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Bioavailability & absorption of Iron and Anemia

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Introduction

Humans derive iron from their everyday diet, predominantly from plant foods and the rest from foods of animal origin. Iron is found in food as either haem or non-haem iron. Haem iron, which is about up to 40 per cent of the iron in meat, poultry, and fish, is well absorbed. All the iron in plants (fruits, vegetables, grains, nuts) is in the form of non-haem iron and is relatively poorly absorbed. Non-haem iron contributes about 90-95 per cent of total daily iron in vegan diets. In western countries,the intake of haem iron from meat and meat products accounts for bulk of the dietary iron. The haem iron consumption is minimal in developing countries with majority obtaining non-haem iron from cereals, pulses, vegetables and fruits'. The diets is plagued by low iron content and poor absorption. Major sources of non-haem iron are plant foods. The iron is chemically diverse, ranging from simple iron oxides and salts to more complex organic chelates such as hydroxyphosphates in phytoferritin(1).

Iron Bioavailability and Type of Foods

Bioavailability of non-haem iron from commonly consumed plant based diets is estimated to be low due an abundance of phytic acid and polyphenols coupled with lowered consumption of meat or ascorbic acid. The subjects consuming plant-food based diet (vegan diet) are predisposed to developing iron deficiency anaemia. The majority of dietary non-haem iron enters the GI tract in the ferric form, which is insoluble and thus inaccessible. This needs to be converted to the ferrous form for absorption at the enterocyte. The acidic pH is essential and critical for iron to be in the soluble ferrous form which in turn determines its subsequent intestinal bio-accessibility (2).

Bioavailability of food iron is strongly influenced by enhancers and inhibitors in the diet. Presently, there is no satisfactory in vitro method for predicting the bioavailability of iron in a meal. Iron absorption can vary from 1% to 40%, depending on the mix of enhancers and inhibitors in the meal. The bioavailability of iron in usual diets can be improved by altering meal patterns to favour enhancers, lower inhibitors, or both(2).

Enhancers of iron absorption include haem iron, present in meat, poultry, fish, and seafood; ascorbic acidpresent in fruits, juices, potatoes and some other tubers, and other vegetables such as green leaves, cauliflower, and cabbage; and some fermented or germinated food and condiments, such as sauerkraut and soy sauce (cooking, fermentation, or germination of food reduces the amount of phytates). Inhibitors of iron absorption include phytates, present in cereal bran, cereal grains, high-extraction flour, legumes, nuts, and seeds; food with high inositol content; iron-binding phenolic compounds (tannins). Foods that contain the most potent inhibitors resistant to the influence of enhancers include tea, coffee, cocoa, herbal

infusions in general, certain spices (e.g. oregano), and some vegetables; and calcium, particularly from milk and milk products. Iron and phytate content are negatively correlated to iron availability. The diets with rice (low in iron and phytates) as staple had better availability of iron as compared to diets with Bajra (high in iron, phytate) as staple (3).

Excessive levels of hepcidin, a hormone which regulates iron, which can be elevated due to inflammation; and the biological factors which can influence that impact the body's ability to absorb any nutrient likegastrointestinal disorders,"chronic low grade inflammation and infections" can also reduce absorption of iron (3).

Iron Absorption and Types of Diet

The iron absorption is related to the individual's iron status. More iron is absorbed by iron-deficient persons and less by those who are iron-replete, although the regulatory mechanism involved is not understood. Unfortunately, this adaptive increase in iron absorption is not great enough to prevent deficiency in people consuming diets typical of the developing world(3).

The broad categories of diets as per the iron bioavailability may be characterized as follows.

Low bioavailability diet. This is a simple, monotonous diet based on cereals, roots and tubers with negligible quantities of meat, fish or ascorbic acid. It contains a preponderance of foods that inhibit iron absorption such as maize, rice, beans, whole wheat flour and sorghum, and is typical diet of many developing countries, particularly among poorer people. There are some diets from which iron absorption is even lower. The very low bioavailability diets is composed almost entirely of cereals and iron absorption may be as low as 3-4%(4).

Intermediate bioavailability diet. Diets in this category consist mainly of cereals, roots or tubers, but include some foods of animal origin and/or ascorbic acid. A low bioavailability diet can be brought up to intermediate bioavailability by increasing the intake of foods that enhance iron absorption such as meat, fish or foods rich in ascorbic acid. Similarly, a high bioavailability diet can be reduced to an inter-mediate level by the regular consumption of meals with iron absorption inhibitors such as tea or coffee.

High bioavailability diet. This is a diversified diet containing generous quantities of meat, poultry, fish, or foods rich in ascorbic acid. Such a diet is typical of most population groups in industrialized countries(3).

