CHAPTER – I
INTRODUCTION

1.1 Anemia

Anemia is a broad term applied to the condition in which there is inadequate or defective formation of haemoglobin and defective maturation and formation of red blood cells. Nutritional anemia may be defined as the condition that results from the inability of the erythropoetic tissue to maintain a normal haemoglobin concentration on account of inadequate supply of one or more nutrients leading to reduction in the total circulating haemoglobin. Nutritional anemia is caused by the absence of any dietary essential that is involved in haemoglobin formation or by poor absorption of these dietary essentials. Some anemias are caused by lack of either dietary iron or high quality protein; by lack of pyridoxine (vitamin B₆) which catalyses the synthesis of the heme portion the haemoglobin molecule; by lack of vitamin E which affects the stability of the red blood cell membrane. Copper is not part of haemoglobin molecule but aids in its synthesis by influencing the absorption of iron, its release from the liver or its incorporation into haemoglobin molecule.

Iron deficiency anemia (IDA) is the most common nutritional disorder in the world. The numbers are staggering as many as 4 – 5 billion people, 66 – 80 % of the world population may be iron deficient; 2 billion people, over 30 % of the world’s population, are anemic, mainly as a result of iron deficiency, and in developing countries, frequently exacerbated by malaria and worm infections. It constitutes a public health condition of epidemic proportions. It particularly affects women in reproductive age group and young children in tropical and sub tropical regions. The world bank estimates that the direct contribution of IDA to global burden of disease is 14 disability adjusted life years per 1000 population. It has the greatest overall effect in terms of ill – health, premature death and lost earning. IDA occurs at all stages of life, but is more prevalent in pregnant women, young children, adolescent girls are
vulnerable to iron deficiency. The functional consequences are known to occur prior to onset of clinical stage of iron deficiency. Iron deficiency and iron deficiency anemia in adolescence is a major public health problem. Studies indicate that the incidence of anemia in adolescents tends to increase with age and corresponds with the highest acceleration of growth during adolescence (WHO-1993-2005).

Adolescence is a transitional period from childhood to adulthood. The early adulthood growth mounts pressure on the overall nutrition requirements of female and micronutrients too are, therefore required in higher proportion. The increase in height and the related skeletal growth and increase in blood volume and menarche raises the requirements for dietary calcium and iron among adolescent girls. The major micronutrients of concern in adolescent girl’s growth and development are iron, calcium and iodine. Thus, the consumption of foods rich in calcium and iron in larger quantities becomes essential for normal growth and development of adolescent girls. Poor nutritional status during adolescence and early adulthood period of female is an important determinant of health outcomes. Short stature in adolescents resulting from chronic under nutrition is associated with reduced lean body mass and deficiency in muscular strength and working capacity. In adolescent girls, short stature that persists into adulthood is associated with increased risk of adverse reproductive outcomes (An Analytical Review-2008).

Early adult transition that is age between 17-22 years is a period of transition between adolescence and early adulthood. In the period of early adulthood, developmental tasks focus on attaining a higher level of maturity, though the cultural definition of this concept is far from clear. It is a crucial period in women’s life. Health and nutritional status during this phase is critical for the physical maturity, which in turn influences the health of offspring. It is seen that the rate of low birth weight, prematurity and neonatal and infant mortality is high among children born to malnourished adolescent girls (Diane Papalia-1984). Adolescents constitute 21.2 % of the total population of India, where malnutrition is an important public health problem.
among children and adolescents. Adequacy of dietary intake in terms of calorie and protein are important in order to improve the chances of child survival and safe motherhood. In India total projected population aged 18-23 years and their share in the total population is 24.1 % in the period of 2001-2012 and total population was 144,287 thousand including male and female contribute 12 % of total population of India and female population was 68,588 thousand in 2012. According to report of UGC on higher education, more than 252 lakhs of college girls were enrolled in different colleges of India including distance education and in Gujarat total projected college population was 7,590 thousand and projected enrolment was 12,20,537 are a significant human resource that needs to be given ample opportunity for holistic development towards achieving their full potential (UGC report- 11th plan-2008). Past research experience has shown that conducive environment facilitates holistic development into mature and productive human resource and several negative influences, affecting the socio cultural growth. Adult females have their own developmental needs, which are peculiar to them and need to be addressed separately.

1.2 Prevalence of anemia

Poor density and bioavailability of dietary iron from staple foods are the major etiological factors for wide spread prevalence of iron deficiency in India. Iron deficiency anemia affects over 2 billion people in the world. In the developing countries alone, 370 million women suffer from iron deficiency anemia. The average prevalence is higher in pregnant women (51%) than in the non pregnant women (41 %). The prevalence among pregnant women varies from 31 % in South America to 64 % in South Asia. South and South – East Asia contribute to 58 % of total anemic people in the developing world. In the developing countries, the problem of iron deficiency is high. In India, about 88 % pregnant women are anemic, in China, however, the prevalence does not exceed 40 %. It is an important public health problem affecting people from all walks of life. Anemia is very widespread, more among females than males and higher among infants and children than adults. Severe anemia ( with blood haemoglobin levels < 8 g/dl ) is more frequently seen in severely
undernourished children who also exhibit signs associated with deficiencies of 
calories, proteins, vitamin, and minerals (Anemia Detection-1996).

Table: 1.1 Classification of anemia as a problem of public health significance.

<table>
<thead>
<tr>
<th>Prevalence of Anemia</th>
<th>Category of public health significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4.9</td>
<td>No public health problem</td>
</tr>
<tr>
<td>5.2 – 19.9</td>
<td>Mild public health problem</td>
</tr>
<tr>
<td>20.0 -39.9</td>
<td>Moderate public health problem</td>
</tr>
<tr>
<td>≥40.0</td>
<td>Severe public health problem</td>
</tr>
</tbody>
</table>

Source: WORLD WIDE PREVALENCE OF ANEMIA 1993-2005

1.3 Causes of anemia

Causes of anemia may be broadly divided in to three groups as following.

   a. Anemias due to inadequate production of erythropoietin
   b. Anemias due to deficiencies of folic acid and vitamin B₁₂ (Megaloblastic anemia)
   c. Iron Deficiency Anemia (IDA)
   d. Anemias due to deficiency of copper, vitamin C, and certain hormones.

2. Anemias due to genetic defects (Hemolytic anemias)
   a. Defective formation of heme.
   b. Defective formation of globins (Haemoglobinopathies and Thalassemias)
   c. Defective formation of red blood cells.
   d. Defects due to deficiency of some enzymes in red blood cells.

3. Anemias due to other causes.
   a. Drugs, toxic chemicals, infections.
   b. Antibodies.
   c. Non – availability of iron that is stored in tissues (Sideroblastic anemia)
   d. Non nutritional anemia- Sports anemia and pregnancy anemia

Reference: Dr. M. Swaminathan-1974
1. Anemias caused by dietary deficiencies

a. Anemias due to inadequate production of erythropoietin

Erythropoiesis - Development of RBC in bone marrow: The term erythropoiesis is used for the normal development and formation of RBC in the bone marrow. The entire process takes about 120 hours (5 days) to be completed.

