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Review Article

Anemia: Etiology, Pathophysiology, Impact, and Prevention: A Review

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Abstract

Background: Anemia is a significant public health problem worldwide in rich and poor countries. Anemia among teenagers can be seriously almost entirely caused by a lack of substance iron, which is closely related to the level of severity of anemia. The most visible effect of anemia is a decline in achievement studying in school. This article briefly introduces anemia, etiology, pathophysiology, impact, and preventive measures.

Methods: Major databases, including Scopus, Pubmed, Proquest, Google Scholar, and Science Direct, were researched to obtain articles related to anemia in adolescent girls. The keywords used in the literature search were " anemia and teenage girls "and " anemia prevention. " The time frame of the articles obtained ranged from 2012 to 2023.

Results: Enhancement observed prevalence during several final years will cause prevalence to exceed the agreed target level. The most visible impact of anemia is a decline in achievement studying in school. Not only that, teenage women who suffer from anemia are at risk of experiencing anemia during pregnancy, which can hurt the growth and development of the fetus in Content. Apart from that, there is the potential to experience complications during pregnancy and childbirth.

Conclusion: Identifying and understanding the etiology of anemia is critical to developing effective prevention strategies with screening. An integrated approach to early prevention of anemia involves collaboration between the health, education, and community sectors.

Keywords: Anemia; Etiology; Pathophysiology; Impact; Prevention

Introduction

Anemia is a condition with a low number of red blood cells. Anemia is a significant public health problem throughout the world, both in rich and poor countries (1). Based on the 2021 Global Nutrition Report, 570.8 million children, girls, and women of fertile age suffer from anemia.

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The prevalence of childhood anemia in women and women of reproductive age is worrying: not only do they not exist to progress in lower prevalence, but, on the contrary, in 2025, an increase in observed prevalence during the number of final years will cause prevalence to more than double the agreed target rate (31.2% instead of 14.3%) (2). According to 2018 Riskesdas data, the prevalence of anemia is national, amounting to 48.9%, with the proportion of anemia in women being 27.2% (3).

Iron deficiency is the primary cause of anemia in teenagers, significantly impacting their overall health. This condition reduces immunity, impairs physical and mental development, decreases physical fitness, and affects academic performance (4) (5). Additionally, adolescent females with anemia face increased risks during pregnancy, potentially affecting fetal development and leading to pregnancy complications (6). These studies contribute to understanding the risks, impacts, and prevention strategies of anemia, supporting interventions such as nutritional education, lifestyle modifications, and nutritional supplementation to reduce the incidence of anemia and improve adolescent health outcomes. The studies also identify key risk factors, including poor dietary patterns characterized by low intake of iron, folic acid, and vitamin C, as well as the physiological conditions of menstruation during adolescence

Search Method

This research used various databases such as Scopus, Pubmed, Proquest, Google Scholar, and Science Direct. The keywords used in the literature search were "Etiology, Pathophysiology, Impact, and Prevention of Anemia. " The time range for accessed articles ranges from 2012 to 2023.

The inclusion criteria cover articles on the etiology of anemia, pathophysiology, impact, and prevention efforts, published in English and available in full-text format. The exclusion criteria cover articles in the form of single case studies, as well as editorial reviews or commentary. The study selection process was conducted by screening titles and abstracts.

Results and Discussion

Definition of Anemia

Anemia is a condition with a decrease in Hemoglobin (Hb) levels and the number of red blood cells below average values, so they are insufficient to meet a person's body's physiological needs (7). As a consequence, laboratory examinations will show a decrease in the amount of Hemoglobin (HGB), hematocrit value (HCT), and number of red blood cells (RBC) (8). Anemia is often viewed as a disease in itself, even though anemia is only a symptom or manifestation of another underlying disease (9).

Hemoglobin levels in the blood are categorized to determine anemia status. According to the WHO, hemoglobin levels indicating anemia vary by age and gender (7). The threshold for anemia can be seen in (Table 1).

