Original Article

Longitudinal study of diet and iron deficiency anaemia in infants during the first two years of life

Anne-Louise M Heath[1] BA(Hons), BSc(Hons), PhD, Cynthia Reeves Tuttle[2] MPH, PhD, Megan SL Simons[1] BSc, MSc, Christine L Cleghorn[1] BSc, MSc and Winsome R Parnell[1] BHSc, MSc, RD

[1]*Department of Human Nutrition, University of Otago, Dunedin, New Zealand*
[2]*Department of Nutrition and Food Science, University of Maryland, College Park, Maryland, USA*

The objectives of this study were: (i) to investigate the energy, iron, zinc, calcium and vitamin C intakes of a group of healthy term Caucasian infants resident in Dunedin, New Zealand, prospectively from age 9 months to 2 years; and (ii) to determine the prevalence of iron deficiency anaemia among these infants. A self-selected sample of 74 Caucasian mothers and their infants born in Dunedin, New Zealand, between October 1995 and May 1996 were recruited. Dietary intake was determined using estimated diet records at 9, 12, 18 and 24 months of age. Haemoglobin concentration, mean corpuscular volume and zinc protoporphyrin concentration were determined at the same ages. The infants' zinc, calcium and vitamin C intakes appeared adequate. Their median iron intakes ranged from 4.3 mg (at 12 months) to 7.0 mg (at 9 months) per day and were below estimated requirements at all ages. At 9, 12 and 18 months of age, 7% (n = 4) of the infants had iron deficiency anaemia. None of the infants had iron deficiency anaemia at 24 months. The iron intakes of this group of Caucasian infants and young children appeared inadequate. However, their rate of iron deficiency anaemia was lower than has been reported in previous New Zealand studies.

Key words: dietary iron, infant, iron deficiency anaemia, iron deficiency, longitudinal study.

Introduction

Iron, zinc and calcium have been described as 'problem nutrients' in both developing and developed countries in a recent World Health Organization document on infant feeding.[1] Yet only two studies in the published literature have investigated the adequacy of the dietary intake of Caucasian infants and young children in New Zealand.[2,3]

The iron intake of young New Zealanders is of particular interest because iron deficiency anaemia has been associated with a number of adverse effects in infants and young children, including impaired motor and mental development.[4] These deficits in very early childhood may not be completely reversible[5] and may be associated with poorer school performance in later life.[6] Concern has been expressed that New Zealand infants may be at high risk of iron deficiency anaemia.[7,8] However, in the past decade, only five papers have been published in the peer-reviewed literature investigating the prevalence of iron deficiency anaemia in New Zealand infants.[3,9–12] Of these, only one investigated iron deficiency in a group of predominantly Caucasian infants in a community setting.[3]

The aims of this study were: (i) to investigate the energy, iron, zinc, calcium and vitamin C intakes of a group of healthy term Caucasian infants resident to Dunedin, New Zealand, prospectively from age 9 months to 2 years; and (ii) to determine the prevalence of iron deficiency anaemia among these infants.

Materials and methods

Participants

The names of mothers of newborn babies were obtained from the Dunedin office of Births, Deaths and Marriages, and from birth notices in the local newspaper. Mothers were then approached by telephone, given information on the study and invited to participate. Eighty-three mothers (approximately one in every six contacted) agreed to take part. Inclusion criteria were: mother of Caucasian descent; mother free from diabetes and other chronic health conditions; and infant full term (38–42 weeks gestation) and normal birth weight (2500–4500 g). Recruitment into the study took place between October 1995 and May 1996. The infants were studied prospectively for 24 months.

Ethical approval for this study was granted by the Southern Regional Health Authority Ethics Committee, Otago, New Zealand. Informed written consent was given by all participating mothers.

Correspondence address: Winsome Parnell, Department of Human Nutrition, University of Otago, PO Box 56, Dunedin, New Zealand.
Tel: +64 3 479 7941; Fax: +64 3 479 7958
Email: winsome.parnell@stonebow.otago.ac.nz
Accepted 22 February 2002

Data collection

Demographic information was collected at the initial home visit when the infants were aged between 4 and 6 weeks. Weekly telephone calls were used to determine when non-milk foods were first introduced, and home visits were then carried out monthly until the infant's first birthday. An estimated 24-h diet record was collected for the infant by their mother prior to each monthly visit. In the second year, an estimated 3-day diet record was completed prior to each of three visits; at 12, 18 and 24 months of age. Data are presented here for the infants at ages 9 (one day record), 12, 18 and 24 months (three day records). At each of these ages, between 0.25 and 0.50 mL of capillary blood was taken from the infant via a heel prick. The procedure was carried out by one of the authors (MSLS) or a research assistant, both of whom were trained in this procedure at Dunedin Hospital. Care was taken not to knead, 'milk' or scrape the puncture site.

Dietary assessment

The mothers were given both verbal and written instructions for recording their infant's food intake. They were asked to record all food, infant formula and cow's milk consumed by the baby immediately after each eating event. Mothers of breast-fed infants were also asked to record the time of day when the baby was fed, and how long the breast-feed lasted (data not presented). The mothers were encouraged to describe the foods and non-breast milk liquids consumed in as much detail as possible – recording both brand names and methods of preparation, and retaining the labels from jars and cans of mixed foods. They were also asked to measure (using level household measures) the amounts of foods eaten or proportions consumed for commercially prepared foods from jars and cans, and to estimate the volume of losses due to spillage or rejection. When the record was collected it was reviewed with the mother to clarify entries and to probe for forgotten foods.

The Diet Entry and Storage program (NutriComp, Dunedin, New Zealand) was used to enter the types and amounts of non-milk foods and infant formulas consumed. Printouts were then checked against the original diet record by a single dietitian to ensure consistency and accuracy. The diets were then analysed using the Diet Cruncher program (NutriComp). The food list and food composition data for these programs were based on the New Zealand Food Composition Database[13] and manufacturers' information (for infant formulas, infant cereals and commercially prepared infant foods), modified where necessary by a nutritionist familiar with food composition data.

Breast milk intake and composition was not quantified directly during the study. Therefore, an average estimated breast milk intake of 674 mL/day was used for infants consuming breast milk at 9 months of age, and an intake of 467 mL/day for infants consuming breast milk at 12, 18 and 24 months of age.[14] For those infants consuming both breast milk and infant formula, the reported volume of infant formula consumed was subtracted from the average estimated breast milk intake for that age. Figures for the composition of breast milk were the estimated nutrient concentrations in mature human milk reported in the recent World Health Organization document on complementary feeding of infants and young children.[1] The value for energy was based specifically on studies in industrialised countries.[1]

The dietary intake data were largely compared with the recommended nutrient intakes for the United Kingdom[15] as these are the most recent complete dietary reference values published. Energy intakes were, however, compared with two more recent sets of energy recommendations.[16,17] An additional, lower, estimated requirement for zinc based on estimated losses and an allowance for growth[18,19] was also included for comparison.[1]

Assessment of iron status

A complete blood count (CBC) was performed at the Dunedin Hospital Haematology Laboratory using a standard Coulter STKS autohaematology analyser (Beckman Coulter New Zealand, Auckland, New Zealand) to determine haemoglobin concentration and mean corpuscular volume (MCV). Zinc protoporphyrin (ZPP) was measured using a haematofluorimeter (model ProtoFluor-Z) and reagent system (Helena Laboratories, TX, USA) at the Department of Human Nutrition (University of Otago). Due to technical error, only 32 (58%) of the 55 sets of blood samples taken were analysed for ZPP at each age.

The following cut-offs were used to define anaemia and iron deficiency in this report: haemoglobin, <110 g/fL; MCV, <77 L; and ZPP, >80 µg/dL red blood cells.[20] Anaemia was defined as low haemoglobin. Iron deficiency anaemia (IDA) was defined as anaemia with a low MCV. Iron deficient erythropoiesis (IDE) was defined as a low MCV and elevated ZPP. At the time this study was carried out, the Dunedin Hospital reference limits for assessing iron status in individual infants aged 9 months to 2 years were: haemoglobin, 92–135 g/L; haematocrit, 27–41%; mean cell volume, 64–84 fL; and mean cell haemoglobin, 22–28 pg. The mother, and general practitioner, of any infant showing a low haemoglobin and two other abnormal indices using these cut-offs were notified of the likely presence of iron deficiency anaemia. One infant was diagnosed as having iron deficiency anaemia at 12 months of age using these criteria, and subsequently withdrew from the study (his data are therefore not reported).

