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Nutritional Strategies For Managing Iron Deficiency Anaemia In Various Populations:

A Comprehensive Review

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Abstract: Iron deficiency Anaemia represents the most common nutritional deficiency disorder worldwide, creating a significant public health issue across all demographics. This condition occurs when the intake, absorption, or utilization of iron is insufficient to meet the body's requirements, leading to reduced hemoglobin production and the development of small, pale red blood cells. Three stages often characterise the condition: first, the body's iron stores are depleted; next, the formation of red blood cells is decreased because of inadequate iron; and last, and the advent of observable Anaemia symptoms. Commonly experienced symptoms include fatigue, pallor, breathlessness, a rapid heart rate, fragile and brittle nails, tongue inflammation, hair thinning, and restless legs syndrome. Important risk factors encompass pregnancy, adolescence, heavy menstrual periods, vegetarian or vegan diets, weight-loss surgeries, regular blood donations, and chronic health conditions. From a physiological standpoint, iron deficiency compromises the body's capacity to transport oxygen, produce cellular energy, create DNA, and facilitate various enzymatic processes. Proper nutritional management is vital for both treating and preventing this condition, highlighting the significance of consuming heme iron sources like meat, fish, and poultry, as well as non-heme sources such as legumes, greens, and fortified grains, while also including enhancers like vitamin C. Nutraceutical strategies, including iron supplements, biochemically enhanced crops, and specially formulated functional foods, are crucial for improving iron levels. If untreated, iron deficiency Anaemia may cause cognitive and learning difficulties, a weakened immune system, complications during pregnancy, and a decreased quality of life.

***Index Term*:** Iron deficiency anemia, nutritional management, dietary strategies, iron supplementation, iron bioavailability, micronutrient deficiency, heme iron, non-heme iron folate, vitamin B12, ferritin; iron absorption inhibitors, phytates, tannins, calcium, women of reproductive age, pregnant women, food fortification, dietary diversification, public health nutrition, nutritional education, Anaemia prevention.

I. INTRODUCTION:

Iron deficiency Anaemia is the most common type of Anaemia globally. The World Health Organization notes that it affects about 30% of the world's population and is the most widespread nutritional deficiency. It is more commonly seen in women and children, but adult men can also be affected, depending on their health and financial conditions. Low iron intake and poor absorption can also cause iron deficiency anemia, even though blood loss from the digestive system and menstrual bleeding are the most common reasons. Iron plays a key role in several essential bodily processes, including enzyme function, DNA production, oxygen transportation, and energy generation in the mitochondria. Anaemia is a condition where the number of red blood cells or the amount of hemoglobin in the blood is lower than normal. [1]

According to the World Health Organization, the following hemoglobin levels are used to diagnose anemia: for men over 15 years of age, hemoglobin levels below 130 g/L; for pregnant women, below 110 g/L; and for non-pregnant women over 15, below 120 g/L. The main characteristic of iron deficiency Anaemia is a lack of hemoglobin, which leads to smaller and paler red blood cells than usual. [2]

Table 1: populations and hemoglobin Diagnostic of anemia

Population	**hemoglobin Diagnostic of Anaemia (g/dL)**
Children aged 6 months to 6 years	Less than 11.0 g/dL
Children aged 6 to14 years	Less than 12.0 g/dL
Adult men	Less than 13.0 g/dL
Adult non-pregnant women	Less than 12.0 g/dL
Adult pregnant women	Less than 11.0 g/dL

About 5% of the Earth's crust is made up of iron, which is extremely beneficial for a variety of biological processes due to its capacity to change chemical forms. Iron is a component of many vital bodily components, and these proteins fall into four major groups:

1. Iron proteins that are mononuclear, such as superoxide dismutase.
2. Di iron-carboxylate proteins, including ferritin and ribonucleotide reductase.
3. Proteins that include iron and sulphur, like aconite.
4. Iron deficiency Anaemia is associated with heme proteins, including haemoglobin.[3]

Definition: According to World Health Organisation, "An iron deficiency occurs when the body does not store enough usable iron, and there are indications that the tissues, particularly red blood cells, are not getting enough iron." Anaemia is the outcome of more severe forms of iron deficiency. Hypochromic-microcytic Anaemia is another name for iron-deficient anaemia.[4]

Figure 1 : iron rich food

History:

Iron deficiency affects approximately 2 billion individuals worldwide, making it perhaps the most widespread nutritional issue. Iron deficiency Anaemia is the most apparent consequence. In more extreme instances, Iron deficiency Anaemia leads to noticeable symptoms such as paleness. However, diagnosing iron deficiency was previously challenging without advanced assessments like bone marrow examinations or blood tests, and Anaemia does not solely account for pale skin. It was not until the 1930s that medical professionals recognized the primary cause of hypochromic microcytic Anaemia (small, pale red blood cells) as iron deficiency, which can sometimes result from an inadequate diet. The clinical effects of iron deficiency, even in the absence of anemia, are currently under investigation. Thus, our discussion will center on the early developments that contributed to the recognition of Iron deficiency Anaemia and the understanding that a deficiency of the fourth most abundant element on earth could lead to health issues. [5] A comprehensive medical history can assist in identifying iron deficiency anemia, despite it being diagnosed through laboratory tests. This history may also shed light on the cause of the Anaemia and possibly the duration of its presence. With mild blood loss, iron deficiency Anaemia often emerges gradually. In such cases, individuals may not show any signs until their iron stores are sufficiently depleted to hinder red blood cell production and other bodily functions, leading to fatigue and additional symptoms. Pagophagia, the craving to chew or suck on ice, occurs in half of patients with moderate iron deficiency anemia. [6]

Iron Deficient Anaemia Stages:

Anaemia is brought on by a lack of iron. Your body often saves some iron for later use in phases after obtaining it from your food. Haemoglobin, the material that carries oxygen in red blood cells, is made from this stored iron. When you don't get enough iron from your food or when your body depletes iron stores more quickly than they can be replenished, you get iron deficiency anaemia. It proceeds in three phases:

Initial stage: Your red blood cells stay normal while your iron levels begin to decline.

Second stage: Your body alters how it produces red blood cells, and your iron levels are extremely low. Your bone marrow begins to manufacture red blood cells with low haemoglobin levels. [7]

Final stages: Healthy erythrocytes that have aged and been removed from the bloodstream are replaced by an increasing number of small, haemoglobin-deficient cells that enter the bloodstream. The development of progressive microcytic, hypochromic anaemia, which is typified by decreased haemoglobin synthesis, increased total iron binding capacity, decreased transferrin saturation, and decreased serum iron, is now associated with iron-deficient anaemia. The haemoglobin level is below the normal range for both age and sex. [8]

Absorption of Iron:

- Iron from the diet is found primarily as heme, derived from myoglobin and hemoglobin, or nonheme iron, derived from plants and iron-fortified foods.
- Ferric iron is first reduced to ferrous iron by duodenal cytochrome B (DCYTB) on the apical membrane.
- Then, ferrous iron is transported across the apical membrane by divalent metal transporter 1 (DMT1).
- After entering the cell, iron is either employed in several cellular functions, stored in ferritin, or transferred across the basolateral membrane via ferroportin.
- After transport across the basolateral membrane, ferrous iron is oxidized to ferric iron by hephaestin.
- Then, transferring circulates and carries ferric iron.
- Iron absorption is reduced when hepcidin binds to ferroportin because hepcidin causes the internalization and degradation of ferroportin. [9]

