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Iron Deficiency Anemia Among Female University Students in Saudi Arabia: Prevalence, Dietary Determinants, and Risk Factors-A Narrative Review

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Abstract **Iron is a vital element that plays a major role in various physiological processes, including HB formation. Oxygen transport adenosine triphosphate (ATP) production, DNA synthesis, mitochondrial function, and cellular defense against oxidative stress. Iron deficiency often develops gradually and may remain clinically silent until it progresses to iron deficiency anemia (IDA). Iron - deficiency anemia is more commonly observed in females than in males and represents a major global health concern, affecting approximately one - third of the world's population. This narrative review study focused on the prevalence of iron - deficiency anemia among female university students. Data were extracted from multiple studies published in different journals (13 articles), with sample sizes ranging between 39 to 507 participants in each study. In the majority of cases, hematological parameters were found below the lower limit for the normal reference ranges for non - pregnant adult females, such as Hb, PCV, MCV, and RBCs. The other parameters, like serum iron and serum ferritin, are variable (normal or at the lower limit) . Moreover, the study highlighted many gaps among female university students concerning IDA including awareness of risk factors and the importance of maintaining optimal iron levels. Besides that, the geographical area covered by reviewed studies is one of the major limitations.**

Keywords: **Prevalence; Iron Deficiency Anemia (IDA); Iron Deficiency (ID); Student; Female; Saudi Arabia.**

I. INTRODUCTION

Iron had long been recognized as a fundamental element in human metabolism, playing a vital role in erythropoiesis [1] and contributing to numerous cellular functions. It was essential for oxygen transport, ATP production, DNA synthesis, mitochondrial activity and cellular defense against oxidative stress [2][3].

Iron Absorption:

Total body iron homeostasis relies on the balance between intestinal absorption by duodenal enterocytes and the body's overall iron requirements. The human body lacks a significant mechanism for iron excretion. Enterocyte Uptake of Dietary Iron.

Dietary iron exists in two primary forms:

Non heme iron (ferric, Fe^{3+}), found in vegetables and whole grains, and heme iron (ferrous, Fe^{2+}) , mainly derived from red meats in the form of hemoglobin .

While non heme iron is the most commonly ingested form worldwide, heme iron predominates in Western diets, contributing approximately 10-15% of daily iron intake.

Ferric iron from non heme sources is poorly absorbed. Gastric acid helps solubilize this form and creates an acidic microenvironment at the apical brush border of enterocytes. This low pH enhances iron transport across the enterocyte membrane via specific membrane transporters. Ferric iron (Fe^{3+}) is enzymatically reduced to the ferrous form (Fe^{2+}) at the brush border by duodenal cytochrome b (DcytB), a ferric reductase. The resulting ferrous iron is then transported across the apical plasma membrane via divalent metal transporter 1 (DMT1), an integral membrane protein.

DMT1 also facilitates the transport of other divalent metals including manganese, lead, zinc, cobalt, and copper.

Heme iron is absorbed more efficiently than non heme iron , although its absorption mechanism is less clearly defined. Gastric acidity and proteolytic enzymes release heme from hemoproteins. Heme is likely taken up into enterocytes via heme carrier protein 1 (HCP1) and proton-coupled folate transporter (PCFT) through receptor-mediated endocytosis. Inside the cell, heme oxygenase releases iron from heme, which then enters the intracellular iron pool alongside iron derived from non heme sources .[4]

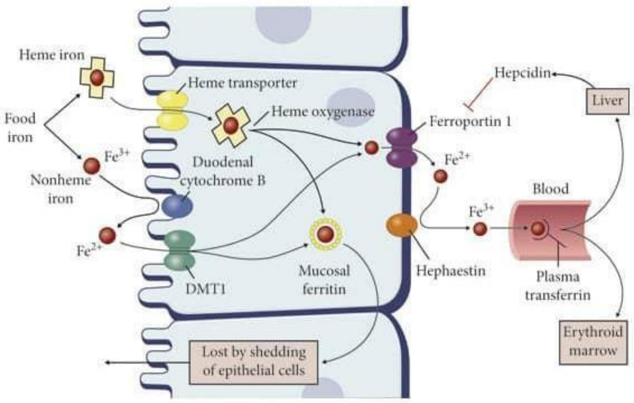

Fig. 1 Iron Absorption

A. Definition of Hemoglobin (Hb) :

Hemoglobin is an iron-containing protein found in red blood cells (RBCs) that is responsible for transporting oxygen from the lungs to body tissues and returning carbon dioxide from the tissues to the lungs .[5] Hemoglobin is a tetramer composed of four polypeptide chains (two alpha and two beta chains in HbA). Each chain is associated with a heme group containing a central Fe^{2+} ion that binds one oxygen molecule.[6]

B. Types of Hemoglobin:

The most common form in adults is Hemoglobin A (HbA), making up about 96-98% of total Hb. Other types include Hemoglobin A2 (HbA2) and fetal hemoglobin (HbF), which predominates in fetuses and newborns. [7]

C. Normal Hb Values:

1) *Men: 13.5-17.5 g/dL.*

2) *Women: 12.0-15.5 g/dL.*

3) *Children: Typically 11-16 g/dL, depending on age. [8]*

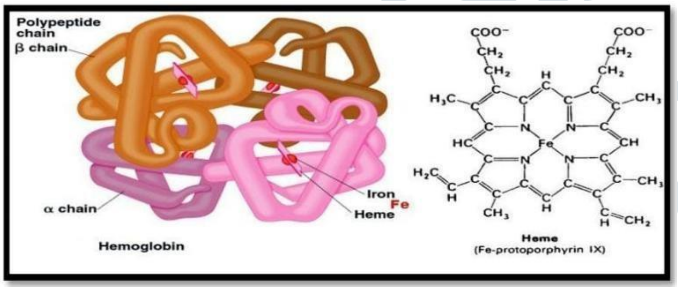

Fig. 2 Hemoglobin

Anemia is a prevalent blood disorder characterized by a reduction in the number of red blood cells (RBCs) or a decrease in the hemoglobin concentration, leading to a diminished capacity of the blood to transport oxygen throughout the body [9] [10]. This condition affects millions worldwide and can manifest through various symptoms , including fatigue , weakness , dizziness and shortness of breath [9] [10] ,which are caused due to a range of nutritional deficiencies due to improper diet or improper absorption of nutrients , also infections like parasitic infections , genetic disorder and obstetric conditions [11].

The severity of anemia and its associated symptoms can vary depending on the underlying cause, the rate of onset, and the individual's overall health [12].

Anemia arises from three primary mechanisms : blood loss , decreased red blood cell production , or increased red blood cell destruction (hemolysis) [12] [13] .

Anemia is classified into different types based on the underlying cause and characteristics of the red blood cells including:

A. Iron-Deficiency Anemia (nutrient Deficiencies): Insufficient intake or absorption of essential nutrients like iron [9] [10].

Iron deficiency anemia is the most prevalent type, often resulting from blood loss or inadequate iron intake [9] [10].

B. Vitamin-Deficiency Anemia: Results from low levels of vitamin B12 or folate, usually due to poor dietary intake or malabsorption [9] [10].

C. Anemia of Chronic Disease: Associated with chronic illnesses , where the body's ability to produce red blood cells is impaired [9] [12].

D. Sickle Cell Anemia : An inherited form of hemolytic anemia where the hemoglobin protein is abnormal , causing red blood cells to become rigid and block blood flow [9] [12].

E. Hemolytic Anemia: Occurs when red blood cells are destroyed prematurely in the blood stream or spleen [9] [12].

F. Other underlying cause: Menstruation, pregnancy and certain gastrointestinal disorders can also increase the risk of anemia [9] [12].

Anemia is diagnosed when a blood test shows a hemoglobin value below the normal range, depending on the age, sex, and other factors [12] .

Despite its importance, iron deficiency remained the most widespread nutritional disorder globally, affecting both industrialized and developing regions [14][15]. According to the World Health Organization (WHO), approximately 30% of the global [16] population was estimated to be iron deficiency (ID)[17][18][19] , with iron-deficiency anemia (IDA) more prevalent among women than men . Anemia , largely attributed to iron deficiency , affected nearly one-third of the world's population[20].

Monthly blood loss during menstruation is one of the main causes of iron deficiency in young women, especially when periods are heavy or prolonged.[21]

In the Middle East, the prevalence of iron deficiency was comparable to that of developing countries, ranging between 25% and 35%, while rates in developed countries were significantly lower at 5% to 8% [22]. Even with advancements in healthcare, ID and IDA continued to represent significant public health challenges, particularly among women of reproductive age [23][24]. The global prevalence of anemia in non-pregnant women within this group had increased to approximately 30% [25].