Statistical analysis

SPSS for Macintosh Version 6.1.1 was used to carry out all statistical analyses. Because the majority of the dietary variables were not normally distributed (tested using the Kolmogorov–Smirnov statistic with a Lilliefors significance level), the median, lower and upper quartiles are used to describe the dietary data. A number of infants did not provide blood samples at each age. Only data for those with blood samples at each of 9, 12 18 and 24 months are reported so that comparisons can be made across the different ages. There were insufficient infants with iron deficiency anaemia

to carry out statistical comparisons of those with and without anaemia. The infants who provided a blood sample at each age were compared with those who did not, using the independent samples *t*-test for continuous variables that were normally distributed, the Mann–Whitney *U*-test for those that were not normally distributed, and the χ^2-test for categorical variables. A *P*-value of less than 0.01 was considered to be statistically significant for these analyses because multiple significance tests were being carried out.

Results

Of the 83 mother–infant pairs recruited, data are presented for 74 (89%). Five withdrew from the study (two due to time commitments, two because they disliked the heel pricks, and one for an unknown reason), two women moved away from Dunedin, one was lost to follow up, and one baby died of sudden infant death syndrome.

All of the mothers defined themselves as Caucasian. They were aged from 20 to 41 years (mean ± SD = 30.3 ± 5.1) and had a mean parity of 2.1 children (SD = 1.1). Ninety-three percent of mothers were either married or in a de facto relationship. Nearly half the mothers (47%) had some form of tertiary education. The family income was greater than NZ$40 000 per annum in 39% of the families.

Forty-nine percent of the infants were female. The mean gestation was 39.9 weeks (SD = 1.2 weeks), and the mean birth weight 3541 g (SD = 401 g). Forty-two percent of the infants were exclusively breast-fed at 3 months, and 34% were still receiving some breast milk at 12 months. Thirty-nine percent of the infants were being given 'follow-on' formula at 9 months. Nearly half the infants (45%) had been introduced to non-milk foods before 4 months, and more than two-thirds (69%) were being given cow's milk as a beverage before the age of 12 months. The mean age of introduction of cow's milk as a beverage was 40 weeks for those who introduced cow's milk before 12 months. Meat products were introduced at a mean age of 6 months (mean ± SD = 29 ± 8.2 weeks).

At age 9 months, nearly half the infants (47%) were receiving some breast milk, and 68% were receiving infant formula, including 'follow-on' formula (22% were given both), in addition to non-milk foods (Table 1). At 12 months, 36% were having some breast milk, but only 6% were still being breast-fed at two years of age. The prevalence of infant formula consumption fell to 35% at 12 months and 5% at 18 months.

The children's median reported energy intake was lower than estimated requirements at 9 and 12 months, and marginal at 18 months (Table 2). Median iron intakes were lower than the estimated requirement at all ages, and intake was highest at age 9 months. Median zinc intake reached the reference nutrient intake of 5.0 mg/day at 18 and 24 months only, but exceeded the estimated losses and an allowance for growth at all ages.[18,19] Median vitamin C and calcium intakes appeared adequate at all ages.

Median daily meat/fish/poultry intake increased considerably from 9 to 18 months (0–32 g), then moderately to 24 months (39 g/day) (Table 3). This trend was still apparent, although somewhat attenuated, when meat/fish/poultry intake was adjusted for energy intake. The median percentage of iron from meat and meat products increased from 0% at 9 months to a peak of 17% at 18 months.

Table 1. Proportion of infants following different feeding modes as recorded in their diet record

Feeding mode	Age (months)							
	9 months		12 months		18 months		24 months	
	n	%	*n*	%	*n*	%	*n*	%
Non-milk foods	5	7	28	39	51	82	43	90
Non-milk foods and breastmilk	17	25	19	26	8	13	3	6
Non-milk foods and infant formula	31	46	18	25	3	5	2	4
Non-milk foods, breastmilk and infant formula	15	22	7	10	0	0	0	0
Total	68	100	72	100	62	100	48	100

Table 2. Dietary intake and estimated requirements for infants by age†

Nutrient intake/day	Estimated requirements at 9 months‡	Actual intake at 9 months (*n* = 68)	Estimated requirements at 12–24 months‡	Actual intake at 12 months (*n* = 72)	Actual intake at 18 months (*n* = 62)	Actual intake at 24 months (*n* = 48)
Energy (kJ)	3470§	3284 (2763, 3868)	4560¶	3986 (3317, 4603)	4512 (4049, 5623)	5008 (4432, 5373)
Calcium (mg)	525	542 (385, 684)	350	639 (493, 874)	768 (595, 945)	659 (438, 834)
Iron (mg)	7.8	7.0 (3.7, 10.7)	6.9	4.3 (3.2, 7.1)	4.9 (3.7, 6.3)	4.6 (3.9, 5.8)
Zinc (mg)	5.0 or 2.8††	4.0 (3.3, 5.1)	5.0 or 2.8††	4.5 (3.9, 5.3)	5.2 (4.3, 6.4)	5.0 (4.0, 5.5)
Vitamin C (mg)	25	52 (39, 73)	30	53 (39, 79)	89 (52, 124)	96 (63, 157)

†Values are presented as median (25th percentile, 75th percentile). ‡UK Reference Nutrient Intakes,[15] unless otherwise stated. §Based on total energy expenditure and growth of breast-fed infants aged 9–12 months,[16] ¶Based on total energy expenditure and growth of infants aged 12–24 months,[17] ††Based on estimated losses and an allowance for growth,[18,19] as cited in the World Health Organization document on the complementary feeding of young children.[1]

Fifty-five infants (74%) provided a blood sample at 9, 12, 18 and 24 months. These mothers and infants did not differ significantly from those ($n = 19$) who did not provide a complete set of blood samples, in terms of the infants' haemoglobin concentrations, energy and dietary-iron intake at 9 and 12 months, gestation, birth weight and gender, or maternal age, marital status, income and highest educational qualification. The rate of iron deficiency anaemia was 7% at 9, 12 and 18 months (only one baby was anaemic at all three ages), but IDA was absent at 24 months of age (Table 4). Among the subgroup for whom ZPP measurements were carried out, the rate of iron-deficient erythropoiesis fell from approximately 20% at 9 and 12 months to 13% at 24 months.

Discussion

This study group was socioeconomically advantaged compared to the general New Zealand population. The mothers were all Caucasian, 10% had a postgraduate qualification and 93% were living in a married or de facto relationship. In contrast, the 1991 census reported that 79% of female New Zealanders were European, while 3% of women of childbearing age had postgraduate qualifications and 78% were married or in a de facto relationship.[21] However, only 39% of the families in the study had a combined income greater than NZ$40 000 per annum, compared to 55% in the 1996 New Zealand census.[22]

Estimated diet records were used to assess dietary intake in this study because, unlike methods such as the diet history, 24-h recall and food frequency questionnaire, the recording of food at the time of consumption avoids errors in recalling the types and amounts of food eaten.[23] The major disadvantage of this method is the heavy burden it places on participants who must record the type, amount and preparation method of each food and beverage consumed, when it is consumed, for the duration of the collection period.[23] This limits the number of days that can be collected, particularly when multiple diet records are to be collected over a period of time, as in this study. This in turn may limit the ability of the record to estimate usual intake.[24] This is particularly likely to be an issue for the 9-month dietary intake data, which are based on only 1 day of diet recording, although the diets of such young children are likely to include a narrow range of foods. Four-day weighed diet records completed by the mother of a preschool child have been shown to give measurements of energy intake that are in close agreement with energy expenditure figures derived using doubly labelled water techniques.[25] Estimated, rather than weighed, records were used in the present study both to lessen the burden on the mothers (particularly as multiple diet records were to be collected from early infancy), and to decrease the likelihood that the foods offered to the child would be changed to foods that would be easier to weigh. Estimated diet records have been shown to give group nutrient intakes in good agreement with those determined using weighed records in women.[26]

An infant's breast milk intake cannot be estimated and recorded in the same way as other foods in an infant's diet. Instead, estimated total breast milk volumes of 674 mL and 467 mL per day were used in this study for the infants consuming breast milk at 9 months and 12–24 months, respectively. These values were derived from the DARLING study,[14] which was carried out among a group of women of relatively high socioeconomic status living in the USA. Breast milk volumes were estimated using test weighing corrected for estimated insensible water loss during feedings. The DARLING values were used because they were very similar to the total volume of infant formula consumed by the infants in this study who were fed infant formula in place of any breast milk (689 and 435 mL, respectively). These values for breast milk volume are higher than those reported in a recent review of breast milk volume in developed countries.[1] If the volumes were overestimated, this would

Table 3. Intake of meat/fish/poultry and percentage of iron from meat and meat products by age†

Dietary component	Age (months)			
	9	12	18	24
Meat/fish/poultry (g/d)	0 (0, 10)	21 (14, 37)	32 (20, 58)	39 (23, 63)
Meat/fish/poultry intake (g/1000 kCal)	0 (0, 12)	25 (18, 40)	28 (19, 45)	31 (21, 47)
Iron from meat and meat products (%)	0 (0, 0)	15 (6, 19)	17 (6, 27)	12 (8, 22)

†Values are presented as median (25th percentile, 75th percentile). The number of infants who provided dietary information at all four ages was 41.

Table 4. Prevalence of iron deficiency states at 9, 12, 18 and 24 months of age

Iron deficiency state	Total *n*	Age (months)							
		9		12		18		24	
		n	%	*n*	%	*n*	%	*n*	%
Anaemia	55	6	11	6	11	4	7	1	2
Iron deficiency anaemia	55	4	7	4	7	4	7	0	0
Iron deficient erythropoiesis	32	6	19	7	22	–	–	4	13

–, No data available.

lead to an overestimate of the nutrient intake, and would therefore make the infants' nutrient intakes less likely to appear inadequate. Although the estimated breast milk volume figures affect nearly half of the intakes at 9 months, only a third of infants were still receiving breast milk at 12 months, and an eighth at 18 months.

The estimated requirements for energy used for comparative purposes in this study were based on reports that the habitual energy intakes and energy expenditure of both infants[16] and young children[17] are lower than those appearing in current official recommendations.[15] Nevertheless, the median energy intakes were below the estimated requirements[16,17] at 9 and 12 months of age, and marginal at 18 months. This may be due to underreporting, although good agreement has been reported between energy intakes reported in diet records and energy expenditure in infants.[25] Unfortunately, body weight and length measurements were not made as part of the present study so it is not possible to determine whether the reported energy intakes are plausible. However, both the DARLING study[14] and the UK National Diet and Nutrition Survey[27] reported similar energy intakes for young children. The mean daily energy intake of the infants in the DARLING study at 9 months of age was 3085 kJ (the median for this study was 3284 kJ at 9 months), and 3528 kJ for age 12 months (the median for this study was 3986 kJ at 12 months).[14] The DARLING data were based on 4-day weighed food records, including test-weighing to estimate breast milk intake. The median daily energy intake of UK children aged 1.5–2.5 years, also determined using 4-day weighed diet records, were lower than those reported here at 18 and 24 months of age.[27] The median energy intakes reported in the present study probably do not reflect inadequate amounts for the maintenance of health and growth as both these studies reported similar figures alongside adequate growth[27] and development.[14] While the energy intakes reported for a group of infants aged 6–24 months in Wellington in the 1970s[2] tended to be higher than those presented here, the more recently reported energy intakes of a group of 9–24-month-old Auckland infants,[3] based on 24-h recall and diet history data, were similar to those in the present study.

The median iron intakes in the present study were below the estimated requirement at all ages. The iron intake was highest at 9 months, both because iron fortified cereals were being consumed and because infant formula was consumed by 68% of the infants at this age (more than half of these infants were given iron-fortified 'follow-on' formula), whereas at 12 months only 35% of infants were given infant formula and by 24 months, only 4%. Interestingly, the rates of iron deficiency anaemia were low in this population (7% at 9–18 months). This may be because the iron consumed was of relatively high bioavailability. For instance, flesh foods (such as meat, poultry and fish) have an important role in iron balance both because of their high content of bioavailable haem iron[28] and also because of their enhancing effect on non-haem iron absorption.[29] The infants increased their intake of meat/fish/poultry between 9 and 18 months as their intake of breast milk and infant formula decreased and their intake of non-milk foods increased. This increased intake of flesh foods may partially explain the decrease in iron deficiency anaemia seen between 18 and 24 months, taking into consideration the expected time delay for increased iron intake to increase iron stores. Vitamin C has also been shown to enhance iron absorption[30] and the median vitamin C intake in this population was high at all four ages (52–96 mg). It is important to note that growth velocity, and therefore iron requirements, decrease after the first year of life and this may also help to explain the decrease in iron deficiency anaemia seen at 24 months.

