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Association between body mass index and hemoglobin levels among university students: a cross-sectional study

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Abstract

Introduction: Obesity is a major global health challenge it is estimated that by 2035, approximately 1.77 billion adults will be overweight 1.53 billion will be obese. Anemia has long been recognized in relation to underweight and malnutrition. However, recent studies have found a paradoxical relationship between obesity and iron deficiency which is mediated by chronic inflammation. **Objective:** This study aimed to determine the association between Body Mass Index (BMI) and Hemoglobin (Hb) levels in university students. **Method:** An analytical cross-sectional study was carried out at Al-Furat Al-Awsat Technical University in Iraq on 413 students using non-probability purposive sampling. Data were collected using a validated self-administered questionnaire for socio-demographic and lifestyle factors, and anthropometric measurements for calculating BMI, and venous blood analysis for hemoglobin estimation using a hematology analyzer. Data analysis was performed using SPSS version 26 software with Chi-square and One-Way ANOVA tests to find associations at a significance level of $p<0.05$. **Results:** The result of 413 students (mean age 20.51 ±1.72 years) showed a high prevalence of anemia (40.7%) and malnutrition, with 17.4% of students being underweight and 32.2% being overweight/obese. There was a statistically significant relationship between BMI and hemoglobin concentration ($p<0.001$); the prevalence of anemia was significantly higher in both underweight and overweight/obese students than in normally weighted students. In addition, hemoglobin concentration was significantly different according to sex, breakfast and dietary habits, sleep duration and physical activity ($p<0.05$). **Conclusion:** The study results revealed a double burden of malnutrition among student anemia posed a serious problem for both underweight and overweight individuals. This condition was closely linked to unhealthy eating habits such as skipping breakfast, high caffeine consumption, and lack of exercise. Therefore, the study recommended integrating anemia screening into all BMI categories and raising nutritional awareness to mitigate the negative health effects of university life.

Keywords: Hemoglobin Levels. Body Mass Index. Anemia. Obesity. Malnutrition. Students.

Introduction

Nutritional status which is an indicator of the balance between nutrient intake and physiological needs is an important primary indicator of health status [1]. Therefore, the body mass index (BMI) and the hemoglobin concentration (Hb) are often used as primary indicators to assess this balance [2]. Maintaining hemoglobin levels within normal physiological limits is essential for metabolic health. However, anemia is a major global public health problem that affects approximately 24.3% of the population [3]. Globally, it is estimated that 30-50% of these cases are specifically attributed to Iron-Deficiency Anemia which is a major global health priority [2].

Body mass index is a widely accepted anthropometric indicator for the classification of

nutritional status [4]. It is a major screening indicator for the identification of metabolic risks that may influence blood indicators [5]. The association between nutritional status and hemoglobin concentration is a widely debated topic among academics. The conventional explanation for anemia is primarily associated with underweight and malnutrition conditions [6].

Recent biological evidence indicates that obesity may have a major impact on the body's iron homeostasis through a complex inflammatory process. Chronic inflammation in obese individuals causes the release of the hormone hepcidin, which inhibits iron absorption [7]. Inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) also cause a hormonal increase that reduces the amount of available iron, leading to "functional iron deficiency" [8]. Obesity is currently a serious biopsychosocial problem. Its global prevalence has doubled since 1980, and currently, approximately 42% of the world's population is overweight it is estimated that by 2035, approximately 1.77 billion adults will be overweight 1.53 billion will be obese [9,10].

University students are particularly vulnerable to these nutritional imbalances. As they are in a phase of rapid growth and lifestyle transition where factors such as a sedentary lifestyle, poor diet and consumption of junk food contributed significantly to nutritional deficiencies [11]. Despite this biological framework research around the world has not always shown consistent results. Recent studies found a strong link between BMI and hemoglobin levels [5,12]. While others studies [13,14] did not suggest that geographic and methodological differences played a role.

This inconsistency was also evident in local studies in Iraq. For example, a previous study limited its scope to obese patients in a clinical setting [15]. While another study exclusively investigated the correlation between anemia and underweight status [16]. The specific focus of local research on isolated weight categories created a clear research gap. There was a lack of comprehensive Iraqi studies that simultaneously examined the "full spectrum" of BMI ranging from underweight to morbid obesity within the university student population.

Therefore, this study was necessitated by the need to resolve these conflicting findings in a local academic setting. The main point of this study was to change the idea that only thin, malnourished people can develop anemia by highlighting the concept of "hidden anemia" among the overweight. Providing such baseline data is statistically and scientifically significant for decision-makers and university health centers to develop effective awareness and nutrition programs [5,17].

Methods

Study Design and Setting

An analytical cross-sectional study was conducted at Al-Furat Al-Awsat Technical University (ATU), Kufa Campus, Iraq, during the academic year 2025-2026. Data collection occurred between November 9, 2025, and January 8, 2026. The study included three key institutions within the campus: The College of Health and Medical Technologies, The Administrative Technical College, and The Technical Medical Institute. This study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Participants and Sampling

The study population included undergraduate students at ATU (total N=3,294). A non-probability purposive sampling method was applied. The sample size was calculated using Cochran's formula based on a 5% margin of error and a 95% confidence level, which resulted in an initial sample of 344 students. To account for a 20%non-response rate and ensure sufficient statistical power, the final sample was adjusted to 413 students.

- **Inclusion Criteria**: Healthy students who voluntarily agreed to participate.
- **Exclusion Criteria**: students with known genetic blood disorders (e.g., Thalassemia and Sickle Cell Anemia), chronic systemic illnesses (e.g., renal failure, malignancy), pregnant or lactating women and those taking iron or vitamin supplements or individuals who had donated blood or undergone surgery within the previous three months.

Ethical Considerations

Ethical approval was granted by the Scientific Research Ethical Committee at the College of Health and Medical Technologies\Kufa (No:ATU-CHMTK-2025/1).Written informed consent was obtained after explaining the study objectives. Participants' confidentiality and their right to withdraw without consequence were fully respected.

Data Collection Instruments

Data were obtained through a structured questionnaire and clinical measurement:

Questionnaire: Validated by a panel of experts (n = 24) and was confirmed reliable by Cronbach's alpha (> 0.86). It covered:

- ***Socio-demographic data:*** Age, gender, marital status, residence and income.
- ***Dietary and lifestyle factors:*** Vegetarian diet, meal frequency, breakfast habits, caffeine use, smoking, sleep duration and physical activity.

Anthropometric Measurement: Height and weight were measured using a calibrated mechanical scale (Model: TRWS-160) with participants in light clothing and no shoes. BMI was calculated as weight (kg) divided by height squared (m^2) and categorized following CDC standards.

Biochemical Analysis: Biochemical Analyses: Approximately 2 ml of venous blood was drawn into EDTA tubes and transported in a refrigerated vaccine container (2-8 °C) to the amines research laboratory. Hemoglobin levels were measured within 2 to 4 hours after blood collection using a Swelab Alpha BM 850 hematology analyzer. Anemia was defined according to WHO criteria, i.e., a hemoglobin level below 13.0 g/dL in men and below 12.0 g/dL in women.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows (Version 26). Descriptive statistics (frequencies, percentages, means and standard deviations) summarized the data. Inferential statistics including Chi-square (χ^2) and One-Way ANOVA tests were used to assess associations between BMI, Hb levels and other study variables. A p-value of < 0.05 was considered statistically significant.

Results

Socio-demographic Characteristics

A total of 413 university students participated in the study. As presented in Table 1, the mean age of participants was 20.51± 1.72 years, with the majority (56.9%) in the 18–20 age group. The sample was gender-balanced (52.3% females, 47.7% males). Most participants were single (89.6%), resided in urban areas (86.2%), and lived with their families (52.3%). Regarding economic status, 47% reported a middle-income level.

Table 1. Socio-demographic characteristics of the study participants (N=413).

Variables	Classification	Frequency (n)	Percentage (%)
Age Group	18–20 years	235	56.9
	21–23 years	154	37.3
	≥24 years	24	5.8
Sex	Male	197	47.7
	Female	216	52.3
Residence	Urban	356	86.2
	Rural	57	13.8
Housing Type	With Family	216	52.3
	Student Housing	189	45.8
	Other	8	1.9

F:Frequency; %:percentage; n:number. Source: Own authorship.

Prevalence of Anemia and BMI Distribution

The descriptive analysis of clinical variables revealed a significant health burden among students. As shown in Table 2 the overall prevalence of anemia (low hemoglobin) was 40.7% (n=168) with a mean Hb level of 13.05 ± