia in the children studied, a nationwide study on the progress and changes in maternal and infant health was undertaken[9] using data drawn from population censuses and national demography and health surveys. Findings showed, despite broader national coverage for delivery and prenatal periods, a prevailing low quality of prenatal care in various regions of the country, particularly in low-income regions such as the Brazilian Amazon. This care was characterized by a lack of, or poor, integration of key services, predisposing both mother and child to a series of nutritional deficits. Furthermore, overuse of surgical delivery has been observed in recent years[9]. Despite broader coverage for prenatal care, this finding was corroborated by the results of our study with a 52% rise in caesarean section. According to our data, caesarean sections accounted for 40% of births, far exceeding the WHO-recommended 15% limit[28]. This abuse of caesarean sections is thought to have various repercussions which in turn impact Fe reserves in infants, such as an increase in preterm births[29]. A systematic review[30] of population-based studies assessing preterm births in Brazil showed a significant increase over the past 20 years. Prematurity is the leading cause of infant deaths in Brazil, predisposing infants to greater nutritional risk, particularly anaemia, due to low Fe status at birth. Despite higher prematurity rates, the prevalence of low birth weight has remained stable at 8% since 2000[9], a level similar to that found in the present study. One explanation for this trend of stable low birth weight concomitant with higher prematurity may lie in the lower frequency of intra-uterine growth restriction[31].

Another aspect to consider is whether the increase in surgical deliveries is linked to more routine early clamping of the umbilical cord in neonates (performed within 1 min of birth), a procedure common in Brazilian hospitals and a practice associated with increased risk of ID in children[32]. However, deliveries performed by midwives, formerly common practice in Acrelândia, have given way to hospital deliveries which include early clamping of the umbilical cord. According to our 2007 data, the prevalence of ID was significantly greater in surgically delivered neonates, with the condition affecting 90% of this infant group.

Besides these perinatal factors, underlying postnatal factors have been extensively discussed in studies investigating ID in early infancy. These factors include monotonous diets, with early introduction of cow's milk, and diets that are milk-based or that offer low Fe bioavailability[33,34]. This inadequate dietary pattern was previously described in the children from the present study area in 2003 and 2007[12,13]. A study by Castro *et al.*[12] assessing a sub-sample of the under-2 s from the 2003 survey identified irregular consumption of meats, fruit and vegetables (promoters of Fe absorption) together with a high intake of cow's milk and thickeners (absorption inhibiters), resulting in a low intake of Fe of animal origin and low amounts of bioavailable Fe in the diet (median: 0·3 mg; interquartile range: 0·2–0·3 mg). In 2007, based on data reported by Garcia *et al.*[13], we concluded that this situation failed to improve, and was likely exacerbated, as a result of the low intake of vitamins A, C, folic acid and Zn. Other contributory factors were low bioavailability of Fe in the diet, calculated as 8%, in conjunction with overconsumption of cow's milk, porridge and ultra-processed foods; the amount of bioavailable Fe in the diet remained similar to levels verified in 2003. It was also noted that, although national surveys[3] indicated improvements in breast-feeding patterns, the region under study continued to show low rates of breast-feeding together with early introduction of cow's milk to replace breast milk, thereby raising the risk for ID in infants under 2 years of age.

Also in relation to dietary patterns, national surveys conducted in Brazil in 2002 and 2008[35,36] collecting data on household food acquisition showed a deterioration in the pattern of consumption of the population of the state of Acre, reflecting the trend in other regions of the country. This shift can increase the risk of ID in the mother–infant population. Specifically in Acre State, a reduction in the consumption of foods rich in Fe and absorption promoters was found, with a 36% decrease in seafood, an 18% decrease in fruit and vegetables and a 22% drop in fortified flour consumption, whereas the intake of meat and poultry remained stable. In parallel, an increase in the acquisition of foods that inhibit Fe absorption was evident such as milk (32% increase), processed foods (200% increase) and processed meat

products such as frankfurters and mortadella (150 % increase).

In addition to continued poor diet with possible decline in quality, a lack of improvement in both environmental sanitary conditions and morbidity patterns was observed, with persistent high rates of diarrhoea (40 %) and intestinal parasites (20 %), exceeding levels reported in poor regions of the world such as south central Nepal[37] and in a rural South African community[38]. The influence of housing and sanitation in the development of anaemia and ID is expected in areas with substandard living conditions, predisposing to infections and parasitic diseases which deplete the children, further contributing to nutritional deficiencies[4].

