IRON IN INFANTS AND YOUNG CHILDREN

INTRODUCTION

Iron deficiency in infants and young children remains a major health problem throughout the world. In New Zealand it continues to cause concern, especially for children living in areas of socioeconomic disadvantage. Iron deficiency has a particularly detrimental effect on the growth, development and learning ability of infants and young children. Because of the potential for permanent, damaging effects, iron deficiency should be prevented whenever possible.

PREVALENCE RATES OF IRON DEFICIENCY ANAEMIA

The 2002 National Children's Nutrition Survey collected data from children aged 5-14 years old. It revealed a general trend showing as children grow older their nutritional status and exercise habits decline. This highlights the importance of incorporating a balanced diet and good eating habits early in life to continue through adolescence and adulthood. This includes obtaining enough iron-rich foods and preventing iron deficiency.

Recent research by Morton et al. (2014) (20) studied newborn iron status, as part of the Growing up in New Zealand study, and found that the mean umbilical cord haemoglobin was highest in infants of European mothers compared to those of Pacific mothers. Seven per cent of all the newborns had iron deficiency and 2% were anaemic. No newborns had both low cord serum ferritin and anaemia.

This study provides a current indication of the prevalence of iron deficiency in New Zealand newborns.

Research conducted in New Zealand during the 1960s and 1970s identified Māori infants at particular risk of iron deficiency anaemia. It was recognised as an important factor contributing to their higher morbidity and mortality rates. Surveys by Tonkin (1), Neave and Prior (2) and Davidson (3) showed Māori infants in both rural and urban areas were likely to have a low iron status. The high prevalence of iron deficiency anaemia appeared to be linked to environmental factors such as poor housing and overcrowding, leading to higher rates of infection.

A small Wellington study in 1994 found 7% European infants and 30% Māori and Pacific infants had iron deficiency anaemia. (4) More recent results from a population-based study of Auckland children aged 6-23 months show 14% had iron deficiency. As in the previous study, prevalence varied with ethnicity - Māori 20%, Pacific 17%, New Zealand European 7% - but not with social deprivation. (5)

The iron status of low birth weight infants at nine months was measured in approximately 80 infants from Dunedin. (6) Thirty three percent were found to be iron deficient and 15% had iron deficiency anaemia. Those with a low iron intake were 13 times more likely to be iron deficient than infants with a high iron intake.

The results of a cross-sectional survey on children aged 6-24 months conducted in 1999 found sub-optimal iron status in 29% of the study population, including 4.3% with iron deficiency anaemia. (7) Analysis also found toddlers were at higher risk (66%) of sub-optimal iron intake than infants (15%). The study concluded a diet high in bioavailable iron is important for obtaining optimum iron stores in young New Zealand children. (8)

Results showing an increased risk of iron deficiency amongst toddlers led to a 20-week randomised placebo-controlled food-based intervention study of 225 healthy, non-anaemic 12–20 month old South Island children. (9)

Three dietary interventions were compared: 2 servings of beef or lamb per day (aiming for 2.6mg iron/day intake from red meat), 360 mls/day of fortified commercial toddler milk (1.5mg iron/100mls prepared milk) or an unfortified powdered cow's milk placebo given ad libitum. Those in the red meat group only achieved an average intake of one serving red meat per day. At the end of the study, serum ferritin was significantly higher in the fortified milk group and the red meat group compared to the control group, with body iron higher in those on fortified milk. The researchers concluded consumption of iron-fortified milk can increase iron stores in healthy, non-anaemic toddlers, whereas increased intakes of red meat can prevent their decline.

Although data from some of these studies cannot be applied to the general population, they do raise concerns for some groups of New Zealand infants and young children. These prevalence rates for iron deficiency anaemia are high when compared to prevalence data from Australia, Europe and the United States (US) (7–9%). (10)

SCREENING

Primary healthcare providers working with socio-economically disadvantaged families may be able to reduce the known adverse effects of iron deficiency anaemia by screening all infants in their care, and educating parents on strategies to prevent iron deficiency. (11)

ASSESSMENT OF IRON STATUS

There is ongoing debate about using haematological tests to diagnose iron deficiency in infants due to possible difficulties in collection of blood samples, availability of appropriate tests and analysis of results. However, haematological tests remain the only means to determine iron status accurately. The potentially serious consequences of untreated iron deficiency mean accurate diagnosis is important.

The development of iron deficiency anaemia is the end result of a three-stage process:

1. **Lowered iron stores**
2. **Iron deficiency without anaemia**
3. **Iron deficiency anaemia**

In the first stage, iron disappears from the bone marrow. This is followed by a loss of transport iron, which causes a reduced serum iron level. Next, the iron deficiency affects red blood cell formation resulting in an increased concentration of free red cell protoporphyrin, increased red cell distribution width and reduced mean corpuscular volume. The end result is overt anaemia. (12)

Ideally, a screening programme will include only one haematological test – either haemoglobin or haematocrit. These can be assessed in the primary care setting using fingerprick blood samples, with results available almost immediately. Unfortunately these tests will only detect iron deficiency severe enough to result in anaemia. Yet recent research indicates iron deficiency, even without anaemia, may have significant effects in infants and later childhood. (13) Thus, it is important blood tests identify all children who are iron deficient, before they become anaemic.

A variety of blood parameters can be used to assess iron status. A New Zealand paper on iron deficiency management recommends the use of full blood count, serum ferritin and iron saturation. (12) **This is the most cost-effective combination to measure the body's three iron pools – iron in the red cell pool (haemoglobin and measures of red cell size), storage iron (ferritin) and transport iron (iron saturation).**

1. RED CELL POOL

A full blood count reveals the haemoglobin concentration and red cell size. Haemoglobin is the oxygen-carrying pigment of the blood. Changes in haemoglobin only occur in the late stages of iron deficiency. The two measures of red cell size are mean cell volume (MCV) and red cell distribution width (RDW). MCV should be used cautiously in New Zealand as a significant proportion of Māori and Pacific children have the ∂-thalassemia trait, which may cause associated microcytosis, so a low MCV is not specific for iron deficiency. RDW detects subtle variations in cell size, and raised RDW appears to be an early manifestation of iron deficiency. A range between 11.5-14% is normal for children. RDW is not affected by the ∂-thalassemia trait. (12)

2. STORAGE IRON

Serum ferritin measures iron stores and can be used to detect the first and second stages of iron deficiency. While infants and toddlers with low serum ferritin may have no symptoms, it is a reliable indicator the iron supply to tissues is being compromised. As serum ferritin is raised by infection, it is not a valid assessment tool when infection is present. (12)

3. TRANSPORT IRON

Iron saturation is the most accurate indicator of iron supply to the bone marrow. Values vary between individuals and are also affected by factors such as age, the time of day and the presence of inflammatory disease, which reduces levels.

CUT-OFF VALUES

Age	Red Cell Pool Hb(g/L) RDW(%)	Storage iron Serum ferritin(µg/l)	Transport iron Iron saturation(%)
12-24 months	<110 >14.0	<10	<10
2-5 years	<111 >14.0	<10	<10

Infection can affect the blood indicators of iron status. Even mild acute infection can depress haemoglobin and iron saturation, and increase serum ferritin. When infection is present, delay blood tests until the infant is healthy.

FACTORS AFFECTING IRON STORES

A foetus builds up most of its iron stores after 34 weeks' gestation. Healthy infants born at full term have usually accumulated sufficient iron stores for the first six months of life. In a premature infant, although total body iron is lower, so is body weight, thus the proportion of iron to body weight at birth is similar to that of the full-term infant. The key difference is a premature infant grows very rapidly during the catch-up growth phase. This means they are at risk of becoming iron depleted more quickly unless the diet is supplemented with iron. (14)

A study of infants aged 4-18 months investigated dietary, physiological and environmental factors affecting iron stores. (15) In very young infants (four months old), birth weight and body weight had the greatest influence on iron stores. At eight months, dietary factors associated with the weaning diet had the most significant effect. Commercial baby food (fortified with iron) had a positive effect, while cows' milk had a negative effect. Iron stores were influenced by gender at eight months and continued at 12 months, with girls generally having higher iron stores than boys. By 18 months the diet of the infant, especially its non-haem content, was the only significant determinant of iron stores.

Two Australian studies have identified factors associated with iron deficiency. Mira et al compared the iron intake of iron-depleted children aged 12-36 months in daycare, with age and sex-matched controls. Low intake of haem iron and the early introduction of cows' milk (before 12 months) were independently associated with iron depletion. (16)

An Adelaide study of younger children aged 6-24 months found age (over 12 months), short duration of breastfeeding and a high intake of cows' milk were associated with iron deficiency. (9)

In New Zealand, Wilson et al looked at 284 children aged 9-23 months admitted to Starship Children's Hospital. (11) Sixty nine percent of children with iron deficiency anaemia had a dietary factor likely to have contributed to their iron deficiency. Fifty percent of Pacific and Māori children were drinking cows' milk before eight months of age and Samoan children regularly consumed tea. For one third of the children, more commonly Europeans, meat was not introduced until after eight months.

IRON REQUIREMENTS

The following table gives the recommended dietary intake of iron for New Zealand infants and toddlers. (17)

	Iron per day (mg)
Infants 0-6 months	0.2*
Infants 7-12 months	11.0
Children 1-3 years	9.0

* AI (adequate intake)

RISK FACTORS FOR LOW IRON STORES IN INFANTS AND YOUNG CHILDREN

- Premature and low birth weight infants have reduced iron stores at birth and higher growth rates.
- Acute, recurrent infections. Impaired iron status may also predispose an infant to infections.
- Chronic malabsorption syndrome such as chronic diarrhoea or coeliac disease. These can lead to a depletion of iron stores.
- Exclusive breastfeeding after six months of age.
- Unmodified cows' milk during infancy. Cows' milk has a low content and poor bioavailability of iron. It also increases the possibility of gastrointestinal blood loss.
- 'Milkaholics'. Toddlers who drink large quantities of milk.
- Limited or restricted food intake through food refusal or a poor appetite.
- Consuming large quantities of tea or wholegrain cereals. Both tannin in tea and phytates in wholegrains inhibit the absorption of non-haem iron.
- Lack of iron-rich foods such as red meat, and to a lesser extent chicken, fish and iron-fortified cereal for children over six months of age.
- Vegetarian households where a well-balanced vegetarian diet is not available.
- Socioeconomically disadvantaged families.

