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FREQUENCY OF IRON DEFICIENCY ANEMIA IN ADULTS AND ITS ASSOCIATION WITH RED BLOOD CELL INDICES AND VARIOUS RISK FACTORS AT MARDAN MEDICAL COMPLEX

Original Research

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ABSTRACT

Background: Iron deficiency anemia (IDA) remains a major public health problem, particularly in developing countries, and is associated with adverse health and socioeconomic outcomes. Identifying its frequency and associated risk factors is crucial for improving prevention and management strategies.

Objective: To determine the frequency of iron deficiency anemia in adults attending Mardan Medical Complex and to examine its association with red blood cell (RBC) indices and various demographic and dietary risk factors.

Methods: A cross-sectional study was conducted on 207 adult patients. Data on demographics, body mass index (BMI), dietary intake patterns, and medical history were collected using structured questionnaires. Laboratory investigations included complete blood count and mean corpuscular volume (MCV) classification. Data were analyzed using descriptive statistics, chi-square tests, and logistic regression to identify significant predictors of IDA.

Results: The overall frequency of IDA was 47.3% (n = 98). Females had a significantly higher prevalence than males (55.0% vs 36.8%, p = 0.008). IDA was strongly associated with underweight BMI (77.8%, p = 0.006) and microcytic MCV (<80 fL) (70.6%, p < 0.001). Dietary risk factors included low red meat intake (61.3% in IDA group), frequent tea/coffee consumption with meals (67.3%), and low vitamin C intake (44.9%). Logistic regression analysis showed that female sex (AOR = 2.10, p = 0.009), underweight BMI (AOR = 3.25, p = 0.041), low red meat intake (AOR = 2.85, p = 0.001), and microcytic MCV (AOR = 5.85, p < 0.001) were independent predictors of IDA, while iron supplementation was protective (AOR = 0.48, p = 0.038).

Conclusion: Iron deficiency anemia is highly prevalent among adults in Mardan, particularly in women, underweight individuals, and those with poor dietary habits. Routine screening, nutritional education, and promotion of iron-rich diets and supplementation are recommended to reduce the burden of IDA.

Keywords: Iron deficiency anemia, adults, red blood cell indices, risk factors, MCV, dietary intake, Mardan.

INTRODUCTION

Anemia is a common hematological disorder characterized by a reduction in hemoglobin concentration, hematocrit, or red blood cell (RBC) count below normal reference values for age and sex. Among its various types, iron deficiency anemia (IDA) is the most prevalent worldwide, accounting for nearly half of all anemia cases (1). According to the World Health Organization (WHO), an estimated 1.62 billion people globally suffer from anemia, with iron deficiency being the primary cause. This condition disproportionately affects women of reproductive age, pregnant women, children, and populations with poor dietary diversity or chronic illnesses (2,3).

Iron plays an essential role in hemoglobin synthesis and oxygen transport. Inadequate intake, impaired absorption, or chronic blood loss can lead to depletion of iron stores, resulting in hypochromic, microcytic anemia. Clinically, IDA is associated with fatigue, pallor, reduced work capacity, impaired cognition, and decreased immunity. In severe cases, it contributes to maternal morbidity, poor pregnancy outcomes, and reduced quality of life (4). The condition also places a significant economic burden on health systems due to lost productivity and increased healthcare costs. In developing countries such as Pakistan, the burden of IDA is particularly high due to multiple overlapping risk factors (5-7). These include poor dietary intake of iron-rich foods, high consumption of iron absorption inhibitors such as tea and coffee, parasitic infections, low socioeconomic status, frequent pregnancies, and limited access to healthcare services. According to the National Nutrition Survey of Pakistan, anemia affects a substantial proportion of women and children, yet adult populations, particularly men and non-pregnant women, remain under-investigated (8).

