

Iron deficiency in infants and young children

Iron deficiency is a common nutrient deficiency in infants and young children that can usually be treated with iron supplements and diet modification. However, GPs can also play an important role in preventing iron deficiency by encouraging a varied diet that contains sufficient dietary iron in a bioavailable form.

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Iron deficiency is the most common single nutrient deficiency in the world, particularly in infants, women and children. These are also the groups at risk of developing the condition. However, the exact prevalence of iron deficiency in Australia is unknown. Two recent Australian studies found that iron deficiency was common in young children, occurring in 30% of those under the age of 2 years.^{1,2} Unlike other nutrient deficiencies, iron deficiency in childhood occurs even in socially advantaged groups. This article focuses on a nutritional approach to the prevention and management of childhood iron deficiency.

Iron requirements of infants and children

During the first 3 to 4 months of life, infants need only low levels of exogenous iron as they reuse fetal haemoglobin. After the first 6 months, they usually need a dietary source of iron because rapid growth will have depleted their iron stores. Their iron requirement from 6 to 12 months is estimated to be 9 mg/day. By 1 year of age, their growth rate has slowed down, so their iron requirement is reduced. It is only increased again during the rapid growth of adolescence (Table 1).

Compared with normal weight infants, low birth weight infants have lower initial iron stores,

IN SUMMARY

- Iron deficiency is a common nutrient deficiency in young children and is usually asymptomatic. However, it may be associated with impaired psychomotor development in those with severe or long term anaemia.
- Low birth weight babies, who have reduced iron stores at birth, are at special risk of developing iron deficiency.
- Diagnosis may be suspected after taking a routine feeding history. Confirmation is via laboratory testing.
- Treatment includes iron supplementation and, most commonly, increasing levels of bioavailable iron in the diet. Dietary measures may involve combining meals with an enhancer of iron absorption; avoiding eating foods containing inhibitors of iron absorption with main meals; or including a variety of foods rich in haem or non-haem iron in the diet.
- While nutritional causes are by far the most common reason for iron deficiency in children, other causes include occult gastrointestinal blood loss with cow's milk protein enteropathy, or haemangiomas.

have a more rapid relative rate of growth and may have lost iron as a result of frequent blood sampling. Iron stores in these children become depleted by about 2 to 3 months of age, or even earlier in very low birth weight infants. Therefore, they need a source of exogenous iron from an earlier age, often from about 2 months. Such children should be under paediatric care.

When does iron deficiency arise?

Iron deficiency occurs when there is an imbalance between iron absorption and iron metabolism.

Iron absorption

Iron absorption, which occurs mainly in the duodenum and upper jejunum, is influenced by a number of factors such as the type of iron in the diet, the body's iron status, and food components that enhance and inhibit iron absorption.

Types of iron and bioavailability

Iron is present in a range of meat and nonmeat foods (Table 2) and comes in two forms:

- haem iron – found in haemoglobin and myoglobin in meat, chicken and fish
- non-haem iron – found in other proteins and present in a variety of foods of plant and animal origin. This is also the form contained in iron supplements.

The two forms differ in bioavailability. While only about 10% of dietary iron is in the haem form, it is more bioavailable than non-haem iron and contributes about one-third of total iron absorbed. Haem iron is also less influenced by body iron status or dietary constituents that enhance or inhibit iron absorption, compared with non-haem iron.

The ferrous (Fe^{2+}) form of non-haem iron in supplements is more soluble and therefore better absorbed than the ferric (Fe^{3+}) form.

Bioavailability is also influenced by the body's iron status, and the presence of inhibitors or enhancers of iron absorption in the diet.

Body iron status

The uptake of iron by the mucosal cells and the subsequent release of iron into the portal circulation are enhanced in the presence of low total iron stores in the body. As there is no physiological mechanism for iron excretion, it is only by

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Table 1. Recommended dietary iron intake

Age	Iron (mg/day)
0–6 months (breastfed)*	0.5
0–6 months (formula fed)†	3
7–12 months	9
1–11 years	6–8
12–18 years	10–13

NHMRC Recommended dietary intakes for use in Australia. Canberra: AGPS, 1991.

