The Lead Education and Abatement Design Group
Working to eliminate childhood and foetal lead poisoning
by the year 2012 and to protect the environment from lead
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Fact Sheet –Iron Nutrition and Lead Toxicity

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Note: a longer more comprehensive version of this article is available at:
www.lead.org.au/lanv9n3/Iron_Nutrition_and_Lead_Toxicity_Full.pdf

Iron metabolism: Overview

Iron is an essential micronutrient[1,2,3]. The total amounts involved are small; an adult female will have 2-4 grams of iron (around 38mg per kilo) in her body, an adult male up to six (around 50mg per kilo)[4]. Males tend to have more due to being larger, not suffering blood loss due to menstruation and some innate differences that begin at puberty[5,6]. Adult males normally have three times the stored iron of premenopausal females (1000 mg to 300mg seems a widely quoted figure but I have not sighted the original source), a fact true for vegetarians as well as omnivores (480 mg to 160 mg; the same source problem applies)[7].

The majority of iron in the body is bound in haemoglobin [or hemoglobin (US spelling)] (found in red blood cells [erythrocytes]) where it is used in transportation and processing of oxygen within the body[8,9,10]. Up to 10% is used in myoglobin that stores oxygen in the muscles[11,12,13,14]. Over 4% is used in lung metabolism[15] playing a vital role in respiration[16]. Most of the remainder is stored in the compound ferritin, over two thirds of which is deposited in the liver, the bulk of the remainder being split between bone marrow and reticulo-endothelial cells[17,18,19]. Transport of iron within the body is handled by the serum molecule transferrin and at a cellular level by DMT1 [Divalent Metal Transporter 1][20,21,22]. The entire complex system is designed to ensure there is minimal free iron since free iron damages body organs through oxidation due to its highly reactive nature[23,24].

Smaller trace amounts fulfill key roles within the body with functions such as immune defense[25,26], neural function[27,28,29], DNA synthesis[30,31], cellular energy production[32], liver function[33], apoptosis[34], elastin production[35] and collagen production[36]. Iron levels are associated with bone strength and density[37]; iron deficiency is linked to stress fractures in female athletes[38].

Iron cannot be systematically excreted from the body and is recycled within the body[39,40] predominantly by macrophages of the reticulo-endothelial system. Macrophages of the spleen and liver generally recycle red blood cells before they reach the end of their natural life (120 days) eliminating 1% per day[41]. The total iron absorbed from food each day is about 0.06% of total adult body iron[42] although for infants this figure can be multiplied by up to six[43]. The main cause of iron loss from the body is blood loss (including significant losses inside the gut[44], particularly for athletes[45,46]). This is the primary determinant of iron status[47,48] though some iron is lost through sweat (peaking within half an hour of heavy sweating) and skin loss[49,50]. Losses from urine are minimal (about 0.1 mg)[51]. For most women menstruation will double to triple iron loss, with losses being slightly higher for adolescents, but it can be even higher[52]. Diet cannot outweigh heavy blood loss[53,54]. Women with heavy menstrual flow should see their doctors as some medication (including the contraceptive pill) can reduce menstrual bleeding.

Iron & lead: interactions and iron supplementation

Low iron levels are associated with higher blood lead levels[55,56,57], though there is no direct evidence of causation. Iron and lead occupy similar sites within the human body and so compete for likely binding sites particularly during absorption[58]. Iron deficiency increases the rate of lead transfer to the brain in rats since they share a common transporter (DMT1)[59]. Rat studies indicate iron may be able to reduce lead induced apoptosis (programmed cell death) in the brain[60] and reduce lead related disruption during brain development[61].

Rectifying significant iron deficiency may significantly impact blood lead levels[62,63,64]. With pregnancy it directly impacts on the blood lead of the newborn[65]. Low maternal iron levels or high lead levels increase the risk to the feotus of schizophrenia later in life[6667]. With children, correcting iron (or zinc) deficiency may lead to the cessation of pica (the compulsive consumption of non-food items such as paint or clay) which can be a source of lead contamination[68].

On the other hand the evidence is poor for supplementation where iron intake is adequate is poor[6970], especially with low lead levels[71]. There might still be advantages to iron supplementation for individuals whose environmental exposure is through ingestion[72].

Iron cooking vessels: The following items have their iron content more than doubled when cooked in iron container without a protective surface. *Rear Row:* red cabbage, tomato, rice, corn meal *Front Row:* tomatoes, capsicum (bell or banana peppers in USA), pureed vegetables, wild rice, apple sauce, scrambled egg, corn meal, *Foreground:* scrambled egg. *Not pictured:* milk.

Iron consumption & iron levels: A long term project

Iron levels can be modified by diet[737475] though the role of individual nutrients should not be overstated[76]. The body regulates the absorption of iron, so iron absorption falls as iron levels rise, due to the influence of the hormone hepcidin[77]. The more hepcidin is produced by liver cells the less iron will be absorbed[78]. Rapid changes in iron status should not be expected[7980].

Iron absorption enhancers

In terms of iron enhancement (increasing the body's iron level) one of the easiest methods is increasing meat in the diet. A significant quantity of the iron in meat is haem [or haeme or heme (US spelling)]. Between 15-40% of haem iron in the diet is absorbed compared with 1-15% of non-haem iron[81]. Haem iron is found in animal products and some supplements, whereas non-haem iron is found in animals, plants and supplements. Cooked beef contains more haem iron (65% of iron content) than cooked pork (39%) and poultry or fish (26%)[82].

For vegetarians and vegans a good supplementation technique is through cooking acidic vegetables (such as tomatoes or cabbage) in non enameled cast iron pots[83]. Non haem iron absorption can be reduced if stomach acidity is impaired[84] (for instance by aging, infection or the use of antacids[85]). Vitamin C (ascorbic acid) clearly enhances non-haem iron absorption[8687], though its impact should not be overstated[88]. Vitamin C may also enhance iron's capacity to displace lead during food absorption[89] Fish oil (and/or carbohydrates) enhances iron absorption where certain significant inhibitors are present[90].

Vitamin C: 120 g of the foods (pictured above) should provide sufficient Vitamin C to optimize iron absorption (up to 480g if cooked, for juice equivalent check labels). Top row: parsley, guava (juice pictured), blackcurrant (juice pictured), kale *Middle Row:* radish, capsicum (bell pepper in US), kiwi fruits, broccoli *Bottom row:* feijoa, baby capsicums, brussel sprouts, guava, horse radish *Not pictured:* Mustard greens, red peppers, thyme.

Vitamin C: 240 g of the foods (pictured above) should provide sufficient Vitamin C to optimize iron absorption (up to 960 g if cooked, for juice equivalent check labels). Top row: watercress, kohlrabi [kohl rabi, german turnip] (leaves), silver beet (spinach in Australia), popcorn. *Middle Row:* kohlrabi (bulbs), grapefruit, orange, lemon, cauliflower *Bottom row:* papaya [paw paw in Australia], strawberries, lime, dill, kaffir lime [K-lime, makrud lime]. *Not pictured:* Lychee

Alcohol reverses the effect of genes governing the hormone hepcidin (decreasing hepcidin levels) leading to much higher iron absorption[91][92]. It is important to note that in spite of high iron levels, individuals who consume significant amounts of alcohol are up to five times more likely to have elevated blood lead[93] and, in the case of pregnant women, are more likely to transfer lead to the fetus[94].

Iron absorption inhibitors

Calcium can reduce iron absorption by 50-60%[95] but the experimental data contains inconsistencies and its impact on a whole diet is difficult to assess[96]. It is the only inhibitor that affects both haem and non-haem iron[97].

The following comments on inhibitors apply only to non-haem iron:

Soy proteins inhibit iron absorption[98] unless the product is fermented (like traditional soy sauce, tempe or miso)[99]. Phytic acid [phytate in salt form] (found abundantly in whole grains, bran, nuts and seeds[100]) can reduce iron absorption by as much as 90%. Even small quantities significantly inhibit iron absorption[101]. However this inhibitory effect is significantly reduced by the presence of ascorbic acid, with vitamin C's impact being proportional to the phytate content[102].

Calcium & soy: The pictured quantity of milk or cheese would minimize iron absorption, half that would little impact. For milk products (like yogurt) check label (impacts at 300ml or more with impact rapidly accelerating). Unfermented soy products (beans, milk and meat substitutes) inhibit iron absorption but are high in iron.

Phytates: The most powerful iron inhibitors. Least inhibitory when baked with yeast (*right rear:* wholegrain bread) and should always be consumed with vitamin C (*left rear:* apple & blackcurrant juice). *Middle row:* baked beans, beans (black turtle, black eye, lima, white, barlotti), bran, peanuts *Front row:* sunflower & sesame seeds, peas, beans, nuts (almond, brazil, cashew), muesli.