It is difficult to compare the rates of iron deficiency anaemia among different studies because there is no consensus as to which indices and cut-offs should be used. There is agreement, however, that in a population in which iron deficiency anaemia is relatively uncommon, low haemoglobin alone is not sufficient for diagnosing iron deficiency anaemia. This is because anaemia has numerous causes, including vitamin B_{12} and folate deficiencies (megaloblastic anaemia), and infection. In this study, an abnormal MCV was used to exclude megaloblastic anaemia. MCV is also unaltered in the presence of infection.[31] The cut-offs used for haemoglobin and MCV were those used in the Third National Health and Examination Survey in the USA.[20]

Iron deficient erythropoiesis precedes anaemia, and is the stage at which the iron stores are exhausted and the supply of iron to the erythropoietic cells is insufficient.[32] In this study, IDE was defined as an abnormally elevated ZPP concentration (ZPP accumulates when there is insufficient iron to chelate with protoporphyrin in the final step of haem synthesis) and low MCV. This was an adaptation of the MCV model of iron deficiency used in NHANES II and III, in which individuals were described as being iron deficient if they had at least two abnormal values among MCV, ZPP and transferrin saturation.[20] The cut-off for zinc protoporphyrin used to diagnose iron deficiency in NHANES III (>70 μg/dL red blood cells) was lower than that used in NHANES II (>80 μg/dL red blood cells), because blood lead concentrations had decreased in the US population with the removal of lead from petrol and soldered cans.[20] Zinc protoporphyrin concentration is elevated by lead toxicity as well as iron deficiency.[32] It was decided to use the higher cut-off for this study because the introduction of unleaded petrol was not fully instituted in Dunedin until the first months of 1996 (Vallabh Patel (Energy Inspection, Ministry of Commerce, Wellington, New Zealand), pers. comm., 1999), and some delay both in the clearance of lead contamination from the environment, and in the response of ZPP to lowered lead exposure (due to red blood cell turnover), was expected.

Iron depletion is the stage before IDE, when the individual is not accumulating enough iron to meet their iron requirements and their iron stores decrease. Unfortunately, it was not possible to use the heel prick blood sample collected in this study to determine serum ferritin concentration. As a measure of the extent of iron stores, serum ferritin is the

most sensitive indicator of the severity of iron deficiency in the absence of anaemia.

Although it has been suggested that capillary blood samples may give lower haemoglobin measurements than venous blood samples in children,[33] it is now generally accepted that haemoglobin measurements from capillary blood are elevated.[34,35] Because this may result in infants with mild anaemia being underdiagnosed, where practicable, venipuncture blood samples are the preferred method for assessing iron status.[35] It was decided in this study, however, that capillary sampling was more appropriate because venipuncture of infants is distressing to parents and the longitudinal study design required repeated blood sampling. The rates of anaemia reported in this study may therefore be underestimated because some infants with mild anaemia may not have been diagnosed.

A number of studies have attempted to describe the prevalence of iron deficiency anaemia in New Zealand infants by investigating the iron status of hospitalised infants.[7,11,12,36,37] However, the rates of anaemia in well infants cannot be assumed to be the same as the rates among infants who are sufficiently unwell to be either assessed at, or admitted to, hospital. Moreover, both infection and inflammation can themselves cause anaemia.[31,38] It is not therefore surprising that the rates of anaemia (2–11%) and of iron deficiency anaemia (0–7%) in this study are substantially lower than have been reported for hospital-based studies. In these studies, the rates of anaemia range from 22[37] to 40%[36] and the rates of iron deficiency anaemia from 14[12] to 21%[11] (rates are for Caucasian infants when reported separately). Although the majority of these studies do not state whether capillary or venipuncture blood samples were analysed, the difference in rates of iron deficiency anaemia between the present study and the hospital-based studies is greater than could be explained by differences in blood sampling techniques. Nor can the difference in rates be explained by the use of MCV and haemoglobin to define IDA, as the rates reported here are lower than those reported for other New Zealand studies that used the same indices, an identical cut-off for haemoglobin (<110 g/L) and a lower cut-off for MCV (<70 fL compared to <77 fL in this study).[7,10,11]

