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Impact of iron deficiency anemia on academic achievement among female university students in Saudi Arabia

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Abstract

Anemia, particularly iron deficiency anemia (IDA), is a prevalent health issue globally and in Saudi Arabia, especially among young adult females. This study investigates the association between anemia and academic achievement among female students at the Female Health Campus of Jazan University, Jazan, Saudi Arabia. This cross-sectional study included 118 randomly selected participants aged 18–22. A validated questionnaire was administered to the study participants. The participants underwent blood tests for complete blood count (CBC) parameters and iron profile analysis. The study reported that 52.5% of the female students had anemia and low serum iron levels. Regarding academic performance, significant positive correlations were found between various CBC parameters including white cell count, hemoglobin, hematocrit, mean cell volume, mean cell hemoglobin, mean cell hemoglobin concentration, and serum iron. However, no significant correlations were observed between red blood cell count and platelet count with academic performance. Demographic variables were also associated with a higher odds ratio of anemia. The study highlights the prevalence of anemia among female students and its potential impact on academic achievement. The current study underscores the importance of addressing anemia in young adult females and implementing appropriate interventions to improve their educational outcomes. *(Afr J Reprod Health 2024; 28 [9]: 85-97).*

Keywords: Anemia, academic achievement, iron deficiency anemia, students, Jazan, Saudi Arabia

Résumé

L'anémie, en particulier l'anémie ferriprive (IDA), est un problème de santé répandu dans le monde et en Arabie Saoudite, en particulier chez les jeunes femmes adultes. Cette étude examine l'association entre l'anémie et la réussite scolaire chez les étudiantes du Campus de santé féminine de l'Université de Jazan, Jazan, Arabie Saoudite. Cette étude transversale a inclus 118 participants sélectionnés au hasard âgés de 18 à 22 ans. Un questionnaire validé a été administré aux participants à l'étude. Les participants ont subi des analyses de sang pour les paramètres de la formule sanguine complète (CBC) et une analyse du profil en fer. L'étude a révélé que 52,5 % des étudiantes souffraient d'anémie et de faibles taux de fer sérique. En ce qui concerne les résultats scolaires, des corrélations positives significatives ont été trouvées entre divers paramètres de CBC, notamment le nombre de globules blancs, l'hémoglobine, l'hématocrite, le volume cellulaire moyen, l'hémoglobine cellulaire moyenne, la concentration moyenne d'hémoglobine cellulaire et le fer sérique. Cependant, aucune corrélation significative n'a été observée entre le nombre de globules rouges et le nombre de plaquettes avec les résultats scolaires. Les variables démographiques étaient également associées à un rapport de cotes plus élevé d'anémie. L'étude met en évidence la prévalence de l'anémie chez les étudiantes et son impact potentiel sur la réussite scolaire. L'étude actuelle souligne l'importance de lutter contre l'anémie chez les jeunes femmes adultes et de mettre en œuvre des interventions appropriées pour améliorer leurs résultats scolaires. *(Afr J Reprod Health 2024; 28 [9]: 85-97).*

Mots-clés: Anémie, réussite scolaire, anémie ferriprive, étudiants, Jazan, Arabie Saoudite

Introduction

Anemia is among the most common disorders globally[1], affecting approximately one-third of the population[2]. Indeed, it poses a major health burden in Gulf countries, including Saudi Arabia.[2-12] The World Health Organization (WHO) indicates that the incidence of anemia in the Middle East among women of reproductive age (15-49 years) is classified as moderate, with rates between 20-40%,

to severe, greater than 40%.[1] In Gulf countries, specifically among women aged between 17 and 24 years old, approximately 30% of them have anemia.[13] Iron deficiency anemia (IDA) is the most prevalent among different types of anemia, accounting for 50% of all anemia cases.[14]

The incidence of IDA varies between developed and developing countries, with rates of approximately 5-8% in developed countries and 25-35% in developing countries.[14] In Saudi Arabia, anemia, particularly IDA, is indeed very common, especially among children, adolescents, and young adult females.[3-5,7,12,15-18] The prevalence of IDA among women of childbearing age in Riyadh was reported to be 37%.[3] According to a recent National Epidemiological Survey, there is a high incidence of iron deficiency and IDA among young adult university female students. The survey reported an incidence of 88.5% for iron deficiency and 94% for IDA among this population.[20] In the Jazan region, the incidence of iron deficiency and IDA among female students was reported to be 67.4%.[18,19] Several causes can contribute to the development of IDA, including blood loss, consumption of an iron-poor diets, iron malabsorption, and increased iron demand during growth, pregnancy, and lactation.[21-23]

Identifying and diagnosing IDA is crucial, particularly in children, adolescents, and young adults. IDA's most common signs and symptoms are pale skin, weakness, fatigue, shortness of breath, dizziness, cold hands and feet, tachycardia, brittle nails, poor appetite, chest pain, and tongue soreness. Additionally, IDA predisposes to poor mood, fatigue, depression, apathy[24], and attention deficit hyperactivity disorder.[23,24] Furthermore, IDA has been suggested to be linked with an impact on motor skills, decreased cognitive performance and development in children, low physical performance and poor quality of life in women, and cognitive abnormality in the elderly.[25-27] A study conducted by Agrawal et al. in 2019 reported a significant impact of hemoglobin levels on cognitive functions, suggesting that all types of anemia can contribute to cognitive impairment.[28] Iron deficiency has even been linked to psychiatric disorders, including autism spectrum disorder.[24] All of these impacts, including the effects on motor skills, cognitive performance, development, and psychiatric disorders, can significantly influence the quality of life in young adult females.[29] Although IDA is highly prevalent in Saudi Arabia, particularly among children and young adult females[3-5,7,12,15-19], up to the best knowledge of the authors, no studies have been conducted to investigate the association of anemia particularly IDA with cognitive performance and academic achievement among Jazan University students in Jazan, Saudi Arabia. The available studies are concerned with the impact of anemia, including IDA, on the health, behavior, cognitive skills, and quality of life of affected individuals, which are still limited and insufficient. Therefore, the current study aims to fill this research gap by investigating the association between anemia, especially IDA, and academic achievement among Jazan University students.

Methods

Study design

The current descriptive cross-sectional study was conducted on young adult female students at the Female Health Campus, Jazan University, located in Gizan City, Jazan region, Saudi Arabia. The study randomly selected 119 adult female students aged between 18 and 22 years. However, the data from one study participant had to be excluded due to insufficient blood collection and lack of data information. A self-structured questionnaire was developed, consisting of questions regarding socio-demographic, health, and nutritional characteristics, as well as educational and academic achievement. The questionnaire included information on academic levels, semesters, cumulative Grade Point Averages (GPA), specialties, and colleges. The GPA was categorized as "Fair/Good" when the mid value was below or equal to the 50th percentile of the GPA, while "Excellent" when the mid value of the GPA was above the mid value of the 50th percentile of the GPA.[32] The Body mass index (BMI) was calculated as previously described.[8] This questionnaire was distributed electronically, and students who provided consent to participate were enrolled in the study. Participants with incomplete data or insufficiently collected blood samples were excluded. Participants with low serum iron and ferritin were considered iron deficient.

Sample collection

Ten milliliters of venous blood were collected from the adult female student participants after obtaining their informed consent. The collection was performed by venipuncture using a 21-gauge butterfly needle at the antecubital vein. Blood samples were collected into two types of tubes: ethylenediaminetetraacetic acid (EDTA), used to perform a complete blood count (CBC) report, and plain tubes, which were centrifugated to separate the serum and stored at -80C for further analysis of iron profile.

Complete blood count, serum iron measurement, and mentzer index

The EDTA anticoagulated tubes were used for CBC determination using Sysmex XN–1000 Hematology Analyzer (Kobe, Japan). The analyzed CBC parameters included white blood cells (WBCs $x10^9$/l), red blood cells (RBCs $x10^{12}$/l), hemoglobin (Hb, g/dl), hematocrit (Hct, %) as well as RBCs indices such as mean cell volume (MCV, fl), mean cell hemoglobin (MCH, pg), mean cell hemoglobin concentration (MCHC, g/dl) and red blood cell distribution width (RDW %). The study was categorized into two groups: (i) the anemic group, which comprised individuals with low Hb levels of less than 12.0 g/dl, and (ii) the control group, consisting of individuals with Hb levels of 12.0 g/dl or higher[21]. Serum iron was measured using HumaStar 200 (Wiesbaden, Germany) chemistry analyzer. Mentzer index (MI) was calculated using the known Mentzer equation MCV/RBC. MI > 13 indicates a probable diagnosis of IDA, while MI<13 indicates a possible diagnosis of beta-thalassemia trait.[33]

Ethical consideration

This study received ethical approval from Jazan university scientific research ethics committee (number REC-43/08/173). All study participants provided their informed consent by signing a consent form. The study was conducted following the principles outlined in the Declaration of Helsinki.

