

"Balancing Iron: Understanding the Implications of Iron Deficiency and Toxicity on Human Health"

Iron is an essential mineral that plays a critical role in numerous physiological processes, including oxygen transport, energy production, and immune system function. According to the National Institute of Health (NIH) (2024) “Maintaining proper iron levels is vital for health, but imbalances: either deficiency or toxicity, can have serious consequences”, coincidentally iron deficiency is one of the most widespread nutritional disorders globally, particularly affecting women, children, and individuals in low-income settings. It can lead to anaemia, developmental delays, and reduced work capacity. On the other hand, iron toxicity, often caused by excessive supplementation or genetic conditions such as hemochromatosis, can damage organs, particularly the liver, heart, and pancreas, and may increase the risk of chronic diseases.

Iron intake recommendations vary based on age, sex, and physiological status, reflecting the body's differing needs throughout life. The following intake values were set by the Committee on Medical Aspects of Food and Nutrition Policy (COMA) 1991 (British Nutrition Foundation, 2021). Infants require between 0.27 to 11 mg per day, with higher needs after six months of age. Children need between 7 to 10 mg daily, while adolescent boys require about 11 mg and girls about 15 mg due to the onset of menstruation. Adult men require 8 mg per day, whereas women of reproductive age need 18 mg to compensate for menstrual blood loss. Pregnant women have the highest requirement at 27 mg daily to support fetal development and increased maternal blood volume, while lactating women need slightly less—around 9 to 10 mg . Factors such as calcium, phytates, and tannins can inhibit iron absorption, highlighting the importance of both dietary sources and absorption enhancers in meeting iron needs effectively.

Iron deficiency is a condition that occurs when the body lacks sufficient iron to meet its physiological needs, particularly for haemoglobin synthesis and cellular metabolism. Iron deficiency mostly happens because people aren't getting enough iron from their diet, or their bodies aren't absorbing it properly. Iron comes in two main forms: heme iron, which is found in meat and is easy for the body to absorb, and non-heme iron, which comes from plant foods and is harder to absorb. Things like vitamin C can help boost absorption, but certain foods—like whole grains, tea, and dairy—can block it. The body uses a hormone called hepcidin to decide how much iron to take in from food. When iron levels are low, hepcidin goes down, helping the body absorb more; when levels are high, hepcidin goes up and blocks absorption. People who eat mostly plant-based diets, especially in low-income areas, are more likely to become iron deficient because their food doesn't have much easily absorbed iron. This is why iron deficiency is so common in certain groups, like kids and women, and why nutrition plays such a big role in preventing disease. Research by **World Health Organization (2008)** and **Zimmermann and Hurrell (2007)** underscores that the most common causes of iron deficiency globally are dietary insufficiency (low intake or poor bioavailability), blood loss

(e.g., menstruation, gastrointestinal bleeding), and increased requirements (e.g., growth, pregnancy). Iron deficiency disrupts oxygen delivery to tissues, impairs cognitive development in children, reduces physical performance, and weakens the immune response.

Iron toxicity occurs when the body takes in or absorbs too much iron, overwhelming its natural ability to regulate and store it safely. Unlike other nutrients, the body has no efficient way to get rid of excess iron, so when intake exceeds needs, especially through supplements or fortified foods, it can build up to dangerous levels. The key regulator of iron balance is the hormone hepcidin, which usually keeps iron absorption in check. However, when people consume very high amounts of iron—either suddenly (as with overdose) or gradually (through chronic high intake) hepcidin can't keep up, allowing too much iron into the bloodstream. According to Ganz and Nemeth (2012), excess iron leads to the formation of non-transferrin-bound iron (NTBI), a free and reactive form that can damage tissues by producing harmful molecules called reactive oxygen species (ROS). Over time, this can hurt organs like the liver, heart, and pancreas. Nutrition plays a major role in this process—not just in how much iron is consumed, but in how it's absorbed. Heme iron from meat is more easily absorbed than non-heme iron from plants, and some people, especially those with genetic conditions like hemochromatosis, absorb even more iron than normal from the same foods. Research also shows that people who take high-dose iron supplements without medical supervision are at increased risk of toxicity. So, while iron is essential, too much—especially from concentrated sources like pills can be harmful, highlighting the importance of balance and individualized nutrition.

Iron plays a vital yet delicate role in human health, with both deficiency and toxicity leading to significant physiological consequences. Iron deficiency, the most common nutritional disorder worldwide, disrupts oxygen transport, impairs cognitive and physical development, and weakens immune function. It typically arises from inadequate intake, chronic blood loss, or increased physiological demands and progresses through a well-characterized depletion of iron stores, culminating in anemia. Conversely, iron toxicity results from excessive accumulation, often due to genetic disorders or unregulated supplementation, and leads to oxidative stress, organ damage, and chronic disease. Both conditions are governed by the hormone hepcidin, which regulates iron absorption and distribution. Disruption in this regulatory mechanism underpins the pathology of both extremes. This highlights the importance of maintaining iron homeostasis—not only through adequate dietary intake but also through careful monitoring and personalized interventions. Ultimately, understanding the processes and implications of both deficiency and toxicity is essential for developing effective strategies to promote optimal iron status across populations.

References

British Nutrition Foundation (2021) Nutrition Requirements. Available at: <https://www.nutrition.org.uk/media/nmmewdug/nutrition-requirements.pdf> (Accessed: 11/04/2025)

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