The rate of anaemia reported by Wham[3] in her study of healthy Auckland infants (20%) was also higher than that reported here. While venipuncture blood samples were used to assess iron status in that study, this is unlikely to account for the entire difference. The Auckland infants did not have lower intakes of total iron, nor were they introduced to cow's milk as a beverage at an earlier age than the infants in the present study. The difference may be explained partly by the presence of Maori and Pacific Islands infants (11%) in the Auckland sample, as studies suggest that these infants are at greater risk of anaemia in general[36,37] and iron deficiency anaemia in particular[12] than Caucasian infants. This may, in part, be due to different cultural practices such as the introduction of tea in infancy (11% of the Auckland infants were consuming tea), because tea is a powerful inhibitor of iron absorption.[39]

The results of this study suggest that zinc, calcium and vitamin C intakes are probably adequate among Caucasian infants and young children aged 9 months to 2 years. Although their iron intakes appear to be inadequate, the rate of iron deficiency anaemia in this population was lower than has been reported in previous New Zealand studies.

Acknowledgements. This study was funded (in part) by the Lotteries Board of New Zealand. The authors would like to thank the following people: Dr Elaine Ferguson for her advice on draft versions of the paper, Professor Rosalind Gibson for her advice on interpretation of the dietary data, Sandra Elias and Nick Prosser for their work with the diet records and food composition database, and Mary Rowlands and Sharon Lauridson for data collection. We would also like to thank the mothers who took part in the study, and their children.

References

1. WHO. Complementary Feeding of Young Children in Developing Countries: A Review of Current Scientific Knowledge. Geneva: World Health Organization, 1998.
2. Davidson F, van Rij A, Grey R. Diets of New Zealand infants and young children. J NZ Diet Assoc 1977; 31: 9–20.
3. Wham C. Dietary iron intake and iron status of young children. Asia Pacific J Clin Nutr 1996; 5: 196–200.
4. de Andraca I, Castillo M, Walter T. Psychomotor development and behavior in iron-deficient anemic infants. Nutr Rev 1997; 55: 125–132.
5. Walter T. Impact of iron deficiency on cognition in infancy and childhood. Eur J Clin Nutr 1993; 47: 307–316.
6. Lozoff B, Jimenez E, Wolf AW. Long-term developmental outcome of infants with iron deficiency. N Engl J Med 1991; 325: 687–694.
7. Poppe M. Iron deficient children (Letter). NZ Med J 1993; 106: 392.
8. Blacklock HA. Iron deficiency anaemia in New Zealand infants (Letter). NZ Med J 1999; 112: 389.
9. Dickson N, Morison I. Iron deficiency in infants of Cambodian refugees. NZ Med J 1992; 105: 83–84.
10. Crampton P, Farrell A, Tuohy P. Iron deficiency anaemia in infants. NZ Med J 1994; 107: 60–61.
11. Rive S, Blacklock H, Hawkins R, Mitchell EA. Anaemia in children aged 6–23 months attending the paediatric acute assessment unit in south Auckland. NZ Med J 1996; 108: 58.
12. Wilson C, Grant CC, Wall CR. Iron deficiency anaemia and adverse dietary habits in hospitalised children. NZ Med J 1999; 112: 203–208.
13. Burlingame BA, Milligan GC, Quigley RJ, Spriggs T. FOOD files Manual. Wellington: New Zealand Institute for Crop and Food Research, 1995.
14. Dewey KG, Heinig MJ, Nommsen LA, Lönnerdal B. Adequacy of energy intake among breast-fed infants in the DARLING study: relationships to growth velocity, morbidity, and activity levels. J Pediatr 1991; 119: 538–547.
15. Panel on Dietary Reference Values. Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. London: HMSO, 1991.
16. Butte NF. Energy requirements of infants. Eur J Clin Nutr 1996; 50: S24–S36.
17. Torun B, Davies PSW, Livingstone MBE, Paolisso M, Sackett R, Spurr GB. Energy requirements and dietary energy recommendations for children and adolescents 1–18 years old. Eur J Clin Nutr 1996; 50: S37–S81.
18. Krebs NF, Hambidge KM. Zinc requirements and zinc intakes of breast-fed infants. Am J Clin Nutr 1986; 43: 288–292.
19. Krebs NF. Whole body zinc metabolism in breastfed infants (Abstract). FASEB J 1993; 7: A153.