Iron deficiency typically developed progressively and often remained asymptomatic until anemia reached a more severe stage [26]. Multiple factors were known to influence iron status during adolescence and early adulthood, including socioeconomic conditions and dietary behaviors [27]. Women in this age group, especially those adhering to vegetarian or vegan diets [28], were considered at higher risk due to limited intake of heme iron and reduced iron bioavailability [29].

In medical laboratory practice, biomarkers such as hemoglobin concentration, serum iron, serum ferritin, transferrin saturation, and total iron-binding capacity (TIBC) had been used to assess iron status accurately. This study aimed to evaluate whether college-aged vegetarian women demonstrated altered iron parameters indicative of compromised iron status.

II. MATERIALS AND METHODS

This narrative study review examines the prevalence of iron deficiency anemia among female students by synthesizing findings from several studies, with the majority conducted in the Middle East and one study from a Western country. The selected papers, focused on female student populations, had sample sizes ranging from 39 to 507 participants in each article selected. The journal links for the reviewed articles are as follows:

A. https://doi.org/10.1155/2020/6642568
B. © 2020 Journal of Appied Hematology|Pubshed by Wolters Kluwer Medknow.
C. http://wwwacademicjournas.org/JMLD 21412618
D. 2023 Almasmoum et al . Cureus 15 (12) e50046 DOI 10.7759 / cureus 50046.
E. DOI: 10.29063/ajrh2024/v28i9.8.
F. https://doi.org/10.2147/IJGM.S275702.
G. 10.4103/jfmpc.jfmpc_730_20.
H. https://doi.org/10.1016/j.ajme.2017.11.010.
I. https://doi.org/10.1155/2018/4157876.
J. doi:10.1017/S1368980018001568.
K. https://www.scirp.org/journal/paperinformation?paperid=1 8325.
L. JKAU: Med. Sci., Vol. 15 No. 1, pp: 63-75 (2008 A.D. / 1429A.H.).

Table I Hematological Parameters

PARAMETERS	Hb	PCV	MCV	RBCs	MCH	MCHC
Paper 1	11.4	36.2	79.4	4.5	25.1	32.1
Paper 2	12.2	38.1	84.9	4.6	27.3	31.5
Paper 3	10.9	33.1	76.2	4.3	25.1	32.8
Paper 4	10.8	33.7	76.9	4.2	25.5	33.3
Paper 5	10.6	32.7	70.5	NA	24.5	32.4
Paper 6	10.7	33.4	72.7	4.5	23.2	31.9
Paper 7	10.9	NA	68.1	5.3	17.7	21.4
Paper 8	12	36.7	81.9	4.5	25.9	31.5
Paper 9	10.8	NA	72.3	NA	NA	NA
Paper 10	11.6	NA	82	NA	NA	35.8
Paper 11	12.1	33.5	67.9	NA	NA	NA
Paper 12	13.1	39	89.1	4.4	NA	33.6
Paper 13	11.9	37.4	80.5	4.7	26.5	33.5
Mean	11.4	35.3	77.1	4.5	24.5	31.8
P.Value	0.01	0.011	0.05	0.03	0.05	0.01

Key:

- Hb: Hemoglobin (measured in grams per deciliter, g/dL).
- PCV: Packed Cell Volume (also known as hematocrit, measured as a percentage, %) .
- MCV: Mean Corpuscular Volume (measured in femtoliters, fL).
- RBCs Count: Red Blood Cell Count (measured in millions per microliter, ×106/μL) .
- MCH: Mean Corpuscular Hemoglobin (measured in picograms, pg) .
- MCHC: Mean Corpuscular Hemoglobin Concentration (measured in grams per deciliter, g/dL) .

Table II Hematological Parameters

PARAMETERS	PLT	WBC	RDW	Iron	Ferritin	TIBC	S.S
Paper 1	NA	NA	13	11.5	21.5	360.7	201
Paper 2	NA	NA	14.3	7.5	8.2	404.7	201
Paper 3	335.5	6.6	16.3	7.8	6	NA	310
Paper 4	343	NA	16	31	4	476	100
Paper 5	367	NA	20.6	42	33.7	NA	118
Paper 6	NA	NA	19.7	50.3	15.9	NA	49
Paper 7	304.3	6.4	NA	NA	5.3	NA	200
Paper 8	NA	NA	15.5	NA	14.8	NA	100
Paper 9	NA	NA	NA	NA	NA	614.4	174
Paper 10	NA	NA	13.8	NA	51.3	NA	330
Paper 11	310.6	NA	NA	NA	120.3	NA	507
Paper 12	NA	NA	12.5	91.8	25.4	366.5	39
Paper 13	NA	NA	21.5	21.5	151.8	NA	123
Mean	332	6.5	32.9	32.9	38.2	445	188
P.Value	0.99	<0.05	0.31	0.71	0.64	0.91	-