Tannins (polyphenols found in tea) can reduce absorption by up to 90%[103] (generally closer to two thirds[104]) but dissipate rapidly while other polyphenols found in coffee have roughly half the effect but are longer lasting[105]. Carotenoids (pigments in other than light green vegetables) and vitamin C can negate the impact of polyphenols[106][107].

Polyphenols: The above items contain polyphenols that may inhibit iron absorption. Note the considerable overlap with phytates. *Left to Right* Nuts (almond, brazil, cashew) beans (black turtle, black eye, lima, white, barlotti), coffee, tea, wine, string beans, snow peas, chocolate, nuts (peanuts), lentils, peanut butter, baked beans *Not Pictured:* Sorghum

Carotenoids – Some of the carotenoids found in the items pictured above may be able to counteract the inhibitory impact of polyphenols in coffee & tea. *Top row* Silver beet (spinach in Australia), yellow Indian corn, endives, lettuce, ruby red grapefruit juice, basil. *Middle row* Squash, red cabbage, broccoli, watermelon, pink grapefruit, cabbage, pumpkin. *Lower row* bananas, asparagus, carrots, tomatoes, red onions, red peppers, feijoa, guavas, apples, red peppers, beans, peas, banana capsicum (banana peppers in USA), avocado. *Not pictured* Pimentos, pepper grass, parsley, kiwi fruit.

Egg whites (egg albumin) can inhibit iron absorption by 27% per egg[108].

Eggs: Products that contain egg whites (such as pavlova centre rear) severely inhibit iron absorption and should be replaced with products such as papaya and egg yolk pudding (as vitamin C will enhance iron absorption from the egg). Simple ceramic egg separators are readily available. Traditional Italian gelato (not all gelato) may use egg yolks (right bowl) or less frequently egg whites (left bowl).

Metallic nutrients: Relatives in competition

Zinc supplements can inhibit iron absorption but only at significant levels[109] (doses of 15 mg/day seem to have no impact). Iron supplementation should have minimal impact on zinc levels[110] though an impact is possible[111]. Consuming iron supplements on other than a daily basis should minimize the problem[112]. Copper deficiency (generally caused by excessive zinc supplementation[113]) inhibits iron absorption in rats[114] and can negate iron supplementation[115][116]. Manganese severely impacts iron absorption[117] and its absorption is hindered by high iron stores[118].

Iron supplementation: approach with caution

Iron supplementation either directly by pill or multi-vitamin should be undertaken with extreme care; particularly with children[119][120]. Where supplements are taken low dosages may be almost as effective as high doses[121][122][123] and

Carotenoids & Vitamin C: The items (pictured above) are high in both of these nutrients and should optimize iron absorption when polyphenols are present: *Left to right:* kale (in pot), thyme, banana capsicum (banana pepper in USA), capsicum (bell peppers in USA), red pepper, guava, broccoli, feijoa, kiwi fruit.

General Note: Not all polyphenols inhibit iron absorption and there insufficient evidence to know exactly how effectively individual food items that contain carotenoids can offset those that do.

may even produce superior long term results with less risk[124][125][126][127]. A recent study of rats' brains found that a lower level of iron supplementation had a more positive effect on lead-induced damage than high level iron supplementation[128].

Although the body loses iron (eg through menstruation) it does not systematically excrete iron, and therefore the cumulative effect from supplementation can be dangerous; a continuous load exceeding 1-2 mg/day can eventually result in iron overload leading to organ failure[129]. Studies of pregnant women indicate that weekly iron supplementation may be preferable to daily supplementation[130]. Weekly or biweekly supplementation can radically reduce the risk of side effects from iron supplementation[131].

High Iron levels: Impacts

It is worth remembering that iron is also a neurotoxin and that in the USA iron is the largest cause of fatal accidental poisonings in children under 6[132]. High iron levels enhance the effect of malaria and tuberculosis[133]. High levels of iron doubles the risk of diabetes[134]. Having both high iron and high Very Low Density Lipoprotein (VLDL) cholesterol levels appears to doubles the risk of cancer[135] and triples risk of Alzheimer's disease[136]. High iron levels impact on the liver and can lead to liver failure[137].

High levels of iron during pregnancy are associated with gestational diabetes mellitus[138]. The birth weight of infants can be adversely affected by high maternal iron levels[139]. It must be emphasized however that for most individuals the risks of high iron during pregnancy are considerably less than those of low iron[140][141]; the argument for considering supplementation is strong[142][143].

'Iron deficiency is not a diagnosis'

Remember that iron deficiency can be the result of disease[144] including cancer[145]. **'Iron deficiency is not a diagnosis.'**[146] An inadequately balanced diet may be.

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