20. Dallman PR, Looker AC, Johnson CL, Carroll M. Influence of age on laboratory criteria for the diagnosis of iron deficiency anaemia and iron deficiency in infants and children. In: Hallberg L, Asp N-G, eds. Iron Nutrition in Health and Disease. London: John Libbey and Company, 1996; 65–74.
21. Statistics New Zealand. All About Women in New Zealand. Wellington, NZ: Statistics New Zealand, 1993.
22. Statistics New Zealand. 1996 Census of Population and Dwellings: National Summary. Wellington, NZ: Statistics New Zealand, 1997.
23. Thompson FE, Byers T. Dietary assessment resource manual. J Nutr 1994; 124: 2245S–2317S.
24. Witschi JC. Short-term dietary recall and recording methods. In: Willett W, ed. Nutritional Epidemiology. New York: Oxford University Press, 1990; 52–68.
25. Davies PS, Coward WA, Gregory J, White A, Mills A. Total energy expenditure and energy intake in the pre-school child: a comparison. Br J Nutr 1994; 72: 13–20.
26. Bingham SA, Gill C, Welch A, Day K, Cassidy A, Khaw KT, Sneyd MJ, Key TJ, Roe L, Day NE. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v 24 h recalls, food-frequency questionnaires and estimated-diet records. Br J Nutr 1994; 72: 619–643.
27. Gregory JR, Collins DL, Davies PSW, Hughes JM, Clarke PC. National Diet and Nutrition Survey: Children aged $1^1/_2$–$4^1/_2$ Years. London: HMSO, 1995.
28. Acosta A, Amar M, Cornbluth-Szarfarc SC, Dillman E, Fosil M, Biachi RG, Grebe G, Hertrampf E, Kremenchuzky S, Layrisse M. Iron absorption from typical Latin American diets. Am J Clin Nutr 1984; 39: 953–962.
29. Hallberg L, Rossander L. Improvement of iron nutrition in developing countries: comparison of adding meat, soy protein, ascorbic acid, citric acid, and ferrous sulphate on iron absorption from a simple Latin American-type of meal. Am J Clin Nutr 1984; 39: 577–583.
30. Hunt JR, Mullen LM, Lykken GI, Gallagher SK, Nielsen FH. Ascorbic acid: effect on ongoing iron absorption and status in iron-depleted young women. Am J Clin Nutr 1990; 51: 649–655.
31. Olivares M, Walter T, Osorio M, Chadud P, Schlesinger L. Anemia of a mild viral infection: the measles vaccine as a model. Pediatrics 1989; 84: 851–855.
32. Gibson RS. Principles of Nutritional Assessment. New York: Oxford University Press, 1990.
33. Moe PJ. Hemoglobin, hematocrit and red blood cell count in 'capillary' (skin-prick) blood compared to venous blood in children. Acta Paediatr Scand 1970; 59: 49–51.
34. Reeves JD, Driggers DA, Lo EYT, Dallman PR. Screening for iron deficiency anemia in one-year-old infants: hemoglobin alone or hemoglobin and mean corpuscular volume as predictors of response to iron treatment. J Pediatr 1981; 98: 894–898.
35. Thomas WJ, Collins TM. Comparison of venipuncture blood counts with microcapillary measurements in screening for anemia in one-year-old infants. J Pediatr 1982; 101: 32–35.
36. Akel RN, Frankish JD, Powles CP, Tyler KR, Watt JM, Weston HJ, Prior IAM. Anaemia in Maori and European infants and children on admission to hospital: a co-operative survey from six New Zealand hospitals. NZ Med J 1963; 62: 29–33.
37. Moyes CD, O'Hagan LC, Armstrong C. Anaemia in Maori infants – a persisting problem (Letter). NZ Med J 1990; 103: 53.
38. Jansson LT, Kling S, Dallman PR. Anemia in children with acute infections seen in a primary pediatric outpatient clinic. Pediatr Infect Dis 1986; 5: 424–427.
39. Disler PB, Lynch SR, Charlton RW, Torrance JD, Bothwell TH, Walker RB, Mayet F. The effect of tea on iron absorption. Gut 1975; 16: 193–200.