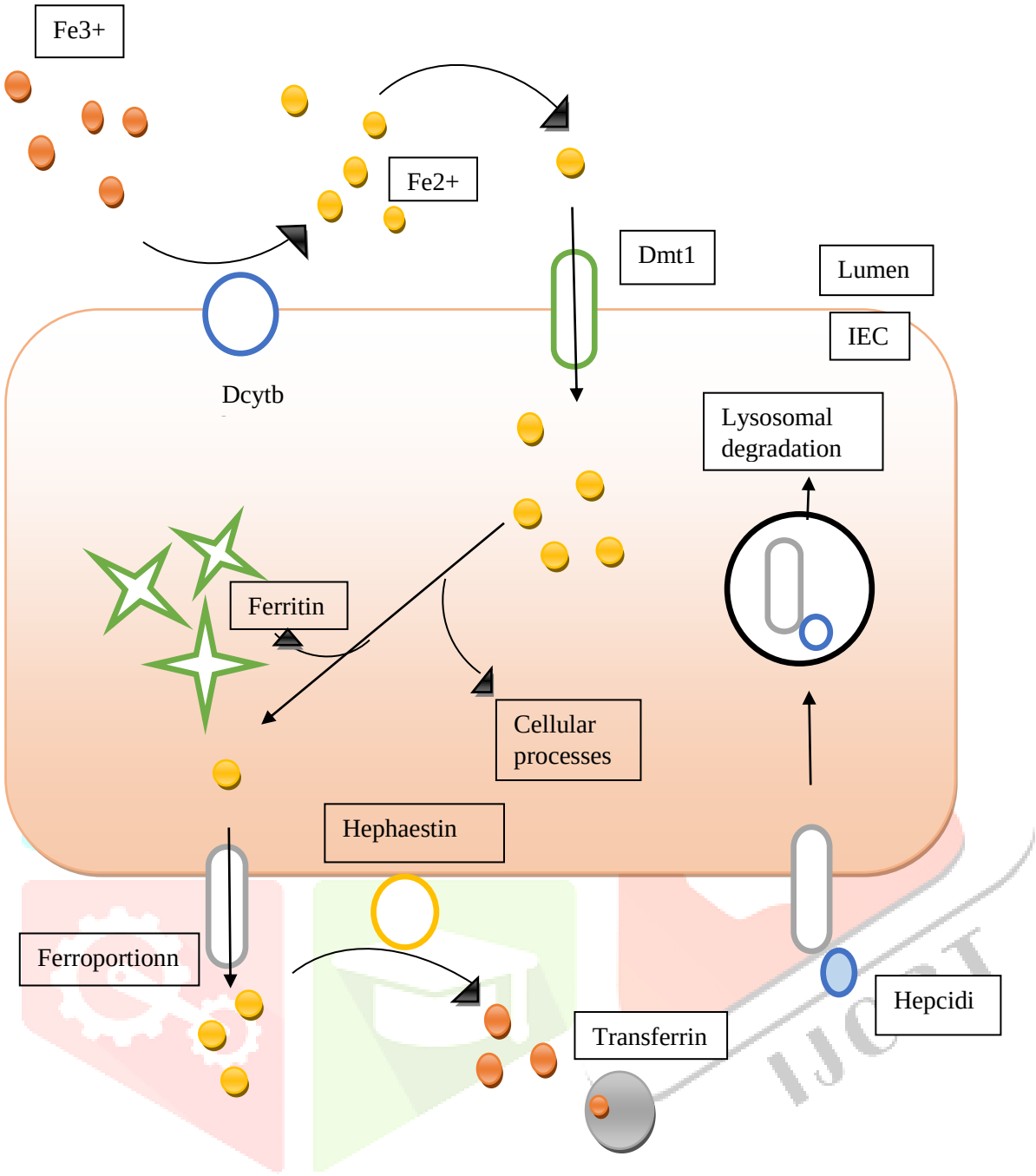


Figure 2: Absorption of non-heme iron by intestinal epithelial cells (IECs). [9]

II. SYMPTOMS:

Iron deficiency Anaemia is a condition that can arise from a lack of iron when your body does not have sufficient iron. Common symptoms include paleness, fatigue, and shortness of breath.

1. **Abnormal fatigue**: Fatigue is one of the most common indicators of iron deficiency anemia. When your body lacks enough iron for hemoglobin production, which is crucial for transporting oxygen throughout the body, you experience tiredness.
2. **Paler skin than usual**: Having skin that is paler than normal, along with light pigmentation in the inner lower eyelids, can also indicate iron deficiency.
3. **Shortness of breath**: Iron deficiency typically leads to low levels of oxygen and hemoglobin. This means your muscles may not receive enough oxygen to carry out everyday activities such as walking.

4. **Heart palpitations**: Individuals with iron deficiency Anaemia may notice a sensation of their heart beating strongly.
5. **Dry and damaged hair and skin:** Iron deficiency Anaemia might result in dry or damaged skin and hair. Nutritional deficiencies can deprive skin and hair of the necessary blood flow and nutrients for proper growth.
6. **Swelling and soreness of the tongue or mouth**: Changes in the mouth or its surface can occasionally signal iron deficiency anemia. Symptoms may include dry mouth, a burning sensation in the tongue, and a swollen, irritated, pale, or smooth mucous membrane, along with painful, red cracks in the corners of the mouth.
7. **Restless legs**: Lower dopamine levels in the bloodstream due to iron deficiency can lead to restless legs syndrome.
8. **Brittle or spoon-shaped fingernails**: Spoon-shaped fingernails, also referred to as koilonychia, are another indication of iron deficiency anemia. [10]