Although the scope of the present study did not include an assessment of the strategies adopted by the Brazilian government for combating anaemia and ID in Amazonian children, the data obtained allow us to discuss these actions in light of the lack of studies reporting on the effectiveness of these strategies in Brazil. The first point to be raised is that the PNSF has yet to gain adherence of mothers and children, evidenced by the low prevalence of use of vitamin and mineral supplements of about 15 % for the period covered by the surveys. In addition to early discontinuation of supplement use, other factors related to low adherence and considered barriers to the success of Fe supplementation include sensory aspects, collateral effects and lack of information[39,40]. Some studies conducted in Brazil suggest reappraisal of the Fe dosages used by the PNSF[41].

With regard to compulsory fortification of wheat and corn flours, according to estimates by Bell and Oakley[42], 27 % of the world population has access to flour fortified with Fe and/or folic acid. Fortification of flour with Fe and folic acid has produced positive results in the USA, Canada and Chile, reducing the frequency of neural tube defects in newborns. However, results of fortification of flour with Fe for the prevention of anaemia in infancy suggest a low level of effectiveness. In Brazil, considering its large geographical extent and the different infant feeding practices across the country, there is a need for further studies in assessing the nationwide effectiveness of the flour fortification programme. A study carried out in the south of Brazil with series of population-based surveys (in 2004, 2005, 2006 and 2008) to ascertain the effect of flour fortification in pre-school children after a 4-year programme revealed no impact of flour fortification, with an increase in anaemia prevalence among children under 24 months of age[43]. Numerous hypotheses have been proposed to justify the ineffectiveness of large-scale fortification in developing countries, one of which holds that flour is an unsuitable dietary vehicle for targeting infants given this group's low flour intake; while other proposed barriers include a lack of monitoring and standardizing of the fortification process plus the use of Fe compounds with low bioavailability[43,44]. The use of less readily absorbed compounds and their associated cost are real issues facing developing countries; since flours tend to be stored for long periods, the use of other more easily absorbed compounds such as ferrous sulfate can produce sensory alterations[45].

Recent recommendations by the WHO for the prevention of ID and anaemia in infants and children include the use of multiple-micronutrient powders for home fortification of foods. This home fortification should be integrated with basic health-care actions, given that insufficient Fe intake tends to be accompanied by threshold or insufficient consumption of other micronutrients required to metabolize Fe and needed for normal growth and development[46]. A systematic review[47] on the impact of home fortification suggested that besides being more effective it is better accepted owing to fewer side-effects and, when used in conjunction with nutritional guidance actions, can result in improvements in overall dietary quality.

In light of the environmental health and nutrition scenario of the children studied, particularly the alarming prevalence of ID, and based on successful experiences in other countries in controlling this deficiency, a reformulation of the current strategies adopted in developing countries such as Brazil is warranted. These measures should extend to include more impoverished regions and actions to improve basic sanitation, drinking water supplies, access to quality maternal and infant health care, and to guidance on healthy complementary foods, without which novel strategies may also fail to have positive outcomes.

Acknowledgements

Sources of funding: The study was funded by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP; grant no. 2009/02640-1). F.S.G. received a Master scholarship from the FAPESP (grant no. 2009/02640-1) *Conflict of interest declaration:* There is no conflict of interest. *Authorship responsibilities:* F.S.G. and M.A.C. were responsible for the study design, project management, data analysis, interpretation of the results and manuscript writing. R.A.A. was responsible for data analysis, interpretation of results and manuscript writing. P.T.M. was responsible for the study design and project management. *Acknowledgements:* The authors express sincere appreciation to CNPq and FAPESP for funding. They would like to thank the research teams of 2003 and 2007; the community health workers and the mothers and children who participated in the study; and Tegan Condon for critical reading of the manuscript.

ACTION (ACre nutriTION) Study Working Group: Pascoal Torres Muniz, Orivaldo Florencio Souza, Cristieli Sergio de Menezes Oliveira, Thiago Santos de Araujo

(Department of Health Sciences, Federal University of Acre, Rio Branco, Brazil); Suely de Godoy Agostinho Gimeno, Luciana Yuki Tomita (Department of Preventive Medicine, Federal University of São Paulo, São Paulo, Brazil); Marcelo Urbano Ferreira (Institute of Biomedical Sciences, University of São Paulo, São Paulo, Brazil); Kézia K.G. Scopel (Department of Parasitology, Immunology and Microbiology, Federal University of Juiz de Fora, Juiz de Fora, Brazil); Barbara Hatzlhoffer Lourenço, Pablo Secato Fontoura, Fernanda Serra Granado, Fernanda Cobayashi, Rosangela Aparecida Augusto, Marly Augusto Cardoso (Department of Nutrition, School of Public Health, University of São Paulo, São Paulo, Brazil).

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