Prevalence of iron deficiency among Chinese children aged 6 to 36 months in Montreal

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Screening for iron deficiency was undertaken among a group of Chinese children aged 6 to 36 months to determine the prevalence of the condition and its association with infant feeding. Of the 346 children studied, 12.1% were found to be iron deficient. The overall prevalence rate of thalassemia minor was 6.7%. Among the 166 children aged 6 to 12 months, more of those who were breast-fed for at least 2 months than of those who were bottle-fed were iron deficient (27.0% v. 7.0%; $p < 0.001$). This difference persisted after controlling for the effect of iron-fortified formula. No such difference was found among those older than 12 months. The observed prevalence of iron deficiency was closer to the rate reported for black children than to that reported for white children in the United States. The findings stress the importance of conducting further studies of iron deficiency among Chinese subpopulations in North America.

Quelle est la fréquence de la carence en fer chez les enfants d'origine chinoise entre 6 et 36 mois, et quel rapport a-t-elle avec l'alimentation? On l'a recherchée parmi 346 tels enfants vivant dans la région montréalaise et trouvée chez 12,1% d'entre eux. Le taux de thalassémie mineure est de 6,7%. Parmi les 166 nourrissons de 6 à 12 mois, la sidéropénie est plus fréquente chez ceux qui ont été allaités au sein pendant au moins 2 mois (27,0%) que chez ceux qui n'ont pris que le biberon (7,0%) ($p < 0,001$); cette différence persiste même si on élimine l'effet des laits enrichis en fer. Elle n'existe pas au-delà de 12 mois. La fréquence de la sidéropénie chez nos enfants est plus proche de celle qu'on trouve aux États-Unis chez les enfants noirs que celle qu'on trouve chez les blancs. Nos résultats soulignent l'importance d'étudier plus avant la carence en fer dans les sous-populations d'origine chinoise en Amérique du Nord.

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Iron deficiency is the most common cause of nutritional anemia in early childhood.[1] While iron deficiency anemia is prevalent primarily in developing countries,[2,3] it still poses a challenge to the medical profession in the developed world.[4-6] It is now recognized that iron deficiency preceding the development of anemia can result in systemic effects.[7-10] Although the total effect of iron deficiency on the growing child is not known, it is generally accepted that iron deficiency in young children should be prevented through breast-feeding[11] and appropriate infant feeding with iron-fortified formula and food[12,13] and that iron deficiency should be detected at an early stage.[1,14]

In recent studies of the prevalence of iron deficiency in the United States, blacks were shown to be at substantially higher risk than whites.[5,15] There has been little documentation of the prevalence of iron deficiency among Oriental populations in North America. One of us (A.C.-Y.), on noting an apparently higher prevalence of iron deficiency among Chinese children than among white children at a pediatric practice in Montreal, undertook a case-finding program within the Chinese community. This survey enabled us to report on the prevalence of iron deficiency among Chinese children and its relation to infant feeding method and, coincidentally, to describe the prevalence of thalassemia minor in this population.

Methods

All consecutive Chinese children seen under the routine pediatric care of A.C.-Y. (who speaks Mandarin and Cantonese) between October 1977 and September 1982 who were between the ages of 6 and 36 months were tested for iron deficiency on one occasion. The children were seen at the Montreal Chinese Hospital pediatric clinic or at the physician's private office. Most of their families were first-generation immigrants from China and southeast Asia. Most of the children had been followed up from early infancy. Testing was done either at 8 to 9 months of age, when the child had been fed whole cow's milk for at least 2 months, or

later, if the child had been older at the start of the survey or had entered the practice later.

Infant feeding recommendations included breast-feeding or use of iron-fortified commercial formula from 3 or 4 months to at least 6 months of age and introduction of iron-fortified cereals at 4 months of age and then conventional *beikost* (vegetables, fruit and meat). No attempt was made to change the feeding pattern of children who had been fed traditional Chinese *beikost*, which is congee (rice porridge cooked with or without meat broth). Whole cow's milk was recommended after 6 months of age for formula-fed infants or upon weaning for breast-fed infants.

A complete blood count was performed in capillary blood with a model S Coulter Counter (Coulter Electronics Inc., Hialeah, Florida). When microcytosis (mean corpuscular volume of 70 fl or less,[16] confirmed by examination of erythrocytes) was detected, venous blood was drawn for further tests.