Statistical analysis

Statistical analysis was performed using GraphPad Prism version 9.0 (GraphPad Software Inc., San Diego, CA, USA). Unpaired Student's t-test was utilized to compare two variables, including hematological parameters. The Chi-squared test was employed to assess the correlation of nonparametric data. In contrast, Spearman's rank test examined the correlation between blood factors and academic performance measured by GPA. Binary logistic regression analysis was conducted to evaluate the association between anemia and demographic variables. The data in this study are presented as mean ± standard deviation (SD) unless otherwise stated. A significance level of $p<0.05$ was considered statistically significant.

Results

Socio-demographic and physical characteristics

The study population comprised 118 Saudi female participants aged between 18 and 22. Table 1 presents an overview of the socio-demographic and educational characteristics of the female participants, including information on height, weight, age, education level, semester and cumulative GPA, marital status, monthly income (in Saudi Riyals; SAR), area of living, and their college affiliations. Furthermore, the sociodemographic and educational characteristics were also categorized based on the Hb levels, distinguishing between the control group with Hb levels of Hb≥12.0g/dl and the anemic group with Hb<12.0g/dl). The results indicated that there were no significant differences in most of the socio-demographic and educational between the two groups ($p>0.05$). However, the area of living showed a significant difference, with female students living in coastal areas differing from those living in high-altitude areas in both the control and anemic groups ($p<0.05$). Among the study participants, 56 females (47.5%) had normal levels of Hb (Hb≥12.0g/dl), classified as the normal group. In contrast, 62 (52.5%) females had low levels of Hb (Hb<12.0g/dl), categorized as the anemic group (Table 1). The mean height (cm), weight (kg), and BMI of the participants did not show differences between the study groups ($p>0.05$), indicating comparability in these characteristics. Regarding the education level of the study population, the majority of the participants (26.3%) were at level 8, followed by

Table 1: Socio-demographic and educational characteristics of the female participants in the study based on hemoglobin levels (n=118). NA=not applied

Variables	Total n=118 (%)	Hb≥12.0g/dl n=56 (%)	Hb<12.0g/dl n=62 (%)	*p* value
Age/years	18-22			
Nationality	Saudi			
Height (cm)	154.4±5.4	154.8±5.3	155.2±5.4	0.6790
Weight (kg)	53.3±9.5	49.8±9.6	50.3±9.4	0.7733
BMI (kg/m^2)	21.2±4.0	20.8±3.7	20.5±4.3	0.6607
Cumulative GPA:				
<2.0	4 (3.4)	1 (1.8)	3 (4.8)	
2.0-2.5	4 (3.4)	2 (3.6)	2 (3.2)	
2.5-3.0	9 (7.6)	2 (3.6)	7 (11.3)	NA
3.0-3.5	3 (2.5)	1 (1.8)	2 (3.2)	
3.5-4.0	24 (20.3)	18 (32.1)	6 (9.7)	
4.0-4.5	33 (30.0)	12 (21.4)	21 (33.9)	
4.5-5.0	41 (34.8)	20 (35.7)	21 (33.9)	
Semester GPA:				
<2.0	1 (0.8)	0 (0)	1 (1.6)	
2.0-2.5	8 (6.8)	3 (5.4)	5 (8.1)	
2.5-3.0	6 (4.2)	2 (3.6)	4 (6.5)	NA
3.0-3.5	6 (4.2)	3 (5.4)	3 (4.8)	
3.5-4.0	17 (14.4)	10 (17.9)	7 (11.3)	
4.0-4.5	30 (25.4)	15 (26.8)	15 (24.2)	
4.5-5.0	50 (42.4)	23 (41.1)	27 (43.6)	
Monthly income (SR):				0.102
<5000	97 (82.2)	46 (82.1)	51 (82.2)	
5000-10000	6 (5.1)	3 (5.4)	3 (4.8)	
10000-15000	9 (7.6)	4 (7.1)	5 (8.0)	
>15000	6 (5.1)	3 (5.4)	3 (4.8)	
Marital status:				0.08
Married	12 (10.2)	6 (10.7)	6 (9.7)	
Pregnant	2 (1.7)	1 (1.8)	1 (1.6)	
Single	104 (88.1)	49 (87.5)	55 (88.7)	
Living:				
Urban (city)	61 (51.7)	26 (46.4)	35 (56.5)	0.630
Rural (village)	57 (48.7)	30 (53.6)	27 (43.5)	
Area of living:				0.003**
Costal	104 (55.3)	47 (83.9)	57 (91.9)	
High altitude (Mountain)	14 (44.7)	9 (16.1)	5 (8.1)	
Educational Level:				
Level 3	2 (1.7)	0 (0)	2 (3.2)	
Level 4	11 (9.3)	8 (14.3)	3 (4.8)	NA
Level 5	30 (25.4)	10 (17.9)	20 (32.3)	
Level 6	23 (10.5)	9 (16.1)	14 (22.6)	
Level 7	21 (17.8)	11 (19.6)	10 (16.1)	
Level 8	31 (26.3)	18 (32.1)	13 (21)	
College:				
Applied Medical Sciences	102 (86.4)	49 (87.5)	53 (85.5)	
Pharmacy	1 (0.8)	1 (1.8)	0 (0)	NA
Public Health & Tropical	6 (5.08)	2 (3.6)	4 (6.5)	
Nursing	5 (4.2)	2 (3.6)	3 (4.8)	
Medicine	3 (2.5)	2 (3.6)	1 (1.6)	
Engineering	1 (0.8)	0 (0)	1 (1.6)	

Table 2: Frequency and percentage of health and nutritional characteristics of the female participants in the study (118)

Variables	Total n=118 (%)	Hb≥12.0g/dl 56 (%)	Hb<12.0g/dl 62 (%)	*p* value
History of Chronic disease				0.113
Yes	12 (10.2)	4 (7.1)	8 (12.9)	
No	106 (89.8)	52 (92.9)	54 (87.1)	
Regular meals				0.059
Yes	66 (55.9)	21 (37.5)	45 (72.6)	
No	52 (44.1)	35 (62.5)	17 (27.4)	
Red meat consumption				0.206
Yes	96 (81.4)	49 (87.5)	47 (75.8)	
No	23 (18.6)	7 (12.5)	15 (24.2)	
Red meat consumption/week				0.198
No answer				
<1	32 (33.3)	0 (0)	32 (68.1)	
2-3 times	33 (34.3)	16 (32.7)	13 (27.7)	
>4times	27 (28.1)	26 (53.1)	1 (2.1)	
	8 (8.3)	7 (14.2)	1 (2.1)	
Regular menstrual cycle				0.486
Yes	111 (94.1)	53 (94.6)	58 (93.5)	
No	7 (5.9)	3 (5.4)	4 (6.5)	
Iron supplementation				0.892
Yes	9 (7.6)	5 (8.9)	4 (6.5)	
No	109 (92.4)	51 (91.1)	58 (93.5)	
Vitamin supplementation				0.552
Yes	22 (18.6)	10 (17.9)	12 (19.4)	
No	96 (81.4)	46 (82.1)	50 (80.6)	

25.4% at level 5, 19.5% at level 6, 17.8% at level 7, and 1.7% at level 3. Furthermore, a significant portion of the female students (86.4%) belonged to the College of Applied Medical Sciences (Table 1). Among the total participants, 34.8% had a cumulative between 4.5 and 5.0, while 42.4% had a semester GPA in the same range (Table 1). Regarding monthly income, 82.2% of the study population had an income less than 5000 SAR, 7.6% had an income between 10000 and 15000 SAR, 5.1% had an income between 5000 and 10000 SAR, and 5.1% had an income higher than 15000 SAR. Regarding marital status, 88.1% of the participants were single, while 51.7% lived in the city (Table 1).

Health and nutritional characteristics

The overall health and nutritional characteristics of the study participants showed that 89.8% (n=106) had no history of any chronic disease, while 10.2% (n=12) had a history of chronic disease (Table 2). These differences were not statistically significant ($p>0.05$). However, 12.9% of the females in the anemic group had a history of chronic disease compared to 7.1% in the control group (Table 2). Furthermore, approximately 81.4% of the study participants reported regular consumption of red meat, indicating a potential dietary source of iron. Additionally, 94.1% reported having a regular menstrual cycle. Moreover, a high percentage of participants (92.4%) reported not taking iron supplementation, and 81.4% reported not taking any vitamin supplementation (Table 2).

Symptoms of anemia

The frequency and percentage of anemia symptoms in the study participants did not show a significant difference between the two groups ($p>0.05$), as indicated in Table 3. Among all participants, the most commonly reported symptoms of anemia were weakness and poor appetite, each reported by 46.6% of the participants. This was followed by cold hands and feet, fatigue, and shortness of breath (Table 3).

Table 3: Frequency and percentage of symptoms of anemia among female participants in the study

Variable	Answer	Normal group Hb≥12.0g/dl n=56		Anemic group Hb<12.0g/dl n=62		Total n (%)	*p* value
Pale Skin	No	45	80.4%	45	72.6%	90 (76.3)	0.374
	Yes	11	19.6%	17	27.4%	28 (23.7)	
	Total	56	100%	62	100%	118	
Weakness	No	31	55.4%	32	51.6%	63 (53.4)	0.814
	Yes	25	44.6%	30	48.4%	55 (46.6)	
	Total	56	100%	62	100%	118	
Fatigue	No	36	64.3%	36	51.4%	72 (61.0)	0.586
	Yes	20	35.7%	26	56.5%	46 (39.0)	
	Total	56	100%	62	100%	118	
Short of breath	No	36	64.3%	37	59.7%	73 (61.9)	0.711
	Yes	20	35.7%	25	40.3%	45 (38.1)	
	Total	56	100%	62	100%	118	
Dizziness	No	37	66.1%	35	56.5%	72 (61.0)	0.356
	Yes	19	33.9%	27	43.5%	46 (39.0)	
	Total	56	100%	62	53.4%	118	
Cold hand and feet	No	30	53.6%	34	54.8%	64 (54.2)	0.758
	Yes	26	46.4%	28	45.2%	54 (45.8)	
	Total	56	100%	62	100%	118	
Fast heartbeat	No	35	62.5%	43	69.4%	78 (66.1)	0.358
	Yes	21	37.5%	19	30.6%	40 (33.9)	
	Total	56	100%	62	100%	118	
Brittle nails	No	39	69.6%	37	59.7%	75 (63.6)	0.357
	Yes	17	30.4%	25	40.3%	42 (36.4)	
	Total	56	100%	62	100%	118	
Poor appetite	No	32	57.1%	31	50.0%	63 (53.4)	0.545
	Yes	24	42.9%	31	50.0%	55 (46.6)	
	Total	56	100%	62	100%	118	
Chest pain	No	35	62.5%	44	71.0%	79 (66.9)	0.268
	Yes	21	37.5%	18	29.0%	39 (33.1)	
	Total	56	100%	62	100%	118	
Soreness of tongue	No	41	73.2%	47	75.8%	88 (74.6)	0.624
	Yes	15	26.8%	15	24.2%	30 (25.4)	
	Total	56	100%	62	100%	118	

Incidence of anemia in the study participants

According to the CBC reports, 52.5% (n=62) of the participants had low Hb levels, indicating the anemic group, while 47.5% (n=56) had Hb levels equal to or greater than 12.0g/dl, indicating the normal group (Table 4). The mean value of Hb in the anemic group was 10.6±1.3g/dl, which was significantly lower than the mean value of 12.9±0.7 in the normal group (p<0.0001). In addition, the anemic group showed significantly lower values of Hct, MCV, and MCHC (p<0.05), while the differences in the RBC count and MCH between the two groups were not statistically significant (p>0.05). The RDW was slightly higher in the anemic group than the normal group, with values of 20.5±3.4 and 20.6±2.9, respectively (p>0.8752).

Comparison of WBCs

WBC count was comparable between the anemic group and the control group (p>0.05) (Table 4).

Comparison of platelet count and platelet indices

Platelet count and platelet indices showed variable findings (Table 4). The platelet count was significantly higher in the anemic group than the control group, with values of 367±115 in the

Table 4: Classification of female participants according to hemoglobin levels. Data are presented as mean±SD

Rubric	Non-anemic (Hb≥ 12.0g/dl)	Anemic (Hb <12.0g/dl)	*p* value
n (%)	56 (47.5%)	62 (52.5%)	
(10^9/l)	6.6±2.4	7.0±6.6	0.7297
(10^{12}/l)	4.9±0.6	4.7±0.6	0.0838
Hb (g/dl)	12.9±0.7	10.6±1.3	<0.0001
Hct (%)	37.6±2.9	32.7±3.9	<0.0001
MCV (fl)	78.4±7.2	70.5±8.0	<0.0001
MCH (pg)	26.9±2.8	24.5±9.7	0.0856
MCHC (g/dl)	34.5±1.9	32.4±2.4	<0.0001
RDW (%)	20.5±3.4	20.6±2.9	0.8752
Platelet	306±75	367±115	0.0011
MPV (fl)	8.2±1.5	9.0±4.1	0.1989
PCT (%)	0.3±0.1	0.3±0.1	1.0
PDW (%)	15.0±1.5	13.7±2.2	0.0011
P-LCC (%)	112±26	126±41	0.0516
P-LCR (%)	39.3±4.7	34.5±6.3	<0.0001
Serum iron (µg/dl)	48.7±29.7	42.0±30.3	0.2290
Serum ferritin (µg/l)	62.3±42.8	33.7±20.6	<0.0001
Mantzar Index	16.5±2.8	15.5±3.2	0.0748

WBC= white cell count, Hb= hemoglobin, RBCs= red cell count, Hct=hematocrit, MCV=mean cell volume, MCH= mean cell hemoglobin, MCHC= mean cell hemoglobin concentration, RDW= red cell distribution width, MPV= mean platelet volume, PCT= plateletcrit, PDW= platelet distribution width, P-LCC= Platelet Large cell count, P-LCR = Platelet Large cell ratio

Table 5: Correlation between blood parameters with academic performance GPA (n=118)

Parameters	§Correlation Coefficient	Significance
(10^9/l)	0.263	0.004
(10^{12}/l)	0.096	0.303
Hb (g/dl)	0.407	0.000
Hct (%)	0.282	0.002
MCV (fl)	0.231	0.012
MCH (pg)	0.343	0.000
MCHC (g/dl)	0.420	0.000
RDW (%)	-0.281	0.002
Platelet	-0.055	0.553
MPV (fl)	-0.211	0.022
Serum iron (µg/dl)	0.415	0.000

§Spearman's rank correlation coefficient

anemic group and the control group 306±75; p<0.01) (Table 4).

Iron profile

Serum iron levels were slightly lower in the anemic group, with a mean value of 42.0±30.3, compared to the control group, which had a mean value of 48.7±29.7. However, the difference was not statistically significant (p>0.5). On the other hand, the ferritin levels were found to be significantly lower in the anemic group, with a mean value of 33.7±20.6, compared to the control group, which had a mean value of 62.3±42.8 (p<0.0001) (Table 4).

Mentzer index

The MI was around 15.7±3.1 in the overall population (data not shown). Both the anemic group and control group had 15.5±3.2 and 16.5±2.8, respectively (Table 4); the MI was high in the control group compared to the anemic group (p=0.0748; Table 4). The anemic group was subcategorized based on the MI. Based on the MI, the number of individuals in the anemic group with MI > 13 was n=48, while with MI< 13 was n=14. The comparison in an anemic group with MI > 13 showed a significantly lower RBC count and significantly higher MI, MCV, and MCH (p<0.05; Table 1). The rest of the parameters were comparable except for serum iron (p> 0.05; Table 1). A similar pattern to the MI in the anemic group was observed in the control group.

Table 6: Anemia association with demographic variables

Variable	Adjusted OR	95% C.I. for OR		p value
		Lower	Upper	
Marital Status (Single)	4.769	1.426	15.957	0.011*
<5000	4.461	.948	0.058	0.058
Income 5000-10000	0.511	.047	0.583	0.583
10000-15000	1.222	.168	0.843	0.843
Place (Coastal)	13.316	3.023	58.666	0.001**
Regular Menstruation (No)	6.363	1.421	28.502	0.016*

Binary logistic regression with forward elimination in 4th iteration with confounding factors: chronic conditions, red meat, iron supplementation, vitamin supplementation. OR: odds ratio, C.I.: confidence interval, ¥Chi square test p-value, **highly significant at 0.01 level, *significant at 0.05 level

Correlation between GPA and hematological parameters

The correlation study between academic performance, i.e., GPA and blood parameters, revealed significant correlations with most parameters (p<0.05), except for RBC and platelet counts, which did not show a significant correlation (p>0.05; Table 5). The following parameters showed a significant positive correlation with academic performance (GPA): WBC, Hb, Hct, MCV, MCH, MCHC, and serum iron (p <0.05). On the other hand, RDW and MPV showed a significant negative correlation with academic performance (p<0.01). Although RBC count had a positive correlation and platelet had a negative correlation with academic performance, these correlations were not statistically significant (p>0.05), as shown in Table 5.

Anemia association with demographic variables

The association analysis of anemia with demographic variables indicated significant findings. Single female students had significantly higher odds of developing anemia compared to married females (p<0.05), as shown in Table 6. Furthermore, living in coastal areas and having irregular menstrual cycles were also significantly associated with higher odds of having anemia (p<0.05; Table 6). Lower monthly income was found to be associated with anemia, as shown in Table 6.