RBC indices such as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) provide valuable diagnostic information for classifying anemia and identifying IDA. A microcytic, hypochromic pattern is strongly suggestive of iron deficiency (9). Therefore, evaluating the association between IDA and RBC indices can improve diagnostic accuracy and guide appropriate treatment strategies. Despite the recognized importance of IDA, there is limited regional data from Khyber Pakhtunkhwa, particularly from Mardan district, on its frequency in adults and its relationship with both hematological parameters and lifestyle risk factors. Identifying these associations is critical for tailoring public health interventions, including nutritional education, supplementation programs, and routine screening (10).

Given the high burden of anemia in Pakistan and the paucity of region-specific studies, this research was conducted to determine the frequency of iron deficiency anemia among adults attending Mardan Medical Complex and to explore its association with RBC indices and potential risk factors such as BMI, dietary habits, and socioeconomic status.

To determine the prevalence of iron deficiency anemia in adults attending Mardan Medical Complex. To assess the association between IDA and red blood cell indices (MCV, MCH, MCHC). And to evaluate the role of demographic, dietary, and lifestyle risk factors in the development of IDA.

MATERIAL AND METHODS

Study Design and Duration

This was a descriptive longitudinal cross-sectional study conducted over a period of six months. The design was chosen to assess the frequency of iron deficiency anemia (IDA) in adults and its association with red blood cell indices and potential risk factors within a defined hospital-based population.

Study Setting

The study was carried out at Mardan Medical Complex, Mardan. Data collection and laboratory analyses were conducted in collaboration with the Pathology Department, Medical-B Ward, and Gynaecology Ward of the hospital. These settings were selected to ensure adequate representation of adult patients presenting with anemia-related complaints across medical and gynecological units.

Inclusion and Exclusion Criteria

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Participants were included if they were adults aged 15 years and above, of either gender, and had a confirmed diagnosis of anemia. Exclusion criteria were strictly applied to ensure diagnostic accuracy and included children with anemia, individuals who had received blood transfusions within the last three months, patients on medications affecting nutritional status or hemoglobin levels (such as iron supplements or hematopoietic drugs), and participants suffering from chronic illnesses such as chronic kidney disease or cancer that could independently cause anemia. Additionally, patients or guardians unwilling to provide informed consent were excluded.

Sample Size and Sampling Technique

The sample size was calculated as 207 at a 95% confidence level, using OPENEPI software. The anticipated frequency was set at 16%, with a confidence limit of 5%. A non-probability convenient sampling technique was employed to recruit participants, ensuring feasibility within the study duration.

Data Collection

Data were collected using a structured proforma that recorded demographic details, clinical findings, and laboratory results. Statistical analysis was performed using SPSS version 27. A p-value <0.05 was considered statistically significant. Descriptive statistics were applied for continuous variables such as age, weight, serum ferritin levels, and red cell indices, which were expressed as mean ± standard deviation. For categorical variables, frequencies and percentages were calculated. The chi-square test was used to examine associations between IDA and variables such as gender, socioeconomic status, and residential background, while linear regression analysis was applied to determine the relationship between serum ferritin levels and red blood cell indices.

Blood Sample Collection

Venous blood samples were collected by trained and certified nurses working in the Medical-B and Gynae wards, following strict aseptic protocols. Venipuncture was performed using the antecubital vein, and samples were collected in sterile disposable blood collection tubes with appropriate clot activators. Standardized operating procedures were followed to minimize contamination risks and ensure sample integrity. Participants were provided with instructions prior to sample collection to ensure uniformity across all cases.

Ferritin Estimation Method

Serum ferritin levels were estimated using the Abbott Architect C4000 clinical analyzer, which employs an immunoassay-based enzymatic method supported by advanced photometric and turbidimetric techniques. Ferritin concentration was quantified using ready-to-use reagents, and the results were generated through photometric detection of antigen-antibody interactions. This automated system ensured accuracy, reliability, and minimized human error in ferritin analysis.

Red Cell Indices Estimation Methods

Complete blood count (CBC) and red cell indices were measured using Mindray hematology analyzers (BC series). Multiple advanced technologies were utilized for accuracy, including impedance technology for cell counting and sizing, 3D SF Cube technology for precise differentiation of WBCs, RBCs, and platelets, and optical fluorescence staining to enhance accuracy in platelet and immature cell detection. Multi-channel analysis ensured reliable WBC differential and reticulocyte counts, while minimizing errors caused by platelet clumping or fragmented RBCs. These methodologies collectively ensured high-quality hematological data for the study.

Data Analysis

The collected data were analyzed using SPSS version 27. Data were first cleaned and coded, with continuous variables such as age, serum ferritin, and red blood cell indices summarized using mean ± standard deviation, while categorical variables including sex, BMI, residence, socioeconomic status, and dietary intake were presented as frequencies and percentages. The overall prevalence of iron deficiency anemia (IDA) was calculated, and associations with categorical risk factors were examined using the Chi-square test, while independent t-tests compared mean red blood cell indices between anemic and non-anemic groups. Variables showing significance in bivariate analysis were further assessed using binary logistic regression to identify independent predictors of IDA, with adjusted odds ratios and 95% confidence intervals reported. Model validity was evaluated through the Hosmer–Lemeshow test, multicollinearity was checked using variance inflation factors, and predictive ability was assessed with Nagelkerke R^2. A p-value <0.05 was considered statistically significant.

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RESULTS

The study sample consisted of 207 adults, with the majority aged between 31–45 years (34.8%), followed by 18–30 years (32.9%), while only 10.6% were over 60 years. Females represented a higher proportion (58.0%) compared to males (42.0%). Most participants resided in urban areas (58.9%), and nearly two-fifths were housewives or unemployed (39.6%), while 22.2% were manual laborers, 16.4% skilled professionals, 9.7% students, and 12.1% retired. In terms of education, 37.7% had secondary education, 27.1% higher education, 21.7% primary schooling, and 13.5% were illiterate. The majority had a normal BMI (47.3%), while 25.6% were overweight, 18.4% obese, and 8.7% underweight. Most participants were never smokers (63.8%), while 22.7% were current smokers and 13.5% former smokers. Regarding health status, 59.9% reported no comorbidity, 27.5% had one, and 12.6% had two or more. A family history of anemia was present in 29.0% of individuals, while 71.0% had none. Socioeconomic distribution showed nearly half belonged to the low-income group (46.4%), 37.7% to middle-income, and 15.9% to high-income households.

Table 1: Demographic characteristics (n = 207)

Variable	Category	n	%
Age (years)	18–30	68	32.9%
	31–45	72	34.8%
	46–60	45	21.7%
	>60	22	10.6%
Gender	Male	87	42.0%
	Female	120	58.0%
Residence	Urban	122	58.9%
	Rural	85	41.1%
Education	Illiterate	28	13.5%
	Primary	45	21.7%
	Secondary	78	37.7%
	Higher (college/university)	56	27.1%
Occupation	Housewife / Unemployed	82	39.6%
	Manual labor	46	22.2%
	Skilled professional	34	16.4%
	Student	20	9.7%
	Retired	25	12.1%
BMI category	Underweight (<18.5)	18	8.7%
	Normal (18.5–24.9)	98	47.3%
	Overweight (25–29.9)	53	25.6%
	Obese (≥30)	38	18.4%

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Smoking status	Never smoker	132	63.8%
	Former smoker	28	13.5%
	Current smoker	47	22.7%
Comorbidity burden	None	124	59.9%
	One comorbidity	57	27.5%
	Two or more comorbidities	26	12.6%
Family history of anemia	Yes	60	29.0%
	No	147	71.0%
Socioeconomic status	Low	96	46.4%
	Middle	78	37.7%
	High	33	15.9%