Children with at least one abnormal iron index (i.e., low serum iron level,[17] elevated free erythrocyte protoporphyrin level[18,19] or elevated total iron-binding capacity[17]) were treated with ferrous sulfate at a dosage equivalent to 5 mg/kg per day of elemental iron, given orally for 3 months. Nine children with microcytosis whose parents refused to allow venous puncture were also treated with this regimen.

Those who responded to therapy with a rise in hemoglobin level of at least 1 g/dl were identified as iron deficient.[15] Cases of borderline iron deficiency were not identified, since determination of ferritin levels[20] was not possible in the clinical setting during the study period.

Children with persistent microcytosis and elevated concentrations of hemoglobin A_2 (more than 3.5%) and hemoglobin F (more than 2%) were identified as having β-thalassemia minor, and the diagnosis was confirmed by family studies. Those with persistent microcytosis but normal results of hemoglobin electrophoresis were considered to have α-thalassemia minor, and the diagnosis was confirmed by establishing that one of the parents had a low mean corpuscular volume, normal iron indices and normal results of hemoglobin electrophoresis.

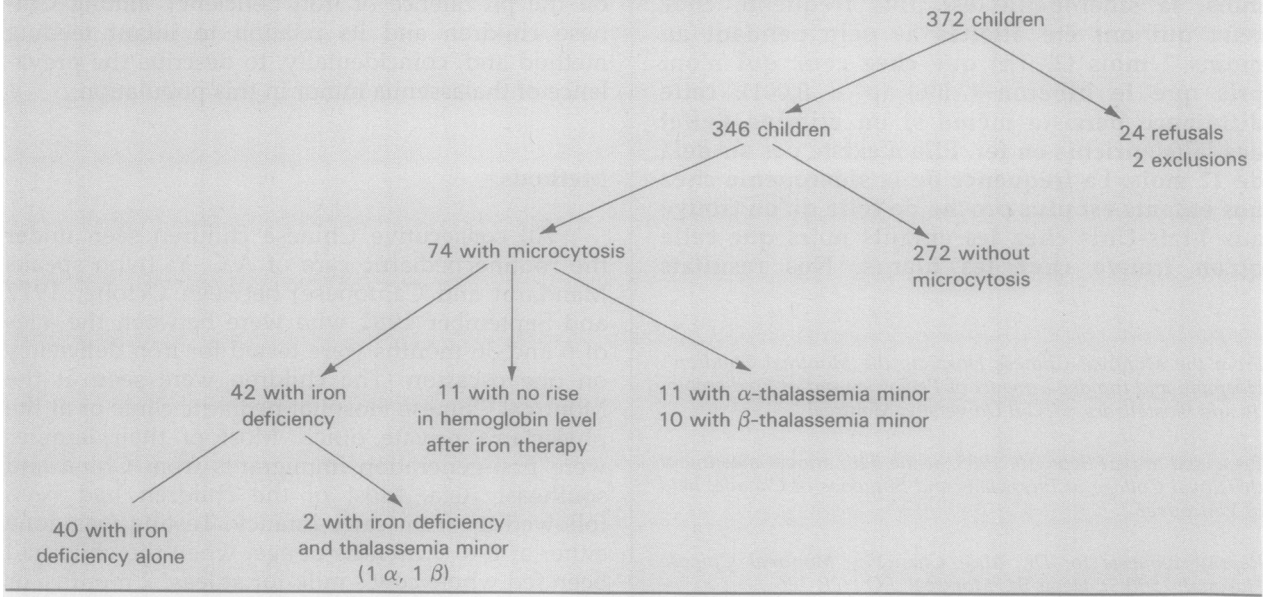
Data were collected on whether the children were breast-fed or bottle-fed at 2 and 4 months of age and whether they received iron-fortified commercial formula.

Results

A total of 372 children were seen during the study period. The parents of 24 children refused to participate, so that the participation rate was 93.5%. Two children were excluded from the study: one had iron deficiency associated with parasite infestation, and the other was identified as iron deficient at 4 months of age on investigation of failure to thrive.

Of the 346 remaining children, 74 (21.4%) had microcytosis. Forty-two of the 74 (12.1% of all 346) were classified as iron deficient (Table I). Eleven of the 74 (3.2% of all 346) had at least one abnormal iron index but did not have a substantial rise in hemoglobin level after iron therapy; however, a follow-up complete blood count in capillary blood showed that the mean corpuscular volume had returned to normal. This group of subjects may have had borderline iron deficiency, which could have been confirmed by measuring the ferritin level. Of the remaining 21 children with microcytosis 11 had α-thalassemia minor and 10 β-thalassemia minor. Two of the children with iron

Table I — Results of screening for iron deficiency in 346 Chinese children



deficiency also had thalassemia minor, one α and one β. The overall prevalence rates of α-thalassemia minor and β-thalassemia minor were 3.5% and 3.2% respectively.

To show the relation of iron deficiency to hemoglobin level, we plotted the distribution of children with or without iron deficiency by hemoglobin level (Fig. 1). Of the 42 with iron deficiency, 39 (93%) had a hemoglobin level below 11.5 g/dl. The mean hematologic results in the children with or without iron deficiency and in those with thalassemia minor are presented in Table II.

Because of the wide range of ages at assessment, we arbitrarily divided the children into three age groups, using larger ranges for the higher ages because of the small numbers of children. The proportions of each age group with iron deficiency and the mean values for mean corpuscular volume and initial hemoglobin level are shown in Table III.

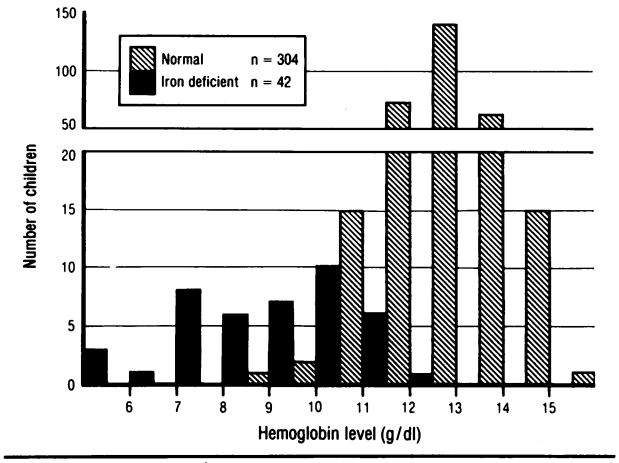


Fig. 1 — Distribution of children with or without iron deficiency, by hemoglobin level.

Analysis of the data on feeding revealed that 21.4% of the children had been breast-fed for at least 2 months, most of them (84%) for at least 4 months. Infants who had been breast-fed for at least 2 months were more likely than those who had been bottle-fed to be iron deficient. However, this association was apparent only among those 6 to 12 months of age: 27.0% of the breast-fed infants versus 7.0% of the bottle-fed infants were iron deficient ($\chi^2 = 11.40$, $p < 0.001$). Within this age group, only 27% of the breast-fed babies ever received iron-fortified formula, compared with 58% of the bottle-fed babies. A stratified analysis was done to determine whether the difference in the rates of iron deficiency between breast-fed and bottle-fed infants in this age group was due to the fact that breast-fed babies were less likely to have received iron-fortified formula. Among the 81 infants who never received iron-fortified formula, 29.6% of the breast-fed versus 13.0% of the bottle-fed infants were iron deficient ($\chi^2 = 3.31$, $p = 0.07$). Among the 85 infants who did receive iron-fortified formula more of the breast-fed than of the bottle-fed infants were iron deficient ($\chi^2 = 5.91$, $p = 0.02$).

Discussion

The prevalence of iron deficiency is reported to vary between racial groups.[1,5,15,21] Sadowitz and Oski[5] found a higher prevalence rate of iron

Table II — Mean hematologic results in the children with or without iron deficiency and with thalassemia minor

Group	Mean result (and standard deviation [SD])				
	Mean corpuscular volume, fl	Hemoglobin level, g/dl	Free erythrocyte protoporphyrin level, μg/dl*	Total iron-binding capacity, μg/dl*	Serum iron level, μg/dl*
Without iron deficiency (n = 283)	77.9 (4.4)	12.5 (0.9)	–	–	–
With thalassemia minor (n = 21)	61.6 (3.6)	11.2 (1.0)	33.7 (20.1)	348.3 (108.0)	69.3 (37.5)
With iron deficiency (n = 42)	60.3 (7.3)	9.1 (1.8)	189.3 (139.0)	419.4 (97.1)	27.6 (13.8)

*Most of the children without iron deficiency did not undergo venous puncture. The number of children for whom results are reported varied owing to technical problems.