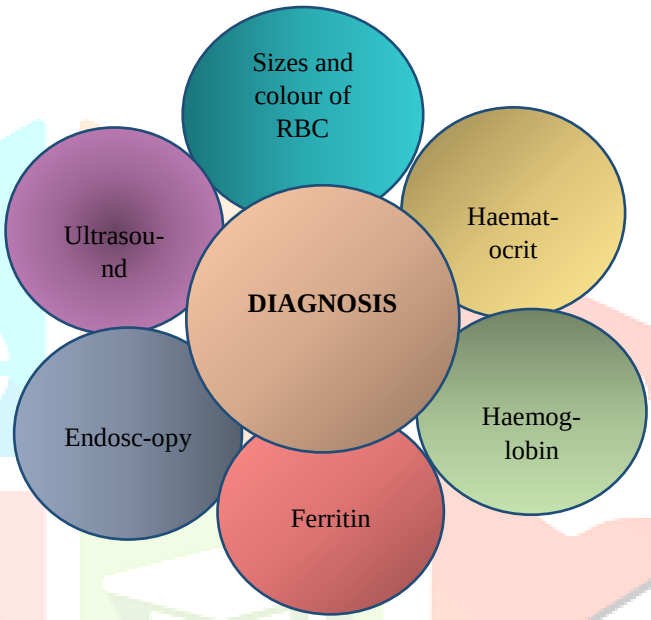


Figure 3: Diagnosis of Iron deficiency anemia. [11]

According to World Health Organisation criteria, people who are not pregnant and have a hemoglobin level between 8 and 11.9 g/dL, as well as clinical symptoms including exhaustion and pallor, are diagnosed with iron deficiency anemia. Iron deficiency anemia's differential diagnosis includes: Lead poisoning, the microcytic Anaemia in chronic conditions, Condition of hemoglobin CC, Hemoglobin dysfunction, Allergy-induced hemolytic anemia, Haemoglobin S-beta thalassemia. [12]

III. CAUSES

1. Inadequate iron: Insufficient consumption of iron, Lack of iron, A poor diet, such as a vegetarian diet, might induce Anaemia by causing inadequate heme iron (because a healthy individual absorbs only 3–5% of their dietary iron). [13]
2. Reduced Absorption: Dietary iron comes in two chemical forms: heme iron, which is found in meat, and non-heme iron, which is found in plant and dairy products. Heme iron absorption is unaffected by the makeup of meals or gastrointestinal secretions. Non-heme iron (1–5%) from a vegetarian diet is not as well absorbed as heme iron (8–10%). Anaemia is therefore more common among vegetarian women, especially after menarche.
3. Increased Requirement: Anaemia may arise from dietary iron deficiencies at times of increased demand, such as infancy, puberty, pregnancy, and breastfeeding. During the perinatal period, the

growing brain undergoes rapid anatomical and functional changes, requiring a consistent iron supply. Long-lasting and frequently irreversible negative effects on neurodevelopment seem to result from either an excess of iron or from failing to achieve the iron requirements during this crucial time. The rapid s, weight gain, and blood volume expansion of adolescents of both sexes, as well as the commencement of menstruation in girls, make them especially susceptible to anemia. Compared to boys, who grow between 13 and 16 years, girls grow during the 12–to 15–year period of middle adolescence. Because of the increased iron requirements during pregnancy and the blood losses during menstruation, a woman of reproductive age needs at least twice as much iron as a male or a post-menopausal women.[14]

4. Post-Menopausal Women: Iron deficiency Anaemia can occur in postmenopausal women as a result of continuous blood loss, even though the body's need for iron declines when menstruation stops. Among the significant reasons during these years are the following:
   - Uterine haemorrhage following menopause brought on by uterine cancer.
   - Bleeding from the digestive tract, including from hiatus hernias and stomach and large bowel cancer.
5. Men of adult age: When iron absorption and dietary iron levels are normal, adult males rarely develop iron deficiency anemia. Chronic blood loss accounts for the great majority of adult male cases of iron deficiency anemia. A persistent haemorrhage may have one of the following causes: Bleeding typically originates in the gastrointestinal system and can be caused by several conditions, including ulcerative colitis, oesophageal varices, hiatus hernia, peptic ulcers, hemorrhoids, hookworm infestation, and cancer of the stomach and large bowel. Following gastrointestinal surgery and malabsorption are two more causes in the gastrointestinal tract. b. Urinary tract conditions, such as hemoglobinuria and haematuria. c. Nose, as in recurring epistaxis, for example. d. The lungs, such as in hemoptysis from several causes. [15]
6. Iron deficiency rapidly affects the epithelial cells, thereby leading to dryness and roughness of the skin, dry and damaged hair, koilonychia, and alopecia. In mild-to-moderate iron deficiency, loss of tongue papillae is reported. Atrophic glossitis is also noted in severe cases. Iron deficiency may be associated with restless legs syndrome. [16]