The stages in the development are as follows:

1. Proerythroblast
2. Basophilic or early normoblast
3. Polychromatophilic or intermediate normoblast
4. Orthochromatic or late normoblast
5. Reticulocyte

**Proerythroblast**: This is formed under the influence of the hormone erythropoietin on erythroid stem cells in the bone marrow. This cell is large (diameter 20-25 µ). This nucleus is large (12 – 16 µ) occupying about ¾ of the cell. It is devoid of haemoglobin. The development of stem cell in the bone marrow into pronormoblast is controlled by the hormone erythropoietin (hemopoitein). It is a glycoprotein, having a molecular weight of about 68,000. Its biological activity is destroyed by the enzyme neuraminidase and also by proteolysis enzymes. The kidney releases an enzyme called renal erythropoietin factor which hydrolyses a globulin called erythropoietin. The anemia observed in chronic renal failure is due to the deficiency of erythropoietin.

**Basophils or early normoblast**: This cell is formed from proerythroblast. The diameter is 12 – 15 µ and the nucleus occupies half the cell and shows active mitosis. The haemoglobin synthesis just begins in this cell.

**Polychromatophilic or intermediate normoblast**: This cell is formed from early normoblast. The diameter is 10 – 15 µ. The cell shows active mitosis and the resting nucleus shows further condensation of the chromatin. Haemoglobin formation is rapid.
Orthochromatic or Late normoblast: This cell aids formed from intermediate normoblast. Mitosis had ceased. The cell diameter is 7 – 10 µ and the nucleus is small. The haemoglobin content has reached the maximum. The nucleus breaks up and disappears.

Reticulocyte: This is formed from late normal last. The name reticulocyte is due to the fact on vital staining with cresyl blue a network of reticulum is noticed in the cytoplasm in the form of threads or dots.

Erythrocyte (Red blood cell): The normal erythrocyte is formed from the reticulocyte. It is free from the network of reticulum found in reticulocyte. It contains about 38 % haemoglobin. It contains enzymes of the glycolytic and the hexosemonophosphatate pathways. Its normal life is 120 days.
b. Anemias due to deficiencies of folic acid and vitamin B$_{12}$ (Megaloblastic anemias)

Both vitamin B$_{12}$ and folic acid are required for the maturation of pronormoblast (Stage – 1) to late normoblast (Stage – 4). Both these vitamins form coenzymes which are required for the synthesis of DNA. In the deficiency of vitamin B$_{12}$ and folic acid, DNA synthesis in pronormoblast is affected and hence the maturation of pronormoblast to late normoblast is affected and hence the maturation of pronormoblast to late normoblast is affected, resulting in an anemia called ‘Megaloblastic Anemia’. This anemia is characterized by the presence in the RBC of the intermediate stage cells (pronormoblast, intermediate normoblasts and late normoblast) in large numbers. The total RBC count is reduced. Two types of megaloblastic anemias i.e., pernicious anemia and megaloblastic anemia are caused by the deficiency of vitamin B$_{12}$ and folic acid respectively.

c. Iron deficiency Anemia

In Iron deficiency, adequate amounts of haemoglobin is not formed. For the formation of heme from protoporphyrin, ferrous iron is necessary. Adequate amounts
of heme are not available to combine with globin to form haemoglobin. This anemia is characterized by a marked reduction (5-7 gm %) of haemoglobin from the normal levels of 11 – 13 gm %. This is most common form of anemia throughout the world affecting mainly women’s reproductive years, infants and children. In both rural and urban areas in the tropics, this type of anemia is extremely common (Dr. M. Swaminathan-1974).

**Etiology of iron deficiency**

Deficiency of iron may occur as a result of the following:

- **Poor iron stores:** The iron stores of Asians are negligible as evidenced by low bone marrow hemosiderin levels and low liver stores. When the infants are born with poor iron stores, iron deficiency is aggravated in infants who are solely breast – fed for prolonged periods.

- **Inadequate iron intake:** A few foods like greens and processed foods like rice flakes and dates are rich sources of iron. People who do not include these foods in the diet may suffer from anemia. Availability of iron from plant sources is not as good as heme iron. Heme iron present in foods of animal origin which are expensive. The average cereal – legume based diets as consumed in most developing countries would appear adequate in iron content (20 – 22 mg) for an adult. But the availability of iron from such diet is very poor. Only 3-5 % of dietary iron is absorbed in normal apparently healthy individual. Pregnant anemic mother gives birth to an infant whose iron stores are inadequate and in turn the infant is susceptible for anemia. In infants and children suffer from iron deficiency anemia due to prolonged breast feeding without the addition of supplementary feeding.

- **Inadequate utilization of iron:** This can take place secondary to chronic gastrointestinal disturbances, defective release of iron from iron stores into
plasma and defective iron utilization owing to a chronic inflammation or other chronic disorder.

- **Blood losses:** This can occur in accidental hemorrhage, in chronic diseases such as tuberculosis, ulcers or intestinal disorders, or excessive blood donation or due to hookworm infestation. Excessive loss of blood during menstruation and childbirth can cause anemia. Perinatal bleeding may result from obstetric complication such as placental abruption. In rural areas, post partum hemorrhage on account of poor obstetric spaced pregnancies and prolonged periods of lactation deplete iron stores with each successive pregnancy. This is reflected in the high incidence of anemia with higher parity. In women using intrauterine contraceptive device, menorrhagia (increased blood loss) may result in further depletion of already poor stores of iron.

- **Increased requirements:** During period of accelerated demand like in infancy (rapidly expanding blood volume), adolescence (rapid growth and onset of menses in girls) and pregnancy and lactation can result in anemia. Losses of iron may occur due to excessive sweating in tropical climate.

- **Inadequate absorption of iron:** This can occur in diarrhoea (Sprue and pellagra) or when there is lack of acid secretion by the stomach or in chronic renal diseases when antacid therapy is given. Gastroctomy impairs iron absorption by decreasing hydrochloric acid and transit time through the duodenum. Excessive amounts of phytates and phosphates in the diet and excess consumption of tea can decrease the absorption of iron (B. Srilakshmi- 2005).

**Stages of iron deficiency anemia**

One’s iron status can range from iron overload to iron deficiency anemia. Routine measurement of iron status is necessary because about most of the people have a negative iron balance, about 10% have a gene for positive balance, and about 1% have iron overload. Deviations from normal iron status are summarized as stages.
Introduction

**Stages I and II negative iron balance (i.e., iron depletion)**

In these stages iron stores are low, and there is no dysfunction. In stage I negative iron balance, reduced iron absorption produces moderately depleted iron stores. Stage II negative iron balance is characterized by severely depleted iron stores. More than 50% of all cases of negative iron balance fall into these two stages. When persons in these two stages are treated with iron, they never develop dysfunction or disease.