Discussion

The present study aimed to investigate the association between anemia, specifically IDA, and academic achievement among young adult female students at Jazan University. Based on the results of the current study, the high prevalence of anemia (52.5%) among female students at the Female Health Campus, Jazan University, is a significant health concern. The findings of the current study align with a previous study conducted at the same university, which reported a high prevalence of anemia among female students[18], and a national study.[3] The observation of low MCV and MCH values in the study participants suggests the presence of microcytic hypochromic anemia. In the Jazan region, IDA and beta-thalassemia minor are the most prevalent causes of microcytic hypochromic anemia.[17] The serum iron and serum ferritin levels in the study participants were at the lower end of the normal range, indicating the possibility of iron deficiency.[23] Consistent with previous studies conducted in Jazan City[18] or other parts of Saudi Arabia[3-12], the most prevalent type of anemia in young females in the current study was IDA. This finding aligns with the global trend, as IDA is known to be the most common form of anemia worldwide.[34] Furthermore, The MI was calculated for both groups, revealing values >13, indicating a probable diagnosis of IDA.[33] Moreover, the sub-analysis of MI within the anemic group showed very interesting data. Specifically, MI > 13 was observed in 48 anemic females, who exhibited lower RBC count along with higher MCV and MCH compared to 14 anemic females with MI < 13, who had higher RBC count and lower MCV and MCH (p<0.0001). Notably, serum levels were higher in the group with MI > 13 compared to those with MI < 13 among the anemic females. This indicates another possible co-existing form of anemia in these groups.

The high prevalence of IDA in young females is likely attributed to many factors, such as increased iron requirements during growth, menstrual blood loss, and possibly inadequate dietary intake of iron-rich foods.[18,23] These findings

emphasize the importance of implementing targeted interventions and public health strategies to address iron deficiency and improve the overall iron status among young females in Saudi Arabia. Furthermore, these findings highlight the need for further investigations to determine the underlying cause of the observed anemia, such as conducting additional laboratory tests or considering other factors that might contribute to the anemic condition in this population. The association between anemia, particularly IDA, and its impact on the quality of life and academic performance of female students has been well-documented.[29,31]

The current study further contributes to this body of knowledge by highlighting the significant positive association between CBC parameters and academic achievement, as measured by cumulative GPA and semester GPA. Indeed, the association between anemia and cognitive skills has been reported in previous studies.[16,30,35] Anemia, particularly IDA, has been linked to cognitive performance. These cognitive effects can significantly impact learning abilities and academic performance among individuals, including students.[16,30,35]

Anemia-induced cognitive impairments can be attributed to the compromised oxygen-carrying capacity of the blood, which affects brain function and neural processes[36]. Iron deficiency, a common cause of anemia, is essential for proper brain development and function. Inadequate iron levels can disrupt neurotransmitter synthesis, impair myelination, and lead to alterations in neural connectivity, ultimately affecting cognitive processes.[37-39] Students with anemia, particularly IDA, may experience difficulties concentrating, paying attention, and memorizing, which hinders their ability to learn and perform well in academic settings[40]. Anemia-related fatigue, weakness, and decreased physical stamina can also affect participation and engagement in school activities.[41,42] Addressing anemia, especially IDA, is crucial in promoting optimal cognitive skills, academic performance, and achievement among affected individuals. Early detection, appropriate treatment, and interventions aimed at improving iron status can help mitigate the negative effects of anemia on cognitive function and academic outcomes.

It is important to note that the association between anemia and academic achievement may vary across different age groups and educational settings.[43,44,45] While some studies have reported a significant association between anemia and poor academic achievement among female high school students and primary school students[45], and also found no such association, particularly among elementary school students.[44,45]

The reason for reporting a positive correlation in the current study could be attributed to the endemic area of anemia among female students in Jazan region and the low sample size.[17,18,48] The conflicting findings could be attributed to several factors. Firstly, the impact of anemia on academic achievement may be influenced by the severity and duration of anemia, as well as individual variations in resilience and coping mechanisms. In mild or transient anemia cases, the cognitive effects may be less pronounced and may not significantly impact academic performance.[41]

Secondly, the academic demands and expectations differ at various educational stages. High school students and primary school children may face more significant academic challenges and performance pressures, which could exacerbate the negative effects of anemia on cognitive skills and academic achievement. On the other hand, elementary school students may be less academically demanding, and the potential impact of anemia on their academic performance may be overshadowed by other factors. Furthermore, differences in study design, sample sizes, and methodologies employed across studies can contribute to variations in findings. Factors such as socioeconomic status, educational resources, and access to healthcare may also influence the relationship between anemia and academic achievement. To better understand the association between anemia and academic achievement, it is important to conduct further research encompassing different age groups, diverse populations, and comprehensive measures of academic performance. Longitudinal studies that consider the duration and severity of anemia, as well as the potential mediating factors, can provide a clearer understanding of the complex relationship between anemia and academic outcomes.[24,27,43-46]