IV. RISK FACTORS:

Iron-deficiency Anaemia is statistically more likely to occur if you:

- They are either pregnant or have recently given birth.
- Breastfeeding is recommended.
- Bariatric surgery is a treatment that involves altering the digestive system to help individuals who are extremely obese lose weight.
- Vegetarians, vegans, and others who avoid foods high in iron in their diets.
- Young female athletes are particularly vulnerable to iron deficiency.
- Have had major surgery in the past, particularly weight loss or gastrointestinal operations. Menstruate, particularly if you experience thick periods. [17] [18]

V. COMPLICATION:

1. **Iron Deficiency Anaemia Concerns**: Typically mild, iron deficiency Anaemia can be treated.. However, if untreated, it may lead to additional health problems.
2. **Rapid or irregular heartbeat:** When you have anemia, your heart has to work harder to pump more blood to bring in enough oxygen, which can make your heart beat more quickly or irregularly. This can lead to irregular heartbeats. In severe cases, cardiac failure or an enlarged heart could occur.
3. **Pregnancy complications:** A significant iron deficiency during pregnancy may lead to an early birth or low birth weight. For this reason, iron supplements are a common element of prenatal treatment for most pregnant women.
4. **Infant and kid growth delays**: Children and newborns with significant iron deficiency may have delayed growth and development. Additionally, it can make them more prone to sickness. [19]

Any severe Anaemia can result in hypoxemia and increase the risk of myocardial ischemia and coronary insufficiency. Similarly, people with chronic lung disease may experience worsening of their pulmonary status. Squamous cell carcinoma of the cricoid region has been linked to dysphagia with solid

foods and Plummer-Vinson syndrome, which is characterized by webbing of the mucosa at the intersection of the esophagus and hypopharynx. Iron deficiency causes atrophic gastritis, which is characterized by a progressive loss of pepsin, intrinsic factor, and acid secretion as well as the development of an antibody against gastric parietal cells. It blunts the small intestinal villi. [20] It is well recognized that iron deficiency Anaemia and isolated iron deficiency (also known as hidden iron deficiency) in pregnant women raise maternal morbidity and mortality. In pregnancy, untreated isolated iron deficiency is associated with an increased risk of iron deficiency anemia, placental hypertrophy, and maternal hypothyroidism. [21]

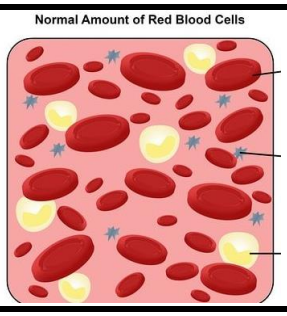
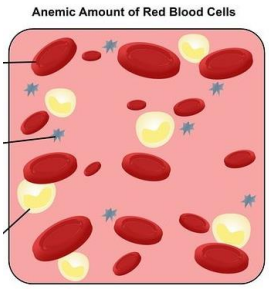
VI. PATHOPHYSIOLOGY

The disorder known as iron deficiency Anaemia impairs the body's capacity to make hemoglobin and meet its metabolic needs, which results in anemia's clinical presentation. Iron metabolism is tightly regulated by the processes of absorption, storage, and recycling. Iron from the diet is absorbed in the duodenum and the upper part of the jejunum in the small intestine, and it originates from both heme sources (animal) and non-heme sources (plant). [22] The protein transferrin then carries the iron to storage locations like the liver or to the bone marrow for erythropoiesis (the creation of red blood cells). Hepcidin, a hormone generated by the liver that regulates iron intake and release from storage, is the main regulator of iron homeostasis. Numerous factors can cause an iron shortage, all of which throw off the equilibrium between iron intake, storage, and utilization. Inadequate dietary iron intake, elevated iron needs, chronic blood loss, malabsorption disorders, and the effect of Iron deficiency Anaemia on hemoglobin synthesis and red blood cell development are the main causes of Iron deficiency anemia. Since iron is more easily absorbed by the body from animal products, including meat, poultry, and fish, inadequate dietary intake is a significant cause of Iron deficiency anemia. [23]