*50% of the iron in breast milk is absorbed.

†recommended daily intake based on 10% absorption of iron from infant formula.

varying iron absorption that iron homeostasis can be achieved.

Main promoters of iron absorption

- At doses less than 1000mg/day, ascorbic acid (vitamin C) can increase absorption of non-haem iron by two to three times in a

continued

Table 2. Sources of dietary iron

Iron in food comes in two forms, haem and non-haem, which differ in bioavailability.

Dietary sources of haem iron

Dietary sources ranked in order of haem content, from the highest to the lowest:

- beef
- lamb
- pork
- chicken
- fish.

Foods rich in ascorbic acid*

- 1/2 cup broccoli
- 1/2 cup boiled cabbage
- 2 strips raw capsicum
- 3/4 cup boiled cauliflower
- 1 kiwifruit
- 1 small orange
- 1/2 cup orange juice
- 3/4 cup rockmelon
- 2 tomatoes

* Serving sizes equal to 50 mg ascorbic acid.

Relative bioavailability of non-haem iron

	Low	Medium	High
Cereals	Corn Oatmeal Rice		
Fruits	Apple Banana Peach Pear Plum Rhubarb Strawberry	Mango Pineapple Rockmelon	Orange Pawpaw Tomato
Vegetables	Legumes Spinach	Carrot Potato	Broccoli Cabbage Cauliflower Pumpkin
Animal protein	Cheese Egg Cow's milk		Chicken† Fish† Meat† Human milk

OLD FRUIT AND VEGETABLE GROWERS



†Meat, fish and chicken are also rich sources of haem iron. Adapted from MacPhail P. Essentials of human nutrition. Mann J, Truswell AS eds, Oxford: Oxford University Press, 1998.

dose-dependent manner.

Effectiveness of enhanced iron absorption depends on the meal and is least effective when a variety of foods is eaten. Foods rich in ascorbic acid are shown in Table 2.

- Meat not only provides haem iron, it enhances the absorption of non-haem iron by up to three times.

Main inhibitors of iron absorption

- Phytates can decrease non-haem iron absorption by 50 to 80% in a dose-dependent manner. They are found in a range of foods including legumes and cereals, with a higher content in unrefined cereals. The phytate content of a typical Western diet ranges from 10 to 100 mg/day, while vegetarian diets average 850 mg/day. Ascorbic acid, and to a lesser degree meat, can reduce the inhibitory effect of phytates.
- Polyphenols inhibit non-haem iron absorption. They are found in tea, coffee and some vegetables (including spinach), certain spices (including oregano) and in some grains (including sorghum).
- Calcium found in dairy foods and calcium supplements inhibit haem and non-haem iron absorption. Calcium has a dose-dependent inhibitory effect, decreasing absorption by about 50%. This effect has been demonstrated in single meals but the effect on the whole diet is less clear.

Iron metabolism

After absorption, iron enters the portal circulation where it is bound to transferrin. It is then redistributed to tissues, largely to the bone marrow for the production of haemoglobin in red blood cells. At the end of their life cycle, red cells are engulfed by cells in the reticulo-endothelial system where iron may be stored as ferritin or redistributed in the circulation.

Table 3. Taking a quick history of dietary iron status

Iron deficiency in the absence of anaemia is usually asymptomatic. However, much can be gleaned from taking a feeding history.

Past

- Was your child breast or formula fed?
- How long did you breastfeed?
- How long did you use formula?
- At what age was cow's milk introduced?
- At what age did you start solids?
- What types of foods did you first give to your baby?
- Did you use vitamin or mineral supplements?
- How old was your baby when you first introduced meat?

Present

- Can you describe a typical day's intake for your child?
- How much milk does your child drink each day?
- What type of cereal does your child eat?
- How often and how much meat, fish or chicken does your child normally eat?
- How often and what amount of legumes (such as peas, chickpeas, dried beans) does your child eat?
- Does your child eat fruit and vegetables? Are these foods eaten with cereals and legumes?