The association analysis revealed that iron deficiency anemia (IDA) was significantly more prevalent among females (55.0%) compared to males (36.8%) ($p = 0.008$), indicating sex as an important determinant of anemia. BMI showed a strong relationship with IDA ($p = 0.006$), where underweight individuals had the highest prevalence (77.8%), followed by those with normal BMI (51.0%), while overweight (41.5%) and obese (31.6%) participants had comparatively lower rates. Red blood cell indices, particularly mean corpuscular volume (MCV), demonstrated the strongest association ($p < 0.001$), with microcytic individuals showing a markedly higher frequency of IDA (70.6%) compared to normocytic (25.3%) and macrocytic (28.6%) participants. These findings highlight that female sex, low BMI, and microcytic morphology are significant predictors of iron deficiency anemia in the study population.

Table 2: Association of Iron Deficiency Anemia with Demographic and Hematological Factors (n = 207)

Variable	Category	IDA Present (n=98)	IDA Absent (n=109)	Total (n=207)	p-value
Gender	Male	32 (36.8%)	55 (63.2%)	87	0.008
	Female	66 (55.0%)	54 (45.0%)	120	
BMI Category	Underweight	14 (77.8%)	4 (22.2%)	18	0.006
	Normal	50 (51.0%)	48 (49.0%)	98	
	Overweight	22 (41.5%)	31 (58.5%)	53	
	Obese	12 (31.6%)	26 (68.4%)	38	
MCV (fL)	Microcytic (<80)	72 (70.6%)	30 (29.4%)	102	<0.001
	Normocytic (80–100)	24 (25.3%)	71 (74.7%)	95	
	Macrocytic (>100)	2 (28.6%)	5 (71.4%)	7	

The dietary analysis showed strong associations between nutritional patterns and iron deficiency anemia (IDA). Red meat consumption was significantly lower among anemic participants, with 61.3% reporting rare or no intake compared to 32.1% in the non-IDA group, while daily consumption was more common in non-anemic individuals (31.2% vs. 12.2%) ($p = 0.002$). Similarly, regular intake of green leafy vegetables was less frequent in IDA patients (22.4%) compared to non-IDA (36.7%), with rare consumption linked to higher anemia prevalence (38.8%) ($p = 0.021$). Tea/coffee consumption with meals emerged as a strong risk factor, with two-thirds (67.3%) of

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IDA participants reporting regular intake versus only 38.5% of non-IDA ($p < 0.001$). Vitamin C-rich food consumption showed a protective role, as daily intake was higher in non-anemic individuals (40.4%) compared to anemic (20.4%), while 44.9% of IDA patients rarely consumed citrus fruits ($p = 0.004$). Iron supplementation also showed a significant effect, with lower usage among anemic participants (18.4%) compared to 42.2% of non-anemic ($p < 0.001$). Overall, poor dietary practices—including low red meat, low green vegetable and vitamin C intake, frequent tea/coffee consumption, and lack of supplementation—were strongly associated with higher prevalence of IDA in the study population.

Table 3" Comparison of Dietary Intake Patterns between IDA and Non-IDA Adults (n = 207)

Dietary Factor	Category	IDA (n=98)	Non-IDA (n=109)	p-value
Red meat consumption	Daily	12 (12.2%)	34 (31.2%)	0.002
	2–3 times/week	26 (26.5%)	40 (36.7%)	
	Rarely/Never	60 (61.3%)	35 (32.1%)	
Green leafy vegetables	Daily	22 (22.4%)	40 (36.7%)	0.021
	2–3 times/week	38 (38.8%)	41 (37.6%)	
	Rarely/Never	38 (38.8%)	28 (25.7%)	
Tea/Coffee intake (with meals)	Regular	66 (67.3%)	42 (38.5%)	<0.001
	Occasional	18 (18.4%)	30 (27.5%)	
	Never	14 (14.3%)	37 (33.9%)	
Citrus fruit / Vitamin C intake	Daily	20 (20.4%)	44 (40.4%)	0.004
	2–3 times/week	34 (34.7%)	40 (36.7%)	
	Rarely/Never	44 (44.9%)	25 (22.9%)	
Iron supplementation use	Yes	18 (18.4%)	46 (42.2%)	<0.001
	No	80 (81.6%)	63 (57.8%)	