**Stages III an IV negative iron balance (i.e., iron deficiency)**

Iron deficiency is characterized by inadequate body iron, causing dysfunction and disease. In stage III negative iron balance, dysfunction is not accompanied by anemia; however, anemia does occur in stage IV negative iron balance.

**Stages I and II positive iron balance.**

Stage I positive iron balance usually lasts for several years with no accompanying dysfunction. Supplements of iron or vitamin C promote progression to dysfunction or disease, whereas iron removal prevents progression to disease. Iron overload disease develops in persons with stage II positive balance after years of iron overload have caused progressive damage to tissues and organs. Again, iron removal stops disease progression (*Krause- 2008*).
PATHOPHYSIOLOGY AND CARE MANAGEMENT ALGORITHM
Iron Deficiency Anemia

**ETIOLOGY**

- Inadequate ingestion
- Defects in release from stores
- Increased blood loss or excretion
- Inadequate absorption
- Inadequate utilization
- Increased requirement

**PATHOPHYSIOLOGY**

- Iron Deficiency

**STAGES OF DEFICIENCY**

1. Moderate depletion of iron stores, No dysfunction
2. Severe depletion of iron stores, No dysfunction
3. Iron deficiency, Dysfunction
4. Iron deficiency, Dysfunction and anemia

**CLINICAL FINDINGS**

- Early
  - Inadequate muscle function
  - Growth abnormalities
  - Epithelial disorders
  - Reduced immunocompetence
  - Fatigue
- Late
  - Defects in epithelial tissues
  - Gastritis
  - Cardiac failure

**MEDICAL MANAGEMENT**

1. Assess for and treat underlying disease
2. Oral iron salts
3. Oral iron, chelated with amino acids
4. Oral sustained – release iron
5. Iron – dextran by parenteral administration

**NUTRITION MANAGEMENT**

1. Increase absorbable iron in diet
2. Include vitamin C at every meal
3. Include meat, fish, or poultry at every meal
4. Decrease tea and coffee consumption

Figure: 1.3 Algorithm content developed by John J.B. Anderson, and Sanford C. Garner, 2000 Updated by Tracy Stowler, MS, RD, 2007.
Iron status has a variety of indicators. Serum (whole blood without coagulation factors) ferritin levels are in equilibrium with body iron stores. Very early (Stage I) positive iron balance may best be recognized by measuring total iron-binding capacity (TIBC). Conversely, measurement of serum or plasma (whole blood that includes coagulation factors) ferritin levels may best reveal early (Stages I and II) negative iron balance, although serum (TIBC) may be as good an indicator (Krause-2008).

**Clinical features of iron deficiency anemia (IDA)**

Anemia is like the tip of an iceberg, major part of iron deficiency is hidden as most adolescents with anemia are asymptomatic. The symptoms of IDA depend on the rate at which anemia develops in an individual. Symptoms may relate to rate of fall in haemoglobin. Since lowering of haemoglobin affects oxygen carrying capacity, in IDA, any physical exertion leads to shortness of breath. Initially, most patients complain of increasing lethargy and fatigue. Most unusual symptoms are headache, tinnitus and disturbance in taste. There is often a poor correlation between haemoglobin level and symptoms. As the severity of deficiency increases, the patients develop pallor of the conjunctiva, tongue, nailbeds and soft palate. In IDA of longer duration, there may be papillary atrophy of the tongue and, the nails may become spoon shaped (koilnychia). There may be enlargement of the spleen (splenomegaly). In children, chronic IDA may lead to behavioral changes, they have impairment of cognitive function and short attention spans and appear withdrawn (Gibney et al., 2013).

**Clinical Findings**

Because anemia is the last manifestation of chronic, long term iron deficiency, the symptoms reflect a malfunction of a variety of body systems. Inadequate muscle function is reflected in decreased work performance and exercise tolerance. Neurologic involvement is manifested by behavioral changes such as fatigue, anorexia, and pica, especially pagophagia (ice eating). Nokes and colleagues, in their report of
Introduction

the international nutritional anemia consultative group (1998), supported earlier work by Pollitt and colleagues (1986) that abnormal cognitive development in children suggests the presence of iron deficiency before it has developed into overt anemia. Growth abnormalities, epithelial disorders, and a reduction in gastric acidity are common. A possible sign of early iron deficiency is reduced immunocompetence, particularly defects in cell-mediated immunity and the phagocytic activity of neutrophils, which may lead to an increased propensity for infection.

As iron deficiency anemia becomes more severe, defects arise in the structure and function of the epithelial tissues, especially of the tongue, nails, mouth, and stomach. The skin may appear pale, and the inside of the lower eyelids be light pink instead of red. Fingernails can become rough and flat, and eventually koilonychias (spoon-shaped) nail may be noted. Mouth changes include atrophy of the lingual papillae, burning, redness, and in severe cases a completely smooth, waxy, and glistening appearance to the tongue (glossitis). Angular stomatitis may also occur as may a form of dysphagia (difficulty in swallowing). Gastitis occurs frequently and may result in achloryhdia. Aggressive, untreated anemia results in cardiovascular and respiratory changes that can eventually lead to cardiac failure. Some behavioral symptoms of iron deficiency seem respond to iron therapy before the anemia is cured, suggesting they may be the result of tissue depletion of iron-containing enzymes rather than from a decreased level of haemoglobin (Krause -2008).

Iron

The total iron content of the normal adult man (70 kg wt) is estimated to be about 4-5 gm. A greater part of the iron in the body is present as haemoglobin. Most of the body iron exists in complex forms bound to protein either as porphyrin or heme compounds or as ferritin and transferrin. Free inorganic iron occurs in the body only in very small amounts. The hemo-protein and flavo-protein enzymes also contain iron.
Some compounds of biological importance containing iron are given below:

(i) Iron porphyrin (heme) compounds: Blood haemoglobin, Myoglobin (in muscles).

(ii) Heme enzymes: Mitochondrial cytochromes, Microsomal cytochrome, Catalase, Peroxidase.

(iii) Flavin – enzymes: Succinic dehydrogenase, Xanthine oxidase, DPNH – Cytochrome, C reductase, Iron chelate enzyme aconitase and

(iv) Transport and storage of iron: Transferrin (2Fe+globulin), Ferritin (4FeOOH n + globulin), Hemosiderin (Ferric hydroxide + non-nitrogenous compound).

**Distribution and Turnover of iron in the body**

Table: 1.2 Relative proportion of Iron in young Healthy adult.