Table III — Proportions of children with iron deficiency, by age group

Variable	Age, mo		
	6–12 (n = 166)	13–18 (n = 101)	19–36 (n = 79)
No. (and %) with iron deficiency	19 (11.4)	10 (9.9)	13 (16.5)
	Mean result (and SD) (n = 346)		
Mean corpuscular volume, fl	74.7 (7.9)	74.8 (7.9)	75.3 (9.0)
Hemoglobin level, g/dl	11.9 (1.5)	12.1 (1.4)	12.0 (1.8)

deficiency anemia among black children aged 9 to 12 months than among white children of the same age (14.3% v. 2.7%). Reeves and colleagues,[15] using a rise in hemoglobin level of at least 1 g/dl in response to treatment as their main criterion for diagnosing iron deficiency anemia, found that 14% of black children but only 8% of white children aged 6 to 24 months were affected. Using the same criterion, we found that 12.1% of Chinese children aged 6 to 36 months had iron deficiency. Brault-Dubuc and associates[21] reported a lower prevalence rate of iron deficiency anemia, 3.3%, among upper-middle-class French-Canadian children in Montreal.

The overall prevalence rate of thalassemia minor in our study, 6.7%, was lower than that reported by Choi and Necheles[22] among the Boston Chinese population. Our study population had diverse origins, whereas the subjects in the Boston study originated mainly from the Guangdong province in China, where a particularly high incidence of thalassemia minor has been observed.[23]

Both genetic and environmental differences in our study population may explain the observed high prevalence of iron deficiency. Intolerance to whole cow's milk is suspected to contribute to the development of iron deficiency before 6 months of age[5,13,24] and possibly until 1 year of age.[25] We suspect that intolerance to whole cow's milk after 6 months of age may be common among Chinese children. We observed that several infants were iron deficient as early as 2 months after starting to receive such milk. Although the quantity of whole cow's milk consumed by the children in our study was not routinely recorded, our retrospective dietary recording at the time of diagnosis of iron deficiency revealed that many infants were fed an excessive amount of such milk. This excess can result in occult intestinal blood loss[25] and inadequate iron intake.[26]

In our study the pediatrician advocated breast-feeding[27] and recommended the use of iron-fortified formula from 4 to at least 6 months of age for bottle-fed infants and iron-fortified cereal followed by conventional *beikost* beginning at 4 months. The prevalence rate of iron deficiency was 12.1% despite these recommendations. In conducting this study we recognized the difficulty and inaccuracy of identifying iron deficiency by relying solely on clinical examination and dietary history. This group of Chinese children appears to be at particularly high risk, and we suggest further studies of iron deficiency in this population. However, given that this was a cross-sectional study in which we examined prevalence, not incidence, we cannot identify the most appropriate time for conducting such tests.

Many of the children in our study were fed traditional Chinese *beikost*, which is known to have low iron bioavailability.[28-31] The difference in the prevalence of iron deficiency between breast-fed and bottle-fed infants was apparent only at an early age (6 to 12 months) and seemed to be due in part to supplementation with iron-fortified formula, but even among those who received such formula, more breast-fed than bottle-fed infants had iron deficiency. Unfortunately, data on other differences between breast-fed and bottle-fed babies that might further explain the observed difference were not routinely recorded. The lack of difference in prevalence of iron deficiency between breast-fed and bottle-fed infants after 1 year of age may have been due to the increasing similarity of the diets of these two groups over time.

Although the iron bioavailability of breast milk is much higher than that of cow's milk, infants who are breast-fed for 6 months or more require iron supplementation.[32,33] Most of the children in our study had been breast-fed for less than 6 months and thus did not need iron supplementation. However, a low iron concentration in the breast milk may have led to a higher prevalence of iron deficiency than expected.[33]

Further clinical research is required to determine the cause of iron deficiency in this ethnic group. Appropriate guidelines for infant feeding and iron supplementation can then be formulated.

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