The subjects consuming a low bioavailability diet, are not be able to meet their iron requirements at a food consumption level which is adequate for their energy needs. This is especially true for young children, adolescent girls, menstruating adult females, and pregnant women(3).

Major determinants of iron absorption

Dietary factors:

1. Factors that enhance non-haem iron absorption:
   Ascorbic acid (vitamin C)
   Meat, poultry, fish and other sea foods
   Low pH (e.g., lactic acid)
2. Factors that inhibit non-haem iron absorption:
   Phytates
   Polyphenols, including tannins

Host factors:

1. Iron status
2. Health status (infections, malabsorption) (3)

Methods of Food Preparation and Processing and Bioavailability of Iron (3)

The methods of food preparation and processing influence the bioavailability of iron. Cooking, fermentation, or germination can, by thermal or enzymatic action, reduce the phytic acid and the hexa- and penta-inositol phosphate content. All inositol phosphates inhibit iron absorption in proportion to the total number of phosphate groups. Processing procedures that lower the number of phosphate groups improve bioavailability of non-haem iron.

The absorption of dietary iron is influenced by the amount and chemical form of the iron, the consumption during the same meal of factors enhancing and/or inhibiting iron absorption, and the health and iron status of the individual. Contamination iron usually has a very low bioavailability. One exception is the iron derived from cooking pots. Iron compounds that are used for food fortification vary considerably in bioavailability. Easily soluble compounds, for example, ferrous sulfate, are readily available but often discolour the food or turn it rancid. Other compounds such as metallic iron powders are only partially available, but usually cause fewer such technical problems (4).

Non-haem iron from foods is absorbed in a fundamentally different way from haem iron.

Haem iron is readily available and may account for as much as one-quarter of the iron absorbed from a diet rich in meat. Its bio-availability is little affected by the nature and composition of a given meal. In contrast, the absorption of non-haem iron is highly variable and depends on what other foods are eaten with the meal, especially on the balance between foods that promote and those that inhibit iron availability.

Enhancers of Iron Absorption

Iron absorption is thus strongly influenced by the combination of foods eaten in a given meal. The meat and fish are enhancers of iron absorption. This means that they are of double value. Not only do they directly contribute rich amounts of haem iron, but they also enhance the absorption of the non-haem iron present in the rest of the meal. Ascorbic acid (vitamin C) is another enhancing factor. In developing countries, where meat intake is low, ascorbic acid is the single most important enhancer of iron absorption. Adding as little as 50 mg of ascorbic acid to a meal, whether in pure form or in vegetables or fruits (for example, an orange or a lemon, or 100 g of cabbage, or 200 g of amaranth), will double iron absorption(3).

Inhibitor of the absorption of iron

Many compounds are known to inhibit the absorption of iron, among them phytates, polyphenols (including tannins), and soy protein. Soy protein can impair iron absorption under certain circumstances, especially when it is used as a meat substitute. However, because of the intrinsically high iron content of soy protein products, the net effect of their addition to a meal increases the total amount of iron absorbed. Phytates are present in wheat and other cereals. Even very small amounts of phytate markedly reduce iron absorption. Fortunately, this inhibitory effect can be counteracted with ascorbic acid(3).

Tannins, which are present in tea and to a lesser extent in coffee, are also iron absorption inhibitors. Other polyphenols are found in nuts and legumes. Once again, the inhibitory effect of all polyphenols can be counteracted by adding ascorbic acid to the meal. For example, 0.17 mg of iron is available from a meal consisting of maize, rice and black beans, but if vitamin C is added in the form of pure ascorbic acid (50 mg) or cauliflower (125 g), the amount of iron absorbed increases respectively to 0.41 mg or to 0.58 mg. Drinking of tea, especially strong tea, with or shortly after the meal has a marked inhibitory effect on iron absorption. The inhibitory effect of tannins could be avoided by encouraging people to wait until after the meal before drinking tea or coffee. In general, however, it may be culturally more acceptable to encourage the addition of an absorption enhancer to the meal than to discourage consumption of an inhibitor(2).

Iron Absorption and Parasitic Infestations

There is evidence that the total number of parasites can interfere with the absorption of iron and othernutrients, particularly if the worm load is heavy; this has been shown for Giardia, which reduces iron absorption(5).

Absorption of iron during Pregnancy and Infancy

Pregnancy

A total amount of about 700-850 mg of iron is needed to meet the iron requirements of a mother and fetus during pregnancy, at delivery, and during the peri-natal period. Iron needs during the first trimester are lower than pre-pregnancy needs; they increase to maximum during the second half of the pregnancy and especially during the last trimester. For unknown reasons, dietary iron absorption in iron-sufficient women is reduced during the first trimester and increased in the second half of pregnancy. The average woman of reproductive-age needs about 350-500 mg additional iron to maintain iron balance during pregnancy. Potentially, this iron could be provided either from the mother's iron stores or from iron supplements. However, this additional iron do not come from iron stores, as women in developing countries very seldom have iron stores. Overall, iron absorption is increased during pregnancy, when menstruations stops. Pregnant women still do not absorb sufficient additional iron, however, and the risk of iron deficiency increases(2).

In developing countries 25-30% of women have no iron reserves at all. Because the situation is especially serious among pregnant teenagers. Hence, all pregnant women (universal supplementation) should be given 60 mg iron and 400 µg folic acid daily during the second half of

pregnancy to control iron deficiency anaemia. There is some evidence, however, that smaller doses of 30 mg daily could achieve similar results(6,7).

The folic acid is always given with iron during pregnancy due to increased folic acid requirement of pregnant women. Also, that iron and folic acid deficiencies are more common in pregnancy(8).

Infancy

Special considerations apply to iron needs during the first year of life. The iron content of human breast milk is low—about 0.5 mg per litre—but so is the term infant's iron requirement for the first 4-6 months of life. An infant taking in 600-650 ml of breast milk daily is ingesting approximately 0.3 mg of iron per day. The bioavailability of this iron is quite high, however; as much as 0.15 mg of iron per day may be absorbed. From about 6 months of age, the iron requirements increase markedly and the supply from breast milk alone is no longer sufficient. Low-birth-weight infants exhaust their iron stores at an earlier age and require additional exogenous iron before 6 months of age(2).

Achlorhydria and Iron Absorption

Achlorhydria has been recognized as an associated feature of iron deficiency anaemia for many years. It is, however, not known whether the extent of acid secretion is associated with the high prevalence of iron deficiency anaemia. Evidence for enhanced iron absorption in the presence of normal gastric acidity compared to cases of achlorhydria has been documented (1). A study was conducted in India in which the gastric acidity was measured in 3 different groups in India (Delhi, Vellore and Mumbai) and compared with that reported from western countries. The basal acid output in normal Indians is significantly lower (~pH 3.4) than that in western subjects (pH 2.5). This difference could compromise non-haem iron solubility and accessibility in Indians and can therefore be play a role in the aetiology of high anaemia prevalence in India(1).

Vitamin C and Iron Absorption

The ascorbic acid can make efficient absorption of dietary non-haem iron. However, the vitamin C intake is very low in vegan diets. Vitamin C becomes negligible upon cooking due to the thermal instability of ascorbic acid.

Over Absorption of Iron

Normal individuals have a mechanism for reducing iron absorption when iron stores are adequate that prevents iron overload in these subjects. In fact, food iron absorption in normal populations is estimated to be nearly nil when serum ferritin levels are greater than 60 mcg / l.

Iron Absorption and Zinc Intake

The adverse effects of zinc on iron absorption is induced by an iron: zinc ratio of 2: 1. This is aggravated by decrease in dietary ascorbate when the dietary phytate content is high (9,10,).

Iron absorption and calcium Intake

The influence of calcium supplements on the absorption of dietary nonheme iron and of iron supplements has been studied. Evidence suggests that all calcium supplements inhibited absorption of the iron supplement when taken with food. Women taking regular calcium supplements with meals are not able to meet their daily iron requirement(11).

Iron absorption and Coffee Intake

Dual isotope studies were performed in iron replete human subjects to evaluate the effect of coffee on non-heme iron absorption. It has been found that a cup of coffee reduced iron absorption from a hamburger meal by 39% as compared to a 64% decrease with tea. Tea is also known to be a potent inhibitor of iron absorption. No decrease in iron absorption occurred when coffee was consumed 1 hour before a meal(12).

Vitamin A and Iron Absorption

Evidence suggests that iron absorption increases (4-12%) depending on the content of carotene or vitamin A added to the meal(13).

Conclusion

The bioavailability of iron from foods is strongly influenced by enhancers and inhibitors in the diet. The absorption iron from the diet can vary from 1-40%. The iron absorption can be doubled by changing the composition of diet like adding vegetables and fruits with ascorbic acid. The consumption of mixed vegetables diet alongwith seasonal fruits and vegetables can provide a sustainable absorption of iron leading to prevention of anemia.

Recommendation

The food based guidelines to improve the absorption of iron can bring the sustainable solution to the problem of Anemia in different age groups. The addition of green leafy vegetables, cauliflower, cabbage, potatoes, germinated foods etc. should be part of the routine diet. The meat, fish and other non-vegetarian foods increase the iron absorption, however, the cultural and religious factors should be considered before recommending them. The tea is known inhibitor of iron absorption. It should be avoided during and immediately after a meal.

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