<table>
<thead>
<tr>
<th>Iron type</th>
<th>Men: Iron content</th>
<th>Women Iron content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg</td>
<td>%</td>
</tr>
<tr>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemoglobin</td>
<td>2300</td>
<td>64</td>
</tr>
<tr>
<td>Myoglobin</td>
<td>320</td>
<td>9</td>
</tr>
<tr>
<td>Heme enzyme</td>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td>Non heme enzyme</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferritin</td>
<td>540</td>
<td>15</td>
</tr>
<tr>
<td>Hemosiderin</td>
<td>230</td>
<td>6</td>
</tr>
<tr>
<td>Transferrin</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Total</td>
<td>3575</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Krause’s Food and Nutrition Therapy(2008), 114

It is evident that (i) over 75% of total iron is present in haemoglobin as ferrous iron, (ii) About 20 % of the total iron is present as storage iron in ferritin (as ferric iron) in intestines, liver and other tissues and (iii) the quantity of iron present in blood as transport iron (Transferrin) is about 3 mg as ferric iron.
Iron metabolism

The human body requires iron for the synthesis of the oxygen transport proteins, haemoglobin and myoglobin in the body, and other iron-containing enzymes that participate in electron transfer and oxidation–reduction reactions. An active process in the duodenum absorbs iron. The iron thus absorbed is mobilized across the mucosal and serosal membranes into the blood where the plasma transport protein (transferrin) transports it to the cells or the bone marrow for erythropoiesis. Transferrin delivers iron to the tissues by transferring specific cell membrane receptors. The cell receptors bind the transferrin-iron complex at the cell surface and carry it into the cell to release iron. In the human body, iron is distributed in six compartments. Total body iron in men is about 3.8 g, while in women it is 2.3 g. In men, about one third of the total body iron is storage iron, whereas in women it forms only about one-eighth. Approximately two thirds of the total iron is functional, serving either a metabolic or an enzymatic function. Almost all of this is in the form of circulating within the RBC. Myoglobin and other iron-containing enzymes constitute about 15% of functional iron.

The factors influencing iron balance are intake of iron, iron stores and iron loss. Adult males require about 1 mg of absorbed iron daily to replace the losses in gut secretions, epithelial cells, urine and skin. In menstruating females this can increases 1.4 mg. Iron homeostasis, as with the most of the other metals, is maintained by controlling absorption, which increases during deficiency and decreases when erythropoisis is depressed. The body can excrete iron in a limited capacity and excess is stored either as ferritin or as hemosiderin in the liver, spleen and bone marrow.

Inadequate iron intake will:

1. Enhance absorption of dietary iron
2. Mobilize the body’s iron stores
3. Reduce the transport of iron to the bone marrow
4. Lower the haemoglobin levels, leading finally to IDA

**Iron absorption**

The primary regulatory mechanism of iron balance is iron absorption through the gastrointestinal tract. Since humans have no physiological pathway for the excretion of iron, the regulation of the intestinal absorption of iron is crucial. As duodenal crypt cells mature into absorptive enterocytes, their capacity for iron absorption reflects the iron status prevailing at the time of maturation. The low $p^H$ of gastric juice helps in dissolving the ingested iron and facilitates enzymic reduction of ferric iron into the ferrous form by a brush-border ferrireductase. However, the mechanism by which the iron absorption is regulated is still not very clear. Body iron stores and the haemoglobin status of individuals determine the percentage of iron absorption. Since women and children have lower iron stores, they absorb a higher proportion of dietary iron. In pregnancy, as iron stores decline with gestation, iron absorption gradually and steadily becomes more efficient. Conversely, the higher iron stores in males reduce the percentage of iron absorbed, thereby protecting against iron overload. About two-thirds of the total body iron is contained in RBC. Destruction or production of RBC accounts for most of iron turnover. Most of the iron of destroyed RBC is recaptured for the synthesis of haemoglobin.

Iron is widely distributed in meat, eggs, vegetables and cereals, but the concentrations in milk, fruit and vegetables are low. The iron content per se of individual foods has little meaning as iron absorption varies considerably. There are two types of food iron: nonheme iron, which is present in both plant foods and animal tissues, and heme iron, coming from the haemoglobin and myoglobin in animal products. Heme iron represents 30-70% of the total iron in lean meat and is always well absorbed. Nonheme iron from meat and vegetable foods enters a common nonheme iron pool in gastric juice, from which the amount of iron absorbed depend to a large extent on the presence of enhancing and inhibiting substances in the meal and on the iron status of the individual. Heme iron is obtained mostly from meat, poultry
and fish, and is at least two to three times better absorbed than nonheme iron. Nonheme iron is derived mostly from plant and dairy products and accounts for more than 85% of dietary iron. Several factors are known to enhance or inhibit iron absorption. The absorption of nonheme iron is strongly influenced by the presence of iron absorption inhibitors and enhancers of iron solubility in the upper part of the small intestine.

**Iron absorption enhancers**

The best known enhancer of iron absorption is ascorbic acid (vitamin C), which can increase nonheme iron absorption significantly. Thus, amla, guava and citrus fruits increase iron absorption from plant foods. Factors present in meat also enhance nonheme iron absorption. Lactoferrin, a milk glycoprotein present in breast milk, binds iron, enabling the optimal use of iron by delivering iron during deficiency and preventing its availability for intestinal bacteria. Although the iron content of breast milk is same as that of cow’s milk, in view of better absorption, breast milk is a better source of iron than either cow’s milk or non fortified milk substitutes.

**Iron absorption inhibitors**

The inhibitors of iron absorption include calcium phosphate, bran, phytic acid and polyphenols. Phytic acid, which is extensively present in cereals and legumes, is the major factor responsible for the poor bioavailability of iron in these foods. Since fiber per se does not inhibit iron absorption, the inhibitory effect of bran is solely due to the presence of phytic acid. Soaking, fermentation and germination of these food grains improve absorption by activating phytases to degrade phytic acid. Polyphenols (phenolic acids, flavonoids and their polymerization products) are present in tea, coffee, cocoa and red wine. Tannins present in black tea are the most potent of all inhibitors. Calcium consumed in dairy products such as milk, cheese can inhibit the iron absorption.
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Iron storage

Iron is stored as ferritin or hemosiderin primarily in the liver, reticuloendothelial cells and bone marrow. In the liver it is stored in parenchymal cells or hepatocytes, while in the bone marrow and spleen it is stored in reticuloendothelial cells. The stored iron is mainly a reservoir of iron to supply cellular needs for haemoglobin production. It is important to note that the iron bound to ferritin is more readily mobilized than that bound to hemosiderin. The total amount of storage iron varies considerably without any apparent impairment of body functions. Storage iron may be totally depleted before the appearance of IDA. Under conditions of long – term negative iron balance, the stores are depleted before the onset of iron deficiency in the tissues. When there is positive balance, iron stores increase slowly even when the absorption of iron is lower, as in postmenopausal women.