Dietary history suggesting iron deficiency

- Late introduction of solids (>8 months)
- Early introduction of cow's milk as a main drink (<10 months)
- Low intake of iron rich foods (Table 2)
- Large intake of cow's milk (>600 mL/day), usually due to prolonged bottle feeding

Iron deficiency develops slowly through several phases. There is an initial depletion of iron stores, although red blood cell production continues. With further depletion, serum ferritin levels decline, as do serum iron levels subsequently. As iron stores continue to be depleted, total iron binding capacity increases. Eventually, haemoglobin synthesis is affected and haemoglobin concentration falls. Knowledge of this response to iron deficiency helps to interpret laboratory investigations (see below).

Common causes

Nutritional causes are by far the most prevalent reason for iron deficiency in infancy and childhood. A low dietary intake of iron, especially of iron in its bioavailable form, is common. Low birth weight babies have reduced iron stores at birth, so are at special risk of developing iron deficiency if they do not receive iron supplements. Occult gastrointestinal blood loss is a much less common cause for iron deficiency in Australian children but may occasionally occur with cow's milk protein enteropathy or haemangiomas. Iron malabsorption due to coeliac disease is rare.

Clinical features: long and short term

Iron deficiency in the absence of anaemia is usually asymptomatic. However, the presence of iron deficiency anaemia in infancy may be associated with impaired psychomotor development. This is more pronounced in those who have had anaemia for a long period or who have more severe anaemia. Some studies suggest that the effects of iron deficiency anaemia on developmental outcome in young children may be long-lasting.³ Lethargy, pallor and decreased physical and mental performance become increasingly apparent as the anaemia of iron deficiency develops.

Occasionally, children with chronic iron deficiency may manifest pica (i.e.

eating unusual items such as dirt), or chew ice.

Making the diagnosis

Diagnosis of iron deficiency anaemia is usually on clinical suspicion after taking a routine feeding history (Table 3) and confirmed by laboratory testing (Table 4). Note that the most convincing evidence of iron deficiency anaemia is the response to iron therapy; within seven to 10 days of starting iron supplementation, there is an increase in the reticulocyte count (Table 4). For more detailed information on the investigation of anaemia in childhood, see Berdoukas.⁴

Management

The treatment of iron deficiency involves both iron supplementation and correcting the underlying cause (usually inadequate dietary intake).

Iron supplementation

Iron can be given orally as ferrous sulfate or ferrous gluconate (6 mg/kg/day of elemental iron divided into two doses daily). Iron absorption is enhanced if given with orange juice and if administered at times other than mealtimes, although this may give rise to abdominal discomfort. Treatment should be maintained for two to three months after haemoglobin levels have returned to normal to replenish iron stores.

Iron supplementation may cause the stools to become firmer and darker, so warn the carer.

Modifying the child's diet

Milk intake

Encourage the continuation of breastfeeding or, for those who are not breastfeeding, the use of infant formula as the main milk drink for the first year. Both cow's milk and human milk have small quantities of iron (0.2 to 0.4 mg/L) but the iron in human milk is more bioavailable. Full-term, solely breastfed infants are usually not iron deficient

during the first 6 months of life. However, if infants are fed cow's milk, they may show signs of iron deficiency. Therefore, all formula milks are fortified with iron (7 to 12 mg/L) to prevent iron deficiency. Formula milks are also supplemented with vitamin C to increase iron bioavailability.

Other foods

Introduce foods, including iron-fortified manufactured infant cereals, fruits, vegetables, meat and dairy products, at around 6 months of age. However, traditional foods for young children (cereals, fruits, vegetables and legumes) only provide small amounts of iron. While cereals and legumes contain iron, it is not in a bioavailable form due to the presence of phytates. Phytate levels can be reduced by cooking or fermentation, methods shown to improve iron bioavailability in some soy products including miso and tofu. Combining fruits and vegetables with cereal can increase iron absorption.

Manufactured infant cereals are fortified with iron and are a better source of iron than the adult equivalents. Avoid tea and coffee in children as they will decrease iron absorption. High intakes of calcium will also decrease iron absorption, so it may be advisable to give milk at a separate time to food.