SYMPTOMS OF IRON DEFICIENCY IN INFANTS AND YOUNG CHILDREN

Many iron-deficient children can remain asymptomatic. Symptoms to consider in at-risk infants and toddlers include:

- lethargy
- irritability
- inability to concentrate
- failure to thrive
- loss of appetite
- susceptibility to recurrent infections, which may be exacerbated by environmental factors such as poor living conditions and overcrowding.

Other behaviours such as increased hesitance, reduced activity and increased proximity to caregivers have been noted in iron-deficient children. This increased 'clinginess' and reduced adventure may lead to functional isolation, with fewer opportunities for stimulus and learning. (18)

The significance of impaired iron status in infants is related to its possible long-term effect on intellectual and psychomotor development. A critical period of development is between nine and 24 months. Iron deficiency during this period may cause irreversible deficits in intellectual and motor development. The severity of these deficits, and whether or not they are reversible, appears to be related to the severity and duration of the iron deficiency. (19)

FOOD SOURCES OF IRON FOR INFANTS AND YOUNG CHILDREN

The bioavailability of iron in breast milk is very high. Infant formulas in New Zealand are fortified with iron and also have additional vitamin C to improve non-haem iron absorption. Infants fed breast milk or iron-fortified infant formula for the first six months of life are likely to have sufficient iron to meet their needs.

- From approximately six months of age, weaning foods containing easily absorbed iron should be encouraged. (16,17) Initially iron-fortified infant cereals can be used, progressing on to minced lean lamb, beef, chicken, liver or kidney by about seven months. As swallowing develops, finely chopped meat can be introduced. Flaked, boned fish can be introduced from around eight to nine months. (18)

IRON ABSORPTION

A number of factors affect iron absorption in the infant gut.

- Iron stores at birth and throughout infancy. More iron is absorbed if the infant's iron stores are low.
- The amount of haem and non-haem iron in the diet of infants over six months. Haem iron is predominantly found in meat, chicken and fish. Absorption ranges from 15-35% depending on the level of iron stores. Non-haem iron, found in vegetables and fruits, legumes, cereals, eggs and soluble iron supplements, is not as well absorbed as haem iron (2-20%).
- The presence of inhibitors of non-haem iron absorption, such as tannins in tea or phytates in cereals.
- The presence of enhancers of non-haem iron absorption, such as vitamin C and meat protein.

PREVENTION OF IRON DEFICIENCY AND IRON DEFICIENCY ANAEMIA

The reduction in the prevalence of iron deficiency anaemia among American toddlers during the past 20-30 years may be due to the increased availability of iron-fortified formula and improved bioavailability of iron used to fortify infant foods. (6) In New Zealand, all infant formula is fortified with iron and a wide range of iron-fortified infant cereal is readily available.

Cows' milk does not contain much iron and its absorption is low. After the first year of life, toddlers who eat a range of iron-rich foods, rather than drinking large quantities of milk will maintain a better iron status. Beef, lamb, other lean meat and fish are excellent sources of haem iron and should be included in the variety of foods offered to young children. For vegetarian infants, iron-fortified cereal, lentils, dried beans, split peas and green leafy vegetables should be served with fruit and vegetables to enhance non-haem iron absorption.

CONCLUSION

Iron deficiency appears to be a common problem, and infants of socioeconomically disadvantaged families are especially at risk.

The significance of iron deficiency is particularly related to its effect on intellectual and pyschomotor development.

Infants who are fed breast milk or iron-fortified infant formula for the first six months of life should have sufficient iron stores. After that time, other foods are increasingly important to supply sufficient iron to meet the infant's needs for growth and development.

Nutrition guidelines for infants and toddlers stress a need for iron-rich foods such as lean red meat, plus plenty of fruit and vegetables containing vitamin C to enhance absorption of non-haem iron. (17)

WHAT DOES THIS MEAN FOR HEALTH PROFESSIONALS?

- Maintain an awareness of the importance of iron for infants.
- Focus on at-risk infants living in areas of socioeconomic disadvantage.
- Check developmental milestones are being met. Infants and toddlers are particularly vulnerable to delayed development as a consequence of iron deficiency and iron deficiency anaemia.
- Encourage breastfeeding during a baby's first six months of life or the use of an iron-fortified infant formula.
- After six months of age, check to see iron-rich foods are being added to an infant's diet – iron-fortified infant cereal, meat or chicken puree, and later minced meats and flaked, boned fish.
- Encourage fruit and vegetables as sources of vitamin C to aid the absorption of non-haem iron.
- Encourage toddlers to eat a wide variety of foods rather than relying on a high intake of cows' milk.
- Discourage high intakes of wholegrains by young infants as they contain phytates, which inhibit non-haem iron absorption.
- Discourage tea drinking by young children.

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