Iron losses

Iron losses in healthy individuals occur primarily in feces (0.6 mg/ day), bile and desquamated mucosal cells, and in minute quantities of blood. Urinary losses are small. Women of reproductive age, in addition to the basal losses, lose iron in menstruation. The median menstrual blood loss is about 30 ml/ day, which is equivalent to an additional requirement of 0.5 mg of iron per day. This daily blood loss is computed from the iron content of blood lost during the menstrual period over a month. About 10 % of women lose as much as 80 ml of blood, corresponding to a loss of 1 mg of iron per day. Adopting the higher value (1 mg/day), the total (basal plus menstrual) lose of iron in women would be 30 microgram/ kg per day( > 1.5 mg /day). Such women cannot maintain positive iron balance if iron requirements are based on median menstrual loss of 30 ml. In the tropical countries, hookworm infestation is a major cause of gastrointestinal blood loss contributing to iron deficiency in older children and adults. In the developed world, among adults, chronic use of drugs such as aspirin, bleeding tumors and ulcers contribute to iron losses.
Reference intakes for iron

Daily (absorbed or physiological) iron requirements are calculated from the amount of dietary iron necessary to cover basal losses, menstrual losses and growth needs. They vary according to age and gender, and in relation to body weight they are highest for the young infant. Current RDA value for iron are summarized in table 1.3. An important aspect that requires consideration while computing requirements for iron is the percentage of iron absorbed from the diet. While a value of 5% is assumed for cereal-legume-based diets, about 10-15% is used for diets containing meat and animal products (Gibney et al. - 2013).

Table : 1.3 RDA values of iron for different age groups.*

<table>
<thead>
<tr>
<th>Age group</th>
<th>Age and gender</th>
<th>Iron (mg / day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td>First 6 months</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>7 – 12 months</td>
<td>11</td>
</tr>
<tr>
<td>Children</td>
<td>1-3 years</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4-8 years</td>
<td>10</td>
</tr>
<tr>
<td>Teenage boys</td>
<td>9-13 years</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>14-18 years</td>
<td>11</td>
</tr>
<tr>
<td>Teenage girls</td>
<td>9-13 years</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>14-18 years</td>
<td>15</td>
</tr>
<tr>
<td>Adult men</td>
<td>Above 19 years</td>
<td>8</td>
</tr>
<tr>
<td>Adult women</td>
<td>19- 50 years</td>
<td>18</td>
</tr>
<tr>
<td>Adults</td>
<td>Above 51 years</td>
<td>8</td>
</tr>
<tr>
<td>Pregnant women</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Lactating women</td>
<td>Below 18 years</td>
<td>10</td>
</tr>
<tr>
<td>Lactating women</td>
<td>19-50 years</td>
<td>9</td>
</tr>
</tbody>
</table>

*Recommended by the US Food and Nutrition Board in 2001. Reproduced with permission from the WHO.
Factors affecting absorption of iron present in foods.

**Heme and Nonheme Iron.**

Food iron may be broadly separated into two separate pools, i.e., heme iron and nonheme inorganic iron. Heme iron is present, mainly in haemoglobin and myoglobin present in meat, fish and other animal foods. Heme iron derived from animal foods is absorbed directly in the human gut to the extent of 60 to 70%. It is taken up by the mucosal cells of the intestines with iron still attached to the porphyrin ring. Its absorption is independent of the presence of inorganic iron, and ascorbic acid. Absorption of heme iron can be measured by adding a small quantity of labelled haemoglobin to a meal just before it is eaten. On the other hand the absorption of inorganic nonheme iron is increased by the presence of ascorbic acid probably forms a chelate with inorganic iron that remains soluble at the alkaline pH of the duodenum (Dr. M. Swaminathan, 1974).

**Role of Stomach**

Since iron is absorbed in the ionic state, it is reasonable to suppose that gastric digestion may help in solubilizing dietary iron. Absorption of iron is impossible in hypoacidity. The presence of anemia and the nature of the food that accompanies the iron are complicating factors. The assimilation of iron may be impaired by rapid emptying of the food from the stomach. It has been demonstrated that much more iron can be extracted from food materials by acid peptic digestion than by saline extraction (Dr. M. Swaminathan, 1974).

**Ferrous versus Ferric Iron**

There is good evidence that iron is absorbed in the ferrous state. *Venkatachalam et al. 1968* showed in rats that radioactive ferric iron was absorbed to about one-fifth the extent of ferrous iron, but that when each was administered with \( \alpha - \alpha \) dipyridyl there was no difference in their absorption. *Moore et al. 1963* showed in human subjects that increments to the plasma iron were greater after the ingestion of
ferrous than of ferric iron, but that there was no difference if a reducing substance was given with the ferric iron. It has been shown in both human subjects and dogs that the incorporation of iron into red cells is greater from ferrous than from ferric salts. In man, the ratio expressing preferential absorption was about 5:1. It has also been shown that ferrous iron maintains higher haemoglobin values in infants than ferric iron in the same dosage (Dr. M. Swaminathan, 1974).

Ascorbic Acid

Considerable attention has been given to a role of vitamin C in this process, and it has been demonstrated that the absorption of iron is enhanced by the simultaneous administration of ascorbic acid. It is reasonable to suppose that the effect is related to the reducing action of ascorbic acid. It has been demonstrated in normal and anemic human subjects that vitamin C increases the absorption of iron, but the effective amounts were very large, 500 to 1000 mg. Infants on a normal diet did not absorb iron better if they were given an extra 100 mg of ascorbic acid per day. It does not seem likely that amounts of vitamin C ordinarily ingested would affect the absorption of iron (Dr. M. Swaminathan, 1974).

Phytic Acid and Oxalic Acid

Phytic acid, the hexaphosphoric acid of inositol, is a common constituent of the parts of plants that are used for food. It is conspicuous as a constituent of the bran of cereals. Many of the salts of phytic acid have a low solubility and phytates has been implicated as a deterrent to the absorption of metals, principally of calcium and iron. It has been shown that the response of serum iron to large amounts of dietary iron taken with bread and jam was less if sodium phytate had been added to the bread. In a similar experiment it was demonstrated that sodium phytate given with test meals decreased the absorption of iron. The absorption of iron from ferric phytate is very low (2 to 5%). It has been demonstrated that anemic patients can utilize some of the iron from very large doses of iron phytate. Oxalic acid present in certain vegetables forms
insoluble iron oxalate and prevents the absorption of dietary iron (Dr. M. Swaminathan, 1974).

**Haemoglobin**

Haemoglobin plays a crucial role in the transport of oxygen. With moderate IDA, there is a compensatory mechanism by biochemical changes to compensate for the reduced oxygen carrying capacity of blood. In contrast, in severe IDA, the markedly reduced haemoglobin content decreases the oxygen carrying capacity, leading to chronic tissue hypoxia.

Packed within each red blood cell are an estimated 200 to 300 million molecules of haemoglobin which make up about 95% of the dry weight of each cell. Each haemoglobin molecule is composed of four protein chains. Each chain, called a globin, is bound to a red pigment, identified in figure 1.5 as a heme molecule. Each heme molecule contains one iron atom. Therefore, one haemoglobin molecule contains four iron atoms. This structural fact enables one haemoglobin molecule to unite with four oxygen molecules to form oxyhaemoglobin (a reversible reaction). Haemoglobin can also combine with carbon dioxide to form carbamino haemoglobin (also reversible), but in this reaction the structure of the globin part of the haemoglobin molecule, rather than of its heme part, makes the combining possible.