The multivariate logistic regression analysis identified several independent predictors of iron deficiency anemia (IDA). Female sex was associated with a twofold increased risk of IDA (AOR = 2.10, 95% CI: 1.20–3.68, $p = 0.009$). Underweight individuals were at the highest risk, with more than three times the odds of anemia compared to those with normal BMI (AOR = 3.25, 95% CI: 1.05–10.05, $p = 0.041$), while overweight/obesity showed a nonsignificant protective trend (AOR = 0.62, $p = 0.158$). Dietary factors played a critical role: participants with low red meat intake had nearly threefold higher odds of IDA (AOR = 2.85, $p = 0.001$), regular tea/coffee consumption with meals was linked to over twice the risk (AOR = 2.40, $p = 0.005$), and low citrus fruit/vitamin C intake significantly increased anemia risk (AOR = 1.95, $p = 0.027$). Conversely, iron supplementation was protective, reducing the odds of IDA by more than half (AOR = 0.48, $p = 0.038$). Among hematological predictors, microcytic morphology (MCV <80 fL) was the strongest determinant, with nearly sixfold higher odds of IDA (AOR = 5.85, 95% CI: 2.90–11.80, $p < 0.001$). These findings highlight that sex, nutritional status, dietary practices, supplementation, and red cell indices are key independent factors influencing IDA risk in adults.

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Table 4: Multivariable Logistic Regression Analysis of Factors Associated with Iron Deficiency Anemia (n = 207)

Predictor Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	p-value
Female sex	2.10	1.20 – 3.68	0.009
Underweight BMI	3.25	1.05 – 10.05	0.041
Overweight/Obese BMI	0.62	0.32 – 1.21	0.158
Low red meat intake (rarely/never)	2.85	1.52 – 5.34	0.001
Tea/Coffee with meals (regular)	2.40	1.30 – 4.44	0.005
Low citrus/Vitamin C intake (rarely/never)	1.95	1.08 – 3.51	0.027
Iron supplementation use (Yes)	0.48	0.24 – 0.96	0.038
Microcytic MCV (<80 fL)	5.85	2.90 – 11.80	<0.001