Furthermore, the findings of the current study imply a significant association between anemia, specifically based on Hb levels, and certain demographic variables. The variables that

showed a significant association with anemia in the study population include marital status, place of living, and irregular menstrual cycle (as presented in Table 6). Marital status was found to be associated with the likelihood of developing anemia, with single female students having higher odds of anemia compared to married females. This finding suggests that marital status may play a role in the prevalence of anemia among female students, potentially influenced by factors such as lifestyle, dietary habits, and overall health status. Furthermore, the place of living was also identified as a significant factor associated with anemia. Specifically, female students residing in coastal areas showed a higher likelihood of having anemia compared to those living in high-altitude places. This finding is in agreement with another study that reported high levels of hemoglobin in females living at high altitudes (Abha and Taif cities) as compared to a coastal city (Jeddah) .[47] This finding may indicate the influence of environmental factors or dietary patterns that differ between these two geographical locations. Additionally, an irregular menstrual cycle was found to be significantly associated with anemia. Female students with irregular menstrual cycles had higher odds of developing anemia compared to those with regular menstrual cycles. This association may be attributed to menstrual blood loss and its impact on iron stores in the body.[41]

These findings highlight the importance of considering demographic variables in understanding the prevalence and risk factors of anemia among female students. The associations observed in this study emphasize the need for targeted interventions and preventive measures among specific subgroups at higher risk of anemia. By identifying these demographic factors associated with anemia, healthcare providers and policymakers can develop strategies to improve the detection, prevention, and management of anemia in these populations. The current study has provided valuable insights into the association between IDA, iron levels, and academic performance among young adult females. However, it is important to acknowledge some limitations that may affect the interpretation of the findings. Firstly, the study had a relatively low sample size, which may limit the generalizability of the results. A larger sample size would provide more robust and representative data, allowing for a more comprehensive analysis of the association between IDA, iron levels, and academic performance. Secondly, the study focused on a specific population of young adult females from a single university, which may limit the external validity of the findings. The results may not apply to other populations or settings, and caution should be exercised when extrapolating the findings to broader contexts. The study did not investigate other potential confounding factors that could influence the association between IDA and academic performance. Factors such as socio-economic status, dietary habits, physical activity levels, and mental health status could play a role in academic achievement but were not considered in the current study. Future research should aim to address these confounders to obtain a more comprehensive understanding of the relationship between IDA, iron levels, and academic performance.

Furthermore, the exact mechanism underlying the association between IDA, iron levels, and academic performance is not fully understood and requires further investigation. It is possible that factors beyond iron deficiency alone, such as cognitive functioning, psychological well-being, and overall health status, may mediate or confound this relationship. Future studies should consider exploring these potential mechanisms to gain a better understanding of the observed associations.

Lastly, it is worth mentioning that the reported prevalence of IDA among young adult females may vary across different populations and regions. The range of 64% to 67.4% reported elsewhere highlights the variability in the prevalence rates and emphasizes the need for context-specific research to accurately estimate the burden of IDA in different populations.[7,18]

Conclusion

In conclusion, this study underscores the high prevalence of anemia, particularly IDA, among young adult female students at Jazan University. The findings reveal significant associations between anemia and various demographic factors, including marital status, place of living, and menstrual cycle regularity. Additionally, the study highlights the impact of anemia on academic performance, with significant correlations between

several CBC parameters and GPA. These results emphasize the critical need for targeted interventions to address anemia in this population to improve both health and educational outcomes. Further research with larger sample sizes and consideration of potential confounding factors is recommended to validate and extend these findings.

Ethics approval and consent to participate

All procedures performed in the current studies involving human participants were approved by the Scientific Research Ethics Committee (REC-44/06/478), Jazan University, and were conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all study participants

Competing interests

The authors declare no conflict of interest.

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Author contributions

HAH designed the study, HAH, KE, MS, GD, AM, AAM, YA and WH wrote the manuscript, SH, AA, DB, AAM, TY, and NAAA collected the samples, SH, AA, DB, AAM, RC, KE, HAH performed the analysis. All authors reviewed and edited the manuscript.

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