![Hemoglobin Molecule](image)

**Figure: 1.4 Structure of Haemoglobin**
**Introduction**

A man’s blood usually contains more haemoglobin than a woman’s in most normal men. 100 ml of blood contains 14 to 16 gm of haemoglobin. The normal haemoglobin content of a woman’s blood is a little less – specifically in the range of 12 to 14 gm per 100ml. An adult who has a haemoglobin content of less than 10 gm per 100 ml of blood is diagnosed as having anemia (from the Greek a-,”not”, and haima, “blood”). In addition, the term may be used to describe a reduction in the number or volume of functional red blood cells in a given unit of whole blood. Anemias are classified according to the size and haemoglobin content of red blood cells.
Figure: 1.5 Classification of Anemia according to Red Cell Morphology

**Diagnosis**

Progressive stages of iron deficiency can be evaluated by six different measurements:

1. Quantity of serum or plasma ferritin
2. Quantity of serum or plasma iron
3. Quantity of total circulating transferrin
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4. Percent saturation of circulating transferrin, which measures the iron supply to the tissues; it is calculated by dividing serum iron by the TIBC; levels less than 16% are considered inadequate for erythropoiesis.

5. Percent saturation of ferritin with iron

6. Quantity of soluble serum transferrin receptors (SFTR): Transferrin molecules are generated on the surface of red blood cells in response to the need for iron. With iron deficiency, so many transferrin receptors are on the cell surface looking for iron that some of them break off and float in the blood (serum). Their presence is an early measurement of developing iron deficiency, with a higher quantity meaning greater deficiency of iron.

A definitive diagnosis of iron deficiency anemia requires more than one method of iron evaluation and preferably includes the first three of the measurements just listed. The evaluation should also include an assessment of cell morphology. The serum or plasma ferritin level is the most sensitive parameter of negative iron balance because it decreases only in the presence of true iron deficiency, as with transferrin saturation.

Protoporphyrin, the iron-containing portion of the respiratory pigments that combine with protein to form haemoglobin or myoglobin, can be used to assess iron deficiency. The zinc protoporphyrin (ZnPP)/heme ratio is measured. However, this (ZnPP)/heme ratio and haemoglobin levels are affected by chronic infection and other factors that can produce a condition that mimics iron deficiency anemia when, in fact, iron is adequate (Herbert et al., 1997).

The TIBC declines, and serum ferritin levels rise in chronic disease unrelated to iron metabolism. By itself, haemoglobin concentration is unsuitable as a diagnostic tool in cases of suspected iron deficiency anemia for three reasons (1) it is affected only late in the disease; (2) it cannot distinguish iron deficiency form other anemias (3) haemoglobin values in normal individuals vary widely.
b. Anemias due to deficiency of copper, ascorbic acid, pyridoxine and of certain hormones.

**Copper deficiency**

Copper containing enzymes Ferro oxidases I and II are essential in the transport of iron from the intestines to the bone marrow. In copper deficiency, orally administered ferrous iron is not effective in curing iron deficiency anemia. Copper is essential along with iron for curing iron deficiency anemia.

**Anemia due to deficiencies of ascorbic acid and pyridoxine**

Anemia due to deficiency of ascorbic acid has been observed in scurvy. This anemia is cured by ascorbic acid. The exact role of ascorbic acid in curing anemia of scurvy is not known. Pyridoxine deficiency has been reported to cause anemia. This may be due to the fact that pyridoxine is essential in the biosynthesis of heme.

**Anemia due to deficiencies of certain hormones**

In thyroid deficiency (Myxoedema and cretinism) owing to depressed bone marrow activity, anemia commonly occurs. This responds to thyroid medication. Thyroxine probably acts as a general metabolic stimulant on the bone marrow. In disorders of pituitary, anemia occurs. Thus in Simmond’s disease, anemia is common. Polycythemia may occur in Cushing’s syndrome. The blood changes are due to general stimulant action of these hormones on the bone marrow.

**2. Anemia due to genetic defects**

The anemia due to genetic defects can be discussed under the following heads

1. Defective Formation of haemoglobin
2. Defective formation of red blood cells;
3. Defects in the metabolism of iron
4. Defects in the metabolism of red blood cells.
Defective formation of haemoglobin

The different hereditary conditions affecting haemoglobin formations are

(1) Defective heme formation and (2) Defective globin formation.

**Defective heme formation:** Heme formation is affected in (1) Porphyria: This is a hereditary disorder in which the formation of protoporphyrin present in heme is affected resulting in anemias of various types. (2) Congenital transferrinanemia: Transferrin carries the iron in plasma to the bone marrow. In the absence of transferrin, iron is not transported for incorporation in heme.

**Defective globin formation:** Two groups of hereditary disorders in the synthesis of globin are known (a) involving mutations affecting the structural genes and (b) involving mutations affecting the regulatory genes.

a. **Mutations affecting structural genes:** This group is known by the general name abnormal haemoglobins. Due to mutations affecting structural genes, the amino acid sequence in globin are altered. For example, haemoglobin S found in the disease called *sickle cell anemia*, contains valine in the 6th position in the β-chain in place of glutamic acid found in this position in normal haemoglobin. This small difference makes haemoglobin S very unstable. The stability of RBC also is poor in sickle cell anemia. A large number of abnormal haemoglobins are known. Some of them cause severe anemia.

b. **Mutations affecting regulatory genes:** Normal haemoglobin A which forms 98% of the Hb present in normal adult blood contains 2α and 2β chains, while HbA2 forming 2% of normal Hb contains 2α and 2δ chains HbF which occurs in the fetus contains 2α and 2γ chains. When mutations affect the regulatory genes, the amino acid sequences in the different chains are not affected but the synthesis of one of the chains α or β is completely suppressed and other chains (γ and δ) are synthesized in their places. The clinical conditions in which this group of abnormal haemoglobins is present are called Thalassemias. The
**Introduction**

stability of haemoglobins containing γ or δ chains is poor. The RBC undergoes hemolysis readily resulting in severe anemias.

**Defective formations of Red Blood Cells**

In some hereditary disorders, the RBC membrane is defective. This changes the shape of the RBC. For example in hereditary Spherocytosis, the RBC is spheroidal in shape and hence easily destroyed while passing through the spleen. Another disorder is hereditary Elliptocytosis in which the RBC is elliptical shaped. Hence these cells undergo rapid destruction while passing through the spleen.

**Defect in the metabolism of RBC**

The mature RBC in adults contains different enzymes of the glycolytic and hexo monophosphate pathways. The pathways are essential for the survival of RBC. Deficiency of any one of the enzymes will lead to a shortening of the life of the RBC and more rapid hemolysis of the cells. Hereditary disorders due to the deficiency of glucose – 6 phosphate dehydrogenase and pyruvate kinase have been reported to occur among human beings in some countries.

**3. Anemia’s due to other causes**

A. The stability of RBC can be adversely affected by (a) toxic chemicals and drugs (b) infections and (c) antibodies (d) Sidiroblastic anemia (e) Non- nutritional anemia.

**Toxic chemicals and drugs:** Some drugs affect the stability of RBC and causes hemolytic anemia. Poisoning with lead interferes with synthesis of heme and this brings about a reduction in the synthesis of haemoglobin. Medication can alter nutrient metabolism, influence erythropoiesis and blood coagulation and sometimes lead to increased red cell destruction.
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Infections: Malaria is a common cause of hemolytic anemia. Many viral diseases affect adversely the stability of RBC. Anemia can occur in patients who have chronic infections, inflammatory conditions, autoimmune disorders or cancer. As a result of the inflammatory response macrophages in the liver, spleen and bone marrow sequester iron, making unavailable for erythropoiesis and hence slowing the rate of production of new blood cells. In addition, RBC is destroyed more rapidly than usual and reduced production of RBC can’t keep pace. Iron absorption is impaired, possibly intestinal cells inhibit release of iron into blood. Eventually outright iron deficiency may result from inadequate iron absorption.

Antibodies: In recent years, hemolytic, anemias caused by anti-red cell antibodies are receiving increasing attention. Two such conditions, viz, Autoimmune hemolytic anemia- Hemolysis of RBC is produced by activation of complement system. Fragmentation and alterations of the shape of RBC to a rigid spherocyte makes them vulnerable to hemolysis. and Isoimmune hemolytic anemia - This disease is seen mainly in the new born. Foetal RBC enter maternal circulation at the time of birth. This causes reaction in infants. The isoantibodies formed react with the RBC of infants and cause hemolysis. The new born infants become markedly anemic in a short time.

Sideroblastic anemia: The Sideroblastic anemias are a heterogeneous group of disorders that are characterized by the presence of excessive iron deposits within the mitochondria of normoblast in the bone marrow. The deposition of excess iron appears to be due to defect in heme synthesis. Consequently the iron brought to the bone marrow is deposited in the mitochondria of normoblasts. In sideroblastic anemia, serum iron and tissue stores of iron are also increased. Excessive amounts of iron are deposited in the reticuloendothelial system and in the parenchymal cells of various organs. In some instances, the excess iron deposition interferes with the function of the organs like liver, pancreas and heart.
Sideroblastic anemias have been divided into two major groups depending on whether it is inherited or acquired as described below:

**A. Hereditary sideroblastic anemia**: This disorder was first described by Rundles and Falls in 1946. Later some workers have reported that in many cases, the anemia responds to treatment with large doses (50 to 200 mg/day) of pyridoxine. Studies carried out by other workers have shown that certain forms of sideroblastic anemia do not respond to pyridoxine or respond only slowly.

(i) X-Linked
   - (a) ALA Synthetase deficiency
   - (b) Coproporphyrinogen oxidase deficiency.

**B. Acquired sideroblastic anemia**:

(i) Idiopathic refractory sideroblastic anemia.

(ii) Sideroblastic anemia due to other diseases.

(iii) Associated with drug toxicity or toxins: Certain toxic drugs and toxins have been reported to cause sideroblastic anemia. These include continuous and long term ingestion of alcohol, certain drugs used in the therapy of tuberculosis or cancer and lead poisoning. Sideroblastic anemia has been reported to be caused by a combination of isonicotinic hydrazide (INH), pyrazinoic acid and cycloserine. These drugs induce sideroblastic anemia by interfering with vitamin B₆ metabolism and hence respond to vitamin B₆ therapy.

**Non nutritional anemias**:

**Sports anemia**: Increased red blood cell destruction, along with decreased haemoglobin, serum iron, and ferritin concentrations, may occur at the initiation and early stages of a vigorous training program. Once called march haemoglobinuria, this anemia was believed to arise in soldiers as a result of mechanical trauma incurred by erythrocytes (RBC) during long marches. The red blood cells in the capillaries are
compressed every time the foot lands until they burst, releasing haemoglobin. It was thought that a similar situation existed in runners, especially long-distance runners; however, it is now thought that it is a physiologic anemia (i.e. transient problem of blood volume and dilution). Athletes who have haemoglobin concentrations below those needed for optimal oxygen delivery may benefit from consuming nutrient and iron-rich foods; ensuring that their diets contain adequate protein; and avoiding tea, coffee, antacids, all of which inhibit iron absorption. No athlete should take iron supplements unless true iron deficiency is diagnosed based on a complete blood cell count with differential, serum ferritin level, serum iron level, TIBC, and percent saturation of iron-binding capacity. Athletes who are female, vegetarian, involved in endurance sports, or entering a growth spurt are at risk for iron deficiency anemia and therefore should undergo periodic monitoring.

**Anemia of pregnancy:** Another physiologic anemia is the anemia of pregnancy, which is related to increased blood volume and usually resolves with the end of the pregnancy; however, demands for iron during pregnancy are also increased so that inadequate iron intake may also play a role (Krause-2008).

### 1.4 Morphological classification or types of anemia

**Hypochromic and Microcytic anemia:** If there is an insufficiency of iron for the formation of haemoglobin, the red blood cell corpuscles are pale and small and the anemia is said to be hypochromic and microcytic.

**Megaloblastic (Orthochromic macrocytic anemia):** Vitamin B12 and folic acid are coenzymes in the DNA synthetic pathway. A deficiency of the vitamins or impairment in their utilization results in damaged or inadequate synthesis of DNA. The synthesis of RNA and protein is unaffected so there is cytoplasmic enlargement, not matched by DNA synthesis which appears to delay or block mitotic division. Thus there appears to be asynchronism between cytoplasmic maturation and nuclear maturation. If the maturation of the red blood corpuscles in the bone marrow is
impaired by lack of folate or vitamin B$_{12}$, the cells which enter the blood stream are irregular in size and shape, but usually larger than normal, and contain their full complement of haemoglobin. This is also known as orthochromic macrocytic anemia.

**Dimorphic anemia**: If both iron and either folate or vitamin B$_{12}$ are deficient it gives rise to hypochromic macrocytic or dimorphic anemia.
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Figure: 1.6 gives multi-factorial causes of anemia.