Etiology of Anemia

Understanding the different types of anemia requires an examination of their causes, particularly in relation to blood cell morphology. Variations in the size, shape, and color of red blood cells can indicate specific underlying conditions, aiding in accurate diagnosis and treatment. Morphological classifications help distinguish between types of anemia, such as microcytic, normocytic, and macrocytic anemia, each associated with distinct causes, including iron deficiency, chronic disease, or vitamin B12 and folic acid deficiencies. A detailed classification of anemia based on blood cell morphology, along with its primary causes, is presented in (Table 2).

Table 1: Concentration (g/dL) The Threshold of Anemia (7)

Population	Anemia			Normal
	Heavy	Currently	Light	
Children aged 6-59 months	<7.0	7.0-9.9	10.0-10.9	≥ 11.0
Children aged 5-11 years	<8.0	8.0-10.9	11.0-11.4	≥ 11.5
Children aged 12-14 years	<8.0	8.0-10.9	11.0-11.9	≥ 12.0
Non-pregnant women (aged 15 years and over)	<8.0	8.0-10.9	11.0-11.9	≥ 12.0
Pregnant women	<7.0	7.0-9.9	10.0-10.9	≥ 11.0
Male (aged 15 years and over)	<8.0	8.0-10.9	11.0-12.9	≥ 13.0

Table 2: Causes of anemia based on blood cell morphology

Types of Anemia	Reason
Aplastic Anemia	Damage to the marrow bones (10)
Microcytic anemia	Lack of substance iron (11)
Normocytic Anemia	anemia caused by disease chronic, disorder production cell blood red with marrow bones, as well as failure function kidneys, bleeding I (12)
Hemolytic Anemia	Damage to cells' blood red that has not yet reached the stage of maturity (13)
Macrocytic anemia (megaloblastic & pernicious	Vitamin B12 deficiency, lack of sour folate, and disturbance in protein synthesis (14) autoimmune (15)
Anemic Hemoglobinopathies	Disturbance genetic causes cell blood to red own form like sickle and thalassemia (16)

The causes of anemia can be classified based on red blood cell morphology. Several types of anemia according to morphology and their causes include aplastic anemia caused by bone

marrow damage (10), microcytic anemia due to iron deficiency (11), normocytic anemia triggered by chronic diseases, disruptions in red blood cell production in the bone marrow, kidney failure, or bleeding (12), hemolytic anemia that occurs due to damage to red blood cells before they reach maturity (13), and macrocytic anemia (megaloblastic & pernicious) resulting from deficiencies in vitamin B12, folic acid, and protein synthesis disorders (14). Hemoglobinopathy anemia, a genetic disorder, leads to abnormal red blood cell shapes as seen in sickle cell anemia and thalassemia (16).

Healthy red blood cells have a red color and a biconcave shape, which means they are shaped like a circle with a concave center. Healthy red blood cells have an average volume ranging from 80-100 femtoliters (fL), with a surface area of around 135±15 mm^2, a diameter of around 7.8 mm, and a thickness of around 0.81 mm (17) (18). Macrocytic means size cell blood red is more significant from ordinary, but normo-chrome occurs because concentration His He-moglobin was normal (MCV increased; MCHC normal) (19). This thing is caused by interfer-ence or cessation of the synthesis of sour DNA nucleic acid as found in B12 or acid deficiency folate (14).

Microcytic refers to small size, while hypochromic refers to hemoglobin content that is less than usual (low MCV; low MCHC) (19). This usually reflects a lack of heme (iron) synthesis, as in iron deficiency anemia, sideroblastic conditions, or chronic blood loss. In addition, this condition can also be associated with impaired globin synthesis, such as thalassemia (14).