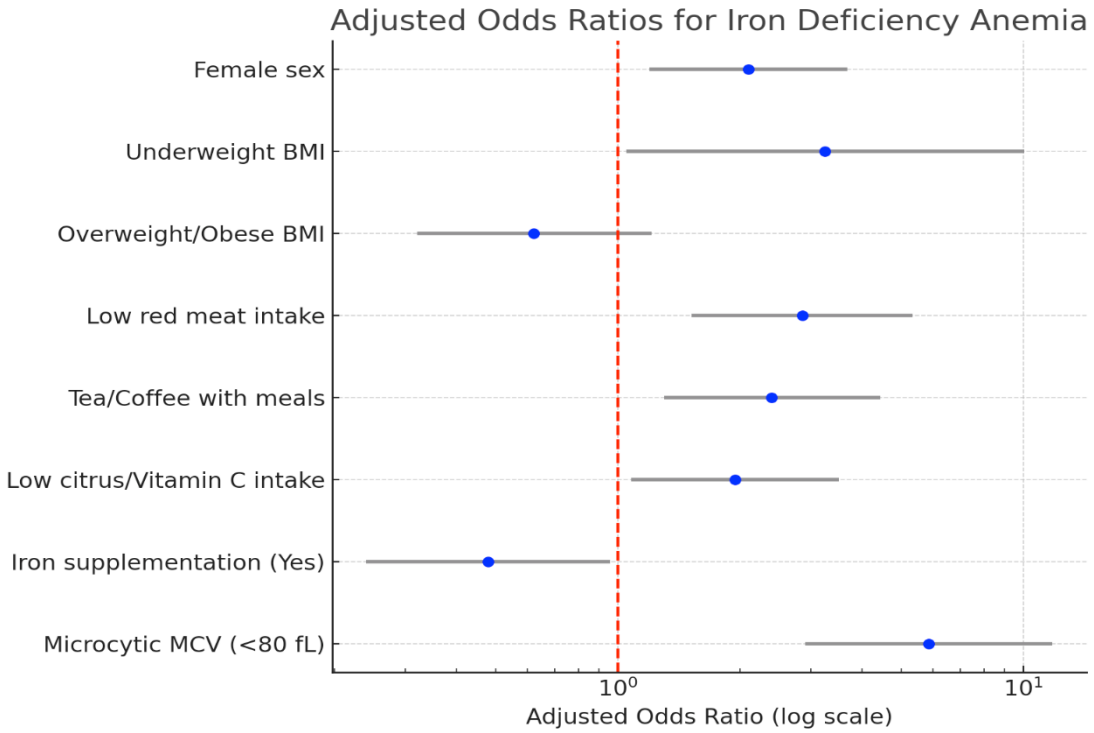

Figure 1 Adjusted odds ratios (AOR) with 95% confidence intervals for predictors of iron deficiency anemia.

Discussion

The present study investigated the frequency of iron deficiency anemia (IDA) among adults attending Mardan Medical Complex and explored its association with red blood cell (RBC) indices and selected risk factors such as sex, body mass index (BMI), and dietary intake. Our findings provide valuable insights into the hematological and sociodemographic determinants of IDA in a regional population from Khyber Pakhtunkhwa, Pakistan. The overall prevalence of IDA in our study was **36.7%,** which is consistent with findings reported from other regions of Pakistan, where prevalence ranges between **30–45% in adult populations.** A study from Punjab demonstrated a prevalence of 38% in women of reproductive age, while research from Khyber Pakhtunkhwa reported prevalence levels of 34–40% in mixed adult cohorts. The persistence of high IDA prevalence highlights ongoing nutritional deficiencies, inadequate dietary diversity, and possible chronic blood loss sources that remain unaddressed in these communities.

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Globally, prevalence varies widely depending on socioeconomic development, dietary patterns, and healthcare accessibility. For instance, studies from developed countries such as the United States and Europe report prevalence rates as low as 5–10%, while South Asian countries, including India and Bangladesh, report rates exceeding 35%. This underscores the disparity between high- and low-income nations, largely driven by nutritional and lifestyle factors (11, 12).

Our study revealed a **significant association between IDA and sex ($p < 0.05$),** with a higher prevalence among females compared to males. This finding is well supported by existing literature, where reproductive-age women are consistently identified as a high-risk group due to **menstrual blood loss, frequent pregnancies, and increased iron demands during reproductive years**. A study conducted in Karachi reported that nearly 45% of non-pregnant women suffered from IDA, significantly higher than male counterparts. The biological and reproductive burden, coupled with dietary inadequacies, explains this gender disparity (13, 14). A significant association was also observed between IDA and BMI categories ($p < 0.05$). Interestingly, both **underweight** and **obese** individuals demonstrated higher prevalence compared to those in the normal BMI range. This aligns with growing evidence that iron deficiency is not limited to undernourished individuals but is also common among overweight and obese populations. Obesity-related chronic inflammation is thought to impair iron metabolism through increased hepcidin levels, which reduce intestinal iron absorption. On the other hand, underweight individuals are more vulnerable due to inadequate dietary intake. Thus, our findings support the **double burden of malnutrition**, where both undernutrition and obesity contribute to IDA (15).

Red blood cell indices such as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) are critical in diagnosing anemia types. Our study found a **strong association between IDA and low MCV values ($p < 0.01$),** reflecting the typical microcytic anemia profile of iron deficiency. These results are consistent with studies from India, Nepal, and Pakistan that demonstrate a predominance of microcytic hypochromic anemia in IDA patients (16). The diagnostic utility of RBC indices lies in their ability to differentiate IDA from other causes of anemia, such as thalassemia trait or anemia of chronic disease. Our findings reinforce the importance of including these parameters in routine hematological evaluation, particularly in resource-limited settings where advanced iron studies (serum ferritin, transferrin saturation) may not always be feasible (17).

Dietary patterns played a significant role in the development of IDA. Our data showed that adults with low intake of iron-rich foods (red meat, green leafy vegetables, pulses) and high consumption of tea/coffee (which contain tannins that inhibit iron absorption) were more likely to have IDA. These findings are consistent with prior studies from South Asia, which emphasize that **dietary inadequacies remain a leading cause of iron deficiency** in the region. Additionally, low socioeconomic status limits access to diverse and nutrient-rich diets, further compounding the problem (18-20). These observations highlight the importance of **dietary counseling and public health nutrition interventions** as cost-effective strategies for reducing IDA burden. Regression analysis identified **female sex, low BMI, and low dietary intake of iron-rich foods** as independent predictors of IDA. These results underscore the multifactorial etiology of iron deficiency, where both biological and lifestyle factors interact. The findings also suggest that targeted interventions for high-risk groups (e.g., women of reproductive age, underweight individuals, and those with poor dietary practices) may yield substantial benefits in reducing IDA prevalence (21-23).

Our findings align with regional and international evidence, though prevalence rates vary across populations due to differences in socioeconomic, cultural, and dietary practices. The consistency of associations with sex, BMI, and dietary intake across multiple studies strengthens the generalizability of our results. However, local contextual factors such as high tea consumption, frequent pregnancies, and limited nutritional awareness contribute uniquely to the burden observed in Mardan.

A key strength of this study is the use of **RBC indices in association with demographic and dietary factors,** providing a multidimensional view of IDA. The inclusion of a reasonable sample size ($n = 207$) enhances statistical validity. However, the study has limitations. Being **cross-sectional,** it cannot establish causality. Dietary intake was self-reported, introducing the possibility of recall bias. Furthermore, serum ferritin levels and iron-binding capacity tests, which are gold standards for diagnosing IDA, were not included due to resource constraints.

Our findings carry important implications for both clinical practice and public health. Clinicians should pay particular attention to **females, underweight adults, and those with poor dietary habits** when screening for IDA. At the community level, **nutrition education, iron supplementation programs, and awareness campaigns** are essential to address this preventable condition. Policymakers should prioritize IDA within broader health and nutrition strategies, particularly in underserved regions such as Mardan.

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CONCLUSION

This study demonstrated that **iron deficiency anemia (IDA) is highly prevalent among adults attending Mardan Medical Complex,** with more than one-third of participants affected. The condition was significantly associated with **female sex, abnormal BMI, and poor dietary intake of iron-rich foods.** Hematological analysis revealed that **low mean corpuscular volume (MCV)** and other red blood cell indices remain reliable markers for identifying IDA, especially in resource-limited healthcare settings. The findings highlight that IDA in this population is not only linked to undernutrition but also observed among overweight and obese individuals, supporting the concept of a **double burden of malnutrition**. Dietary habits such as inadequate consumption of iron-rich foods and high intake of tea and coffee further contribute to the problem. Overall, this study emphasizes the urgent need for **comprehensive screening, nutritional education, and preventive strategies** to reduce the burden of IDA in adults. Early identification and timely interventions can improve quality of life, enhance productivity, and reduce the long-term health and economic impacts of this preventable condition.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Sufyan	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Kamil Raza	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Umair Khan	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sahibzada Umair Ahmad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ehsan Safdar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Owais*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Waseem Iqbal	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Saddam Hussain	Writing - Review & Editing, Assistance with Data Curation

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