1.5 Prevention and control of iron deficiency anemia

The basic principles in the prevention of IDA are to ensure regular consumption of iron to meet the requirements of the body and to increase the content and bioavailability of iron in the diet, there are four main approaches;
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- Provision of iron supplements
- Fortification of commonly consumed foods with iron
- Nutrition education
- Horticulture-based approaches to improving the iron bioavailability of common foods

Iron supplementation

The essential principle of management of IDA is iron replacement therapy and treatment of the underlying cause, such as parasitic infections or gastrointestinal bleeding. Oral iron therapy is the preferred form of treatment. Ferrous sulfate is the most inexpensive and widely used oral iron preparation. Other preparations such as ferrous gluconate or ferrous fumerate may also be given. A total dose equivalent to 60 mg of elemental iron (300 mg of ferrous sulfate) per day is adequate for adults, and should be given between meals either in the morning or at bed time. In the case of infants and young children, 30 mg/day of elemental iron would be adequate. In general, over a period of 4 weeks a haemoglobin rise of about 2 g/dl would be expected. It is important to remember to continue iron therapy for about 3 months, even after the haemoglobin level becomes normal. In very severe IDA with haemoglobin in the range 5-7 g/dl, packed cell transfusion is recommended. The common side effects of iron supplementation are nausea, constipation, black stools and even diarrhea. The risk of side effects is proportional to the iron dose, poor compliance is the major reason for failure to respond to iron therapy, so simultaneous and appropriate counseling of the individuals may be required.

Oral iron is the treatment of choice for prevention of IDA. In general, daily supplements providing about 100 mg of elemental iron are recommended for a period of about 100 days to the most vulnerable groups of population, such as pregnant women. The dosage is fixed, taking into consideration the biological effectiveness and the side-effects. The common side-effects of oral iron therapy are gastrointestinal disturbances such as constipation and the passing of dark stools. Prolonged use may lead to joint pains.
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**Fortification**

Fortification of some commonly consumed foods with iron is an attractive option to tackle the problem of inadequate dietary intakes in the community. The food fortification and food vehicles should be safe and effective. Foods successfully used as vehicles for food fortification are wheat, bread, milk powder, salt, infant formula and sugar. Sweden has a long history of fortifying wheat flour with iron, at a rate of 65mg/kg. In the USA wheat flour is also fortified with iron (44mg/kg). In India, multicentric field trials indicate that iron-fortified common salt has been effective in reducing the prevalence of IDA in rural communities.

**Nutrition education**

Extensive and persuasive efforts are required to bring about behavioral changes in the community for people to adopt dietary diversification. Ultimately, the only sustainable solution to IDA is to help the communities to consume regularly foods that are rich in iron, to encourage intake of promoters of iron absorption such as vitamin C and to discourage high consumption of inhibitory factors.

The following approaches are considered as important in preventing and controlling nutritional anemias in general:

- promotion of the consumption of iron-rich foods, e.g. pulses, green leafy vegetables, other vegetables and meat products
- encouraging regular consumption of food that are rich in vitamin C, e.g. citrus fruits, guava and amla
- promotion of the addition of iron-rich foods to weaning foods
- discouraging consumption of food that inhibit iron absorption, particularly by women and children.

**Agriculture and horticulture approaches**

Horticulture strategies to encourage production of iron-rich vegetables and fruits are an important component of long-term approach to control and prevent IDA in the developing countries. It is paradoxical that IDA is widely prevalent in countries...
where a wide variety of iron-rich foods and iron absorption promoters are already available. At the government level, there is a need to add nutrition components to all horticulture and social forestry programs, while at the household level, efforts should be made to encourage production of vegetables. Home gardening is one of the sustainable approaches to control IDA in poor rural communities. It is rather paradoxical that communities involved in agriculture require extension and education to raise nutritious food in their backyards. An advantage of home gardening is that it facilitates consumption of multiple nutrients. In the case of IDA, in addition to providing iron-rich foods, it facilitates inclusion of iron absorption promoters in the diet (Gibney et al., 2013).

**1.6 Significance of the study**

Anemia is a worldwide problem in persons of all ages; it is not a diagnosis but rather a sign or symptoms of an underlying disorder. The rate of prevalence is higher in the developing countries. In India the prevalence of anemia among adolescent and college girls, non pregnant and pregnant women, and children under 6 years of age is seen in higher percentage. Iron deficiency and anemia reduce work capacity of individuals and entire population, and obstacles to national development. Conversely, treatment can arise national productivity levels by 20%.

In developing countries, where IDA is widely prevalent, universal iron supplementation to people of vulnerable groups would be appropriate. In segments of the population of higher socio-economic groups, selective provision of iron supplements only to anemic individual would be preferable. This approach, however, requires screening of individuals for IDA, requiring suitable skilled staff and laboratory facilities. The success of such a program depends on the distribution of adequate quantities of iron supplements and adherence to treatment. The experience in India is an example of the shortcomings of such program when attempted on a large scale. In 1970, India adopted a national program of supplementation of daily iron and
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folic acid tablets (for 100 days) to pregnant women, lactating mothers and young children.

Unfortunately, under the present socioeconomic conditions in which the current dietary intakes are not adequate, people in developing countries will continue to require iron supplementation to meet their iron needs. For this reason, there is a need for alternative approaches to supplementation such as the use of small – dose iron supplementation and slow release iron preparations. Slow release iron preparations can achieve the same benefit as the lower dose iron with very few side-effects. Weekly iron supplementation in place of daily iron distribution has also been suggested this may result in greater absorption of the iron dose, but may only be effective under supervised conditions.

Person-to-person communication still remains an effective method of communication in most of the developing countries. Group talks, slide shows, folk plays, street plays, television and radio are the other methods of nutrition education. Social marketing which applies marketing principles to improve nutrition awareness by involving communication experts, may be one of the strategies to be adopted.

There is a need to provide scientific information to college girls regarding health and nutrition and anemia, as they are the major portion of Indian population. So there is a need to create overall awareness regarding anemia and its prevention. This will help in attaining good health, providing good information and decrease the myths about anemia, as it is necessary for healthy living and good economy of the country. The measurement of knowledge of selected communities towards anemia and nutrition is useful to health workers for researching and designing approaches in right direction. This study will also be helpful to students, researchers, people of NGO’s and government and all those engaged in the field of health and nutrition to implement and create awareness through education programs.
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The fight against IDA must continue indefinitely. Once IDA is diagnosed in area, it is likely that iron intervention will be required indefinitely. Several examples have shown a return of IDA during lapses in iron prophylactic measures. Sustainability of IDA elimination programs is absolutely critical and requires continuous political support, administrative backup and the generation of scientific data to maintain the fights against IDA.

1.7 Research aim

General objective

1. To study nutritional status and estimation of haemoglobin level in college girls of Mehsana city and taluka.
2. To implement intervention program for enhancing awareness regarding diet and Iron supplementation in need based college girls of Mehsana city and taluka.

Specific Objectives:

1. To assess the prevalence of anemia in college girls.
2. To assess the dietary and nutritional knowledge among college girls.
3. To study dietary pattern and nutrient intake of college girls (N= 70).
4. To determine the age at menarche of college girls.
5. To create awareness regarding iron rich food (recipes).
6. To study the nutritional anthropometric indices among college girls.
7. To study average nutrient intake among college girls.
8. To study the effect of iron supplementation on haemoglobin levels of college girls.
9. To study the effect of dietary intervention program on haemoglobin levels of college girls.
10. To study the effect of knowledge intervention program on nutritional knowledge level.
11. To study the effect of socioeconomic factors on nutritional status of college girls.