Meat is a good source of haem iron but this is often only a minor part of a child's diet. Commercial baby foods, except iron-fortified infant cereals, are a low source of iron; the iron salts in infant cereals are absorbed in the same way as non-haem iron.

Further tests and when to refer

If iron deficiency does not respond to iron supplementation and dietary iron intake:

- enquire about treatment adherence
- reconsider the diagnosis; could there be occult blood loss?
- refer to a paediatric expert for further investigation.

Prevention

As well as diagnosing and managing iron deficiency, GPs are in a good position to prevent young children developing it. For example, encourage:

- breastfeeding and recommend exclusive breastfeeding for the first six months
- infants who are not breastfed to be fed a commercial infant formula for the first 12 months
- the use of an iron-enriched cereal among the first foods; then mix with a vitamin C rich food at the same meal
- introduction of foods rich in haem iron as first foods
- combining meat with vegetables

Table 4. Laboratory diagnosis of iron deficiency anaemia

Only laboratory testing can confirm a diagnosis of iron deficiency made on clinical suspicion.

Selected haematological age-related reference values⁵

Test	Age	Range
Haemoglobin	1 month	100–130 g/L
	3–12 months	95–140 g/L
	5 years	115–140 g/L
Haematocrit	1 month	0.30–0.48
	3–12 months	0.28–0.45
	5 years	0.35–0.45
Mean cell volume	1 month	84–105 fL
	3–12 months	70–85 fL
	5 years	75–90 fL
Reticulocytes	1 month	20–65 × 10 ⁹ /L
	3–12 months	20–105 × 10 ⁹ /L
	5 years	20–105 × 10 ⁹ /L
Serum iron	6–12 months	5–15 µmol/L
	>1 year	10–30 µmol/L
Serum ferritin*	>6 months	10–150 µg/L

*Ferritin is an acute phase reactant and can be raised in the presence of inflammation, malignancy and liver disease.

Laboratory confirmation of iron deficiency

- Decreased haemoglobin
- Decreased haematocrit
- Decreased mean cell volume
- Decreased serum ferritin level
- Decreased serum iron level
- Microcytosis and hypochromia on the blood film
- Increased reticulocyte count within 7–10 days of starting iron supplements.

Further information for patients and their families

Nutrition Australia

Nutrition Australia (was the Australian Nutrition Foundation) has leaflets including:

- Nutrition for toddlers and young children
- Food for under 2s
- Eating the vegetarian way
- Are you getting enough iron?

Contact the Nutrition Australia office in your capital city, or look at

<http://www.nutritionaustralia.org>

New Children's Hospital, Westmead, NSW

The leaflet 'Ways to boost iron intake' can be downloaded from the New Children's Hospital's internet site at <http://www.nch.edu.au/parents/health/factsheets/ironprint.htm>. Alternatively, contact the hospital's Health Promotion Unit on (02) 9845 3585.

Meat and Livestock Australia

Meat and Livestock Australia (MLA) produces leaflets including:

- Easy iron-rich meals for babies 6 to 12 months
- Easy iron-rich meals for toddlers.

Contact the MLA on (02) 9463 9333 or toll-free on 1800 550 018. Alternatively, the MLA internet site is at <http://www.mla.com.au>

- combining vitamin C rich foods with cereals
- avoiding feeding whole cow's milk as a drink in the first year
- limiting cow's milk intake to no more than 600 mL/day (in children aged more than 12 months)
- using a variety of iron containing foods
- vegetarians to obtain enough dietary iron by careful meal planning.

Vegetarians could include foods like legumes (pea and bean group) and grains. Note that legumes are a rich source of iron but in a form that is of low bioavailability. Include vitamin C rich foods at each meal as this will improve the bioavailability of all plant sources of iron.

Conclusion

Iron deficiency during childhood is a common problem that can be prevented by choosing a diet based on a variety of foods. The main challenge is to provide

enough dietary iron in a bioavailable form. It is the bioavailability of iron that is the major determinant of the likelihood of developing iron deficiency. **MT**

References

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