On a biological level, anemia develops due to an imbalance of erythrocyte loss compared with production, which can be caused by ineffective or deficient erythropoiesis and excessive erythrocyte loss due to hemolysis, blood loss, or both. Anemia is often classified based on the biological causal mechanism, such as IDA, hemolytic anemia, and inflammatory anemia (AI). However, in obese teenagers, anemia can occur due to a lack of proper nutritional intake, such as iron, folate, and vitamin B12, which can affect red blood cell production (20).

Anemia results from direct causes, such as nutrient deficiencies and chronic blood loss, and indirect causes like socioeconomic factors and limited healthcare access. These factors influence dietary habits and overall health, increasing anemia risk. A detailed classification is presented in (Table 3).

Table 3: Causes of anemia

Reason Direct	Deficiency substance iron (21)
	Abnormalities Genetic (16) (22)
	Disease infection (24) (25) Menstruation (5) (27) (28)
	Bleeding consequence accident (29)
Indirect causes	Parenting family (23)
	Health facilities, hygiene, and sanitation (30,31)
	Knowledge (30) (28)
	Attitude (33) Social economics (26)
	Age (11)
	Education (29.31)

Anemia etiology identifies how distal factors contribute to the determinants of anemia, such as food insecurity, clean water, and sanitation, and, ultimately, the most direct causes of anemia (e.g., nutritional deficiencies, disease, inflammation, and Hb disorders) (32–34). Many determinants are interrelated. Poverty, for example, is a significant determinant of health and nutrition, and poor socioeconomic position is associated with a greater risk of anemia in women and children (38). Likewise, low levels of education were also associated with a greater risk of anemia. A recent analysis of 53 demographic and health surveys with Hb data found that anemia among PSC (affecting 70% of the PSC population studied) was strongly associated with maternal anemia, household wealth, maternal education, and low birth weight (39).

The most common cause of anemia is a lack of substance iron (40). Because of the lack of iron in the body, the absorption of insufficient iron and the need for a substance increases iron, as well as the loss of the substance, increased iron, such as moment menstruation (37) (41). Chronic blood loss from digestive disorders (ulcers, NSAID use, cancers, diverticulitis, hemorrhoids, and hookworms), menstrual bleeding, urinary tract bleeding, or respiratory tract bleeding can cause iron deficiency. Increased iron needs occur in premature infants, during growth, and in pregnancy. Absorption issues, such as those from gastrectomy, tropical disease, or chronic colitis, can also contribute. (42).

Iron bound to protein forms Hemoglobin, which transports oxygen throughout the body (43). Iron is an essential micronutrient that plays a role in various cellular metabolic processes, including energy production (44), enzyme synthesis, maintenance of neuronal activity, and support of the immune system (45). Iron deficiency is the main factor causing anemia because of its crucial role in the body. Iron deficiency can occur due to insufficient food intake, failure of the absorption process in the duodenum and jejunum even though intake is sufficient, infection with microorganisms that interfere with the absorption and circulation of iron, and excessive need for iron (33).

Pathophysiology of Anemia

Iron deficiency anemia occurs when the body's need for iron exceeds the available supply, so the amount of iron is insufficient for optimal hemoglobin formation. This condition causes the red blood cells formed to have a smaller size (microcytic) and a paler color (hypochromic). The pathophysiology of iron deficiency anemia develops through several stages, from mild deficiency to marginal deficiency until finally becoming real Iron Deficiency Anemia (IDA) (46).

The pathogenesis of iron deficiency anemia develops through several stages, namely mild deficiency, marginal (mild functional) deficiency, and finally, IDA. In the mild deficiency stage, there is a depletion of iron levels in the bone marrow or a decrease in iron reserves, characterized by low ferritin concentrations. Marginal or mild functional deficiency is characterized by a reduced erythropoiesis process, which results in decreased red blood cell production. This condition occurs when iron reserves are depleted, the supply of iron to erythrocyte-forming cells is reduced, and transferrin saturation decreases, even though hemoglobin levels are still within the normal range. Iron stores have been depleted in the iron deficiency anemia stage, and hematocrit values and hemoglobin levels decrease. The red blood cells formed in this condition are smaller than usual (microcytic) and have a low hemoglobin concentration (hypochromic) (46).

Impact of Anemia

Anemia will cause somebody to experience a decline in the Power stand body, which quickly causes problems and indicates poor nutritional status and health (46). The prevalence of anemia in women occurs at puberty due to menstruation and is experienced in young women aged 10-19 years, which is a transition

period experienced by somebody with a change in physique or psyche (48, 49). Data on high levels of anemia in adolescent daughters is also supported by the research conducted (20, 22), who explain that as many as 78.5% of teenage daughters suffer from anemia (51). The research aligns with research that explains that 70% of teenagers and daughters suffer from anemia (52).

Anemia can give rise to various impacts on teenagers, including lowering the body's power so that they quickly catch disease and a decline in activities and achievements Because of lack of concentration (53). Deficiency anemia, problem iron, and low nutritional status will be harmful during pregnancy later, babies with heavy babies born with low pain, even death in mothers and babies (54, 55), as well as an impact on decline cognitive, decline learning, and performance of children at school (4, 56). This is also annoying for concentration teenage daughters, lower success in education, productivity, and physical power, as well as increasing the risk of infection (58).

Prevention of Anemia

Efforts to prevent anemia require a comprehensive approach that addresses various contributing factors, including diet, nutrition, education, and behavioral changes. These strategies can be grouped into three main areas: improving dietary intake, enhancing educational awareness, and promoting behavior modification. A well-balanced diet rich in iron, folic acid, and other essential nutrients plays a crucial role in preventing anemia. Additionally, educational interventions help increase awareness about the importance of proper nutrition and adherence to iron supplementation. Behavior modification strategies, such as promoting regular consumption of iron-rich foods and encouraging a healthy lifestyle, further support anemia prevention efforts. A detailed overview of these preventive measures is presented in (Table 4).

Table 4: Efforts to prevent anemia

Through In-take/consumption of food	**Administration of Hemoglobin Level Increasing Tablets / additional tablets blood (59)**
	Variation in Consumption of Food (60)
	Fortification food to increase Content The nutrition (61)
	Supplementation substance iron and acid folate (62)
	Fortification to improved micronutrient status (59)
	supplement with lipids (64)
Education	Impact education nutrition to knowledge, attitudes, and practices regarding anemia (62)
	Peer education on anemia prevention (62)
	Nutrition Education (57)
Change Behavior	Change habit pattern Eat (21)
	Change Health behavior (63)
	Anemia Detection (64)
	Enhancement facility Cleanliness and sanitation (68)

Efforts to prevent and control anemia in adolescents are generally carried out through three main programs: iron supplementation, nutrition education, and food

fortification (65, 66). These efforts need to be made by adapting fun and exciting methods for teenagers (70). The involvement of teenagers as role models for their peers is also one of the things that will continue to be developed to promote healthy lifestyles for the teenage generation (71, 72).

Taking food supplements rich in vitamins and minerals is one of the measures to prevent anemia (73). Consume folate from green leafy vegetables, citrus fruits, and animal protein. Folic acid will undergo metabolism to become tetrafolic acid, which is needed to synthesize iron nucleic acids obtained from meat, which is the iron complex absorbed by the duodenum and jejunum (69). Iron will then be saved in the heart in the form of fibrin (14). Supplementation, fortification, and diversification programs are Steps to prevent anemia (73). Apart from that, the government gives drug worms, prevent as well as treat disease concomitant, and folate via enhancement tablets blood (75).

Implementation of the program for providing blood supplement tablets to teenagers still faces obstacles, especially in matter level specified compliance low. 2018 Riskesdas data shows that only about 32% of teenagers comply with taking Blood Supplement Tablets, while the other 68% did not follow suit with Blood Supplement Tablets consumption. Reasons for non-compliance: teenage daughter covers forget by 20%, less interest by 22%, and felt unnecessary, amounting to 21.6% (76). With so, necessary steps to improve level compliance, for one, involve education health-based *peer education* with Empowering School Health Enterprises.