Key:

- PLT: Platelet Count (measured in thousands per microliter, ×103/µL) .
- WBC Count: White Blood Cell Count (measured in thousands per microliter, ×103/µL) .
- RDW: Red Cell Distribution Width (measured as a percentage, %).
- S.Iron: Serum Iron (measured in micrograms per deciliter, µg/dL) .
- S.Ferritin: Serum Ferritin (measured in nanograms per milliliter, ng/mL).
- TIBC: Total Iron-Binding Capacity (measured in micrograms per deciliter, µg/dL).
- S.S: Sample size.
- NA: Indicates data not available or not provided.

III. RESULT AND DISCUSSION

A. *Result:*

The articles analyzed included a range of laboratory parameters, starting from HB , PCV , RBCs , MCV , MCH , MCHC , PLT , WBCs , RDW , S.Iron , S. Ferrtin and TIBC binding The results showed variability in values , ranging from low to normal levels . These findings are presented in detail in Table 1.

B. *Discussion:*

The mean hemoglobin levels across the studies (table 1) range from 10.6 g / dL to 13.1 g / dL . Several columns show mean Hb levels below the generally accepted lower limit for adult females (typically around 11.4g / dL) . This suggests a considerable prevalence of low hemoglobin , indicative of anemia , among females at university stage .

The mean PCV levels across the studies (Table 1) range from (32.7 % to 39 %) . Several columns show mean PCV levels below the generally accepted lower limit for adult females (typically around 35.3 %). This suggests a considerable prevalence of low PCV, indicative of anemia , among females at university stage .

The average RBC levels reported across the studies (table 1) range between 4.2 g/dL and 5.3 g/dL. Notably, several columns present mean RBC values below the commonly accepted lower threshold for non-pregnant adult females (approximately 4.5 g/dL). This pattern points to a significant occurrence of reduced RBC levels, suggesting a notable prevalence of anemia among the studied populations

MCV levels across the studies (table 1) range from 80.5 g/dL to 89.1g/dL . Several columns show mean MCV levels below the generally accepted lower limit for non-pregnant adult females (typically around 77.1 g/dL) . This suggests a considerable prevalence of low MCV, indicative of anemia, in the populations studied.

MCH levels across the studies (table 1) range from 17.7 g/dL to 27.3 g/dL . Several columns show mean MCH levels below the generally accepted lower limit for non-pregnant adult females (typically around 24.5 g/dL) . This suggests a considerable prevalence of low MCH , indicative of anemia , in the populations studied .

The MCHC levels across the studies (table 1) range from 21.4 g/dL to 35.8 g/dL . Several columns show MCHC levels below the generally accepted lower limit for non-pregnant adult females (typically around 32 g/dL) . This indicates a considerable prevalence of low MCHC , or hypochromia , which is often associated with iron-deficiency anemia in the populations studied

Assessment of Platelet and White Blood Cell Levels in Relation to Iron Deficiency Anemia.

Our analysis of thirteen studies reveals consistent mean levels for both platelets (PLT) and white blood cells (WBCs), largely falling within expected normal ranges. The average mean platelet count across the studies was 332.08 (ranging from 304.3 to 367), and white blood cell counts averaged 6.5 (ranging from 6.4 to 6.6). While a specific study on female university students found no significant difference in mean platelet counts between those with iron deficiency anemia (IDA) and their non-anemic counterparts, it emphasized the role of individual dietary intake and general health in platelet variation . Though our data indicates no significant impact on WBC levels , it's important to consider external research suggesting a correlation between lower iron intake and higher

WBC counts, potentially linked to stress or other health issues . This highlights the multifactorial nature of hematological parameters beyond iron status alone.

The RDW levels across the studies (table 2) range from approximately 12.5% to 21.7%. Several columns show RDW values above the generally accepted upper limit for non-pregnant adult females (typically around 14.5%). Elevated RDW indicates increased variation in red blood cell size (anisocytosis) , which is commonly observed in different types of anemia , particularly iron-deficiency anemia and mixed nutritional deficiencies , suggesting a considerable prevalence of red cell size variability in the populations studied .

The mean serum iron concentrations, as reported in columns (table 2), ranged from 7.5 µg/dL to 91.8 µg/dL. Several of these values fall below the standard lower reference limit for adult non-pregnant females, which is approximately 32.9 µg/dL. This indicates a notable reduction in iron stores, further supporting the likelihood of iron deficiency anemia among the sampled subjects.

Mean serum ferritin levels across columns (table 2) ranged from 4 µg/L to 151.8 µg/L. Despite some variation, the majority of values were below the lower reference limit of 38.2 µg/L for adult non-pregnant females, indicating a high prevalence of ferritin deficiency and a potential risk of iron deficiency anemia in the studied population.

The mean TIBC levels across the studies (table 2) range from 360.7 mcg/dL to 614.4 mcg/dL. Several columns report mean TIBC levels above the generally accepted upper normal limit for non-pregnant adult females (typically around 445 mcg/dL). This indicates a considerable prevalence of elevated TIBC, which is commonly associated with iron deficiency anemia in the populations studied .

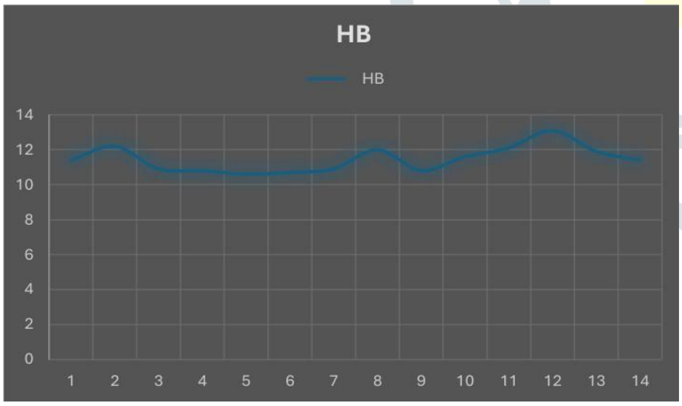

Fig. 3 Hemoglobin (HB)

This type of parameter demonstrates relative stability in its readings , with values clustering closely together — as is the case with Hemoglobin , which shows minimal to no variation . This pattern is clearly illustrated in the chart.

Fig. 4 Serum Iron (S.IRON)

In contrast, the Serum Iron parameter exhibits noticeable variability, indicating significant differences among the studied samples.

IV. CONCLUSIONS

Iron deficiency anemia (IDA) is considered a common and serious health problem among university students in both Middle Eastern and Western countries. Evidence suggests that the high prevalence of IDA is largely attributed to lifestyle and dietary factors, such as low consumption of iron-rich foods, excessive tea drinking, and irregular breakfast intake. These have been identified as key risk factors contributing to the increased incidence of IDA among university students.

To reduce the prevalence of IDA in this population, there is a need for effective health education programs aimed at increasing awareness about anemia, its causes, the importance of consuming iron-rich foods, and avoiding unhealthy dietary habits .

Although Saudi Arabia is classified as a high-income country with a strong socioeconomic status , the prevalence of IDA among university students remains high. This highlights the urgent need to develop comprehensive and effective strategies to reduce iron deficiency and its associated anemia in this age group .

V. RECOMMENDATIONS

In our studie we recomended the future studies should focus on.

A. Research frequently overlooks educational interventions aimed at increasing awareness about IDA prevention strategies .

B. Implement educational programs focused on nutrition and healthy lifestyles .

C. Establish campus-based health screening for early detection of IDA .

D. Encourage iron-rich diets and discourage harmful practices like consuming (tea) immediately after meals .

E. Improve the quality of food served on campus .

F. Encourage routine screening for iron status in long-term vegetarians .

VI. LIMITATIONS

The study was conducted within a geographically limited area , which may restrict the generalizability of the findings to broader populations and poorly highlighted the regional dietary habits , socioeconomic factors , and access to healthcare services may vary and influence iron status differently in other settings .

VII. GABS

Many gabs were detected among the selected articals such as soluble transferrin receptor or hepcidin were not included , which may have provided a more complete picture of iron metabolism .

Many studies may have a limited sample size or may not adequately represent the broader population of female university students , leading to potential biases in the findings .

VIII. DATA AVAILABILITY

The data used to support the findings of this paper are upon request to the corresponding author .

IX. CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper .

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