Since blood contains a large amount of iron, chronic blood loss is frequently the cause of iron deficiency anemia. The main causes of chronic blood loss include frequent blood donation, parasitic infections, heavy menstruation (menorrhagia), and gastrointestinal bleeding. People with conditions that affect the small intestine, which is where iron absorption mostly occurs, may experience iron malabsorption. Inflammatory bowel disease, stomach surgery, and celiac disease are common causes. Smaller, hypochromic (pale) red blood cells are the result of direct inhibition of hemoglobin synthesis caused by iron shortage. Red blood cells' capacity to carry oxygen is hampered by low hemoglobin, which causes symptoms like weakness, exhaustion, pallor, and dyspnea. Inflammatory bowel disease, stomach surgery, and celiac disease are common causes. Smaller, hypochromic (pale) red blood cells are the result of direct inhibition of hemoglobin synthesis caused by iron shortage. Red blood cells' capacity to carry oxygen is hampered by low hemoglobin, which causes symptoms like weakness, exhaustion, pallor, and dyspnea. [24]

The proper diagnosis and successful treatment of iron deficiency Anaemia depend on an understanding of its pathophysiology, namely the equilibrium between iron metabolism and the many causes of insufficiency. To restore iron balance and avoid long-term repercussions, the underlying reasons must be addressed, whether by dietary modifications, supplements, or the treatment of underlying disorders. [25] There are two types of dietary iron: heme and non-heme. Heme iron, which is produced from the hemoglobin and myoglobin present in meat, poultry, and fish, is more efficiently absorbed. Although it is more difficult to absorb, non-heme iron is mostly present in plant-based meals. Plant-based substances like phytate, oxalate, polyphenols, and tannins, as well as some medications like proton pump inhibitors, reduce the absorption of non-heme iron. [26, 27]

Table 2 :Laboratory finding iron deficiency Anaemia [28]

LABORATORY FINDING	NORMAL	IRON DEFICIENCY ANEMIA
Red Cell Morphology		
Red Cell Indices	MCV, MCH, MCHC All Normal	MCV Decrease, MCH Decrease, MCHC Decrease.
Marrow Erythropoiesis	 Normoblastic	 Micronormoblastic
Marrow Iron Stores	 Normal	 Deficient

VII. ALLOPATHIC REMEDIE:

Classification:

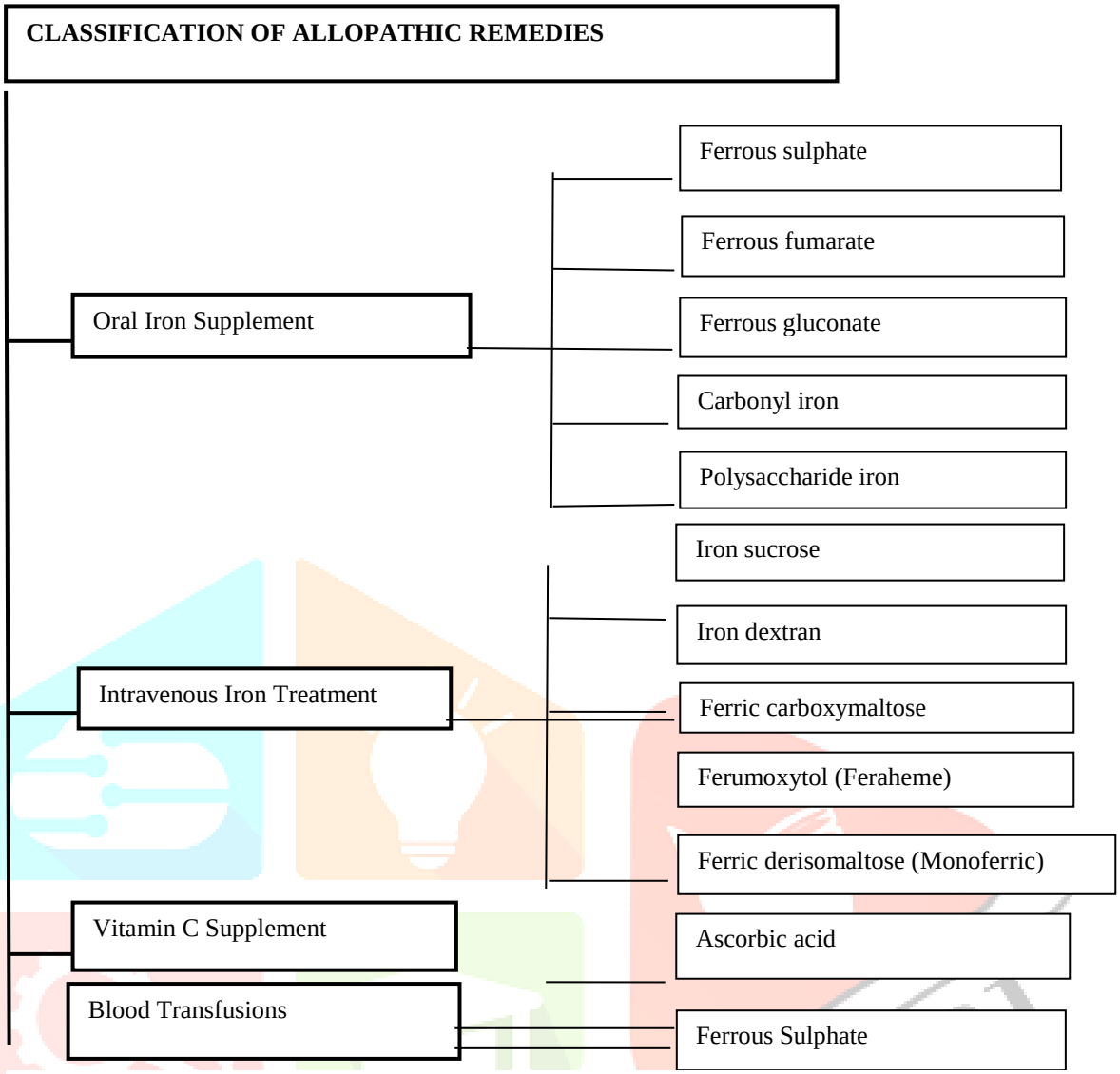


figure 4 :classification of allopathic remedies.

VIII. NUTRACEUTICAL MANAGEMENT AND ADVANCES:

The treatment of iron-deficiency Anaemia includes oral iron supplements as well as treating the underlying cause, such as gastrointestinal haemorrhage. When taking iron supplements, it is best to consume them empty-handed. Iron absorption is facilitated by a low pH in the stomach. A low pH in the stomach makes it easier to absorb iron. Usually seen within 14 days, a rapid response to treatment is demonstrated by a rise in hemoglobin levels. Iron supplements should be used for at least three months to restore tissue iron stores, and for an additional month once hemoglobin levels have stabilized. Ferrous sulfate, which is usually taken in two to three doses per day, is an inexpensive and efficient therapeutic alternative. Constipation, nausea, diarrhea, and loss of appetite are common side effects of oral iron. Intravenous iron may be required if a patient cannot tolerate oral iron, has malabsorption disorders such as celiac disease or post-gastrectomy, or experiences severe losses that oral therapy is unable to make up for. Intravenous iron does not cause hemoglobin levels to rise more quickly than oral iron, but it is more reliably and rapidly delivered to the reticuloendothelial system. When iron is administered intravenously, nausea is the most common adverse effect. Anaphylaxis is rare but can occur following intravenous iron therapy. Iron solutions can cause brownish discolorations that are unsightly for the patient and may be permanent when they seep into the subcutaneous tissue. [29][30][31]

Restoring the body's iron reserves and relieving symptoms are the main goals of treatment. If treatment is not received, this could result in negative results for expecting mothers and children, including neurodevelopmental delays. Women of reproductive age are at risk since Anemia's frequently brought on by pregnancy and monthly periods. [32]

Due to diseases like gastritis or concealed malignancy, older persons may have delayed gastrointestinal bleeding and typically eat diets low in iron. Hemodialysis patients and those with chronic renal disease frequently have an iron deficiency, which makes it difficult for their kidneys to manufacture erythropoietin, exacerbating anemia. Malabsorptive conditions, which include pernicious anemia, small intestinal bacterial overgrowth (SIBO), celiac disease, and Whipple disease, might cause patients to have trouble properly digesting the iron in their food. [33]

Plant-based sources such as Colocasia esculenta, amaranth, and Cowpea leaves are rich in iron and antioxidants, making them highly beneficial for individuals with inflammatory bowel disease (IBD). Effective probiotic strains that improve the absorption of dietary iron include Bifidobacterium bifidum W23, Bifidobacterium lactis W51 and W52, Lactobacillus plantarum, Lactobacillus acidophilus W37, Lactobacillus casei W56, Lactobacillus brevis W63, Lactococcus lactis W19 and W58, and Lactobacillus salivarius W24. These probiotics are known to increase iron absorption by 50% and also increase its stability and vitality. One type of algae, known as Mankai alga (or duckweed), has been found to rehabilitate hemoglobin levels and restore normal blood parameters.

Six months in a rat model of anaemia. Similarly, algae of the genus Gracilaria have a large amount of inorganic iron and bioactive components and have the potential to reduce inflammatory cytokine production. Macroalgae of the genera Porphyria, Sargassum, and Ulva are known to possess the highest iron contents during spring.

Ganoderma lucidum extracts significantly improve the hematological parameters in healthy rats and increase the leukocyte population; this probably could be because of the combination of its iron content and antioxidant and anti-inflammatory properties. [34]

Talinum triangulare, Telfairia occidentalis, and Amaranthus hybridus are some of the most prevalent and commonly eaten leafy greens in West Africa. Talinum triangulare, commonly known as water leaf, is a perennial deciduous herb that has woody stems and succulent leaves from the family of Portulacaceae. In Nigeria, it is consumed as a vegetable, normally as a constituent.

It contains important nutrients such as proteins, vitamins, and β-carotene, as well as essential minerals like potassium, magnesium, and calcium. Water leaf is used medicinally for addressing diarrhea and various digestive issues, reducing inflammation, aiding in weight management, and improving cardiovascular health. Documented reports have shown Talinum triangulare to possess hematopoietic potentials, antioxidant properties, hypoglycaemic and hypolipidaemic activities, and anti-ulcer potentials. Telfairia occidentalis, commonly known as Fluted Pumpkin, is another staple vegetable that is commonly found in Nigeria and many other West and Central African regions. It is a vegetable with luxuriant green leaves from the family of Cucurbitaceae that is mostly cultivated for both culinary and medicinal uses. It is rich in antioxidants, proteins, fiber, minerals like calcium, iron, and sodium, as well as vitamins B1, B3, and C. It is widely used in the folk remedies of diabetes mellitus, hypertension, inflammation, and bacterial infections. Reports have shown Telfairia occidentalis to possess hematopoietic potentials antioxidant and hepatoprotective, antiplasmodial, and antimicrobial properties, antidiabetic activities, anti-inflammatory and analgesic activity, and the ability to enhance male fertility.

Amaranthus hybridus is a perennial monoecious plant belonging to the Amaranthaceae family, often referred to as pigweed or amaranth. It is commonly found growing as a weed in cultivated fields and is characterized by green leafy vegetables with its abundant flowers. They are consumed alone or with other leafy vegetables as soup or other delicacies. Amaranthus hybridus is rich in protein, carbohydrate, and fibre, as well as sodium, potassium, magnesium, iron, and phosphorus. It also contains high levels of vitamins A and C, as well as nitrates and oxalates. Its medicinal applications encompass the treatment of indigestion, toothaches, boils, burns, and snake bites. Several reports have demonstrated its hematopoietic, immunomodulatory, antioxidant and hepatoprotective, antimicrobial, and anti-carcinogenic potentials. [35]

IX. CONCLUSION:

Globally, iron deficiency Anaemia remains a major health concern that impacts social, emotional, and physical well-being. Iron deficiency for proper hemoglobin synthesis is the hallmark of this condition, which progresses from early depletion to overt Anaemia due to a complicated interaction between chronic losses, elevated physiological demands, and inadequate food. Risk groups are disproportionately affected, including children, pregnant women, women of reproductive age, and people with gastrointestinal illnesses. The condition can be reliably diagnosed through hematological and biochemical parameters, and its pathophysiology underscores the clinical consequences of reduced

oxygen delivery, including growth retardation, poor pregnancy outcomes, and diminished productivity. While allopathic management with oral and parenteral iron is effective, nutritional strategies form the cornerstone of sustainable prevention and management. These include promoting iron-rich foods, enhancing absorption with vitamin C, discouraging iron inhibitors, and utilizing food fortification and biofortification. Thus, an integrated approach combining clinical therapy with targeted nutritional interventions remains the most effective path to reducing the burden of iron deficiency Anaemia worldwide.

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