Why anemia needs to be prevented

a. Anemia with cognitive decline and decreased learning.

Teenager daughters are vulnerable to anemia due to the need for substance-increased iron to support rapid mental growth and development as well as replace lost consequence menstruation. Lack of substance iron is capable of causing cognitive disturbance in humans, with damage to the mitochondria of the brain as the basis for change (77). Disturbance cognitive impairment is caused by deficiencies in the substance iron (86), which is related to range attention, intelligence, and function perception sensory especially quoted, as well as related to emotions and behavior. Generally, a nuisance is linked with deficiency anemia iron. Juvenile anemia has been reported to increase the risk of psychiatric disorders, including mood disorders, autism, spectrum disorders, attention deficit hyperactivity disorder, and developmental disorders (78, 79).

b. Anemia and high maternal, perinatal, and fetal mortality

An anemic teenager will contribute to high maternal mortality, increasing incidence of birth weight , perinatal death, and fetal death (90). Adolescent childbirth can impair growth due to malnutrition. Early pregnancy and breastfeeding deplete micronutrients like iron, increasing the risk of anemia. Poor nutrition during pregnancy further worsens the condition (80).

Teenagers, frail, and pregnant daughters tend to give birth to babies with low body weight (81). Anemia during adolescence can progress to pregnant women with anemia who are at risk of giving birth to premature and LBW babies. Babies with LBW will grow up to be stunted (short) children who will then become malnourished teenage girls and pregnant women and give birth to the next stunted generation who are not only short but also have low intelligence (IQ), psychological disorders, and at risk of developing diabetes, hypertension, and various other chronic diseases in the future (82).

According to WHO, in 2015, around 29.4% of women age fertile suffered from anemia.

The majority of South Asian adolescent girls are anemic; for example, anemia was detected among 70, 51.8 %, and 67.7% of adolescents in Bangladesh, India, and Nepal, respectively (65).

Recent Advances

Anemia research is advancing, focusing on new treatments like gene therapy and drugs that boost erythropoietin (EPO) and red blood cell production (8). This provides new hope for patients with chronic anemia, such as kidney disease (83).

In addition, there are also efforts to create iron supplements that are easier to absorb and more effective in treating iron deficiency anemia (7). This way, we can increase iron absorption from food and supplements, making it a more efficient solution (7).

In understanding pathophysiology, we have seen breakthroughs thanks to advances in genomics and proteomics. This research provides insight into the molecular mechanisms underlying anemia associated with chronic diseases such as cancer and colitis (84). We can develop more targeted therapies by understanding the cellular signaling pathways and transcription factors involved.

Early detection and screening for anemia is also a priority. New DNA-based diagnostic methods and biomarkers are being developed to detect anemia more accurately and efficiently. There are efforts to create portable and affordable screening tools for areas with limited resources (67).

On the other hand, nutritional interventions and food fortification have received significant attention. Field studies are underway to test the effectiveness and safety of various strategies for enriching foods with iron, folic acid, and vitamin B12 to prevent anemia (63,85). Researchers are also working to develop more effective and culturally acceptable nutritional supplements for at-risk populations (86).

Conclusion

Anemia is caused by infections, bleeding, and nutritional deficiencies, with iron deficiency being the main cause in adolescent girls. Direct factors include behavior, diet, and rest, while indirect factors involve knowledge, age, socio-economics, and healthcare access. Prevention includes fortification, supplementation, and education, whose effectiveness can be explored in future research.

Journalism Ethical considerations

The author has paid full attention to ethical issues, such as plagiarism, informed consent, errors, falsification and fabrication of data, double publication and submission, redundancy, etc.

Conflict of Interest

The authors declare that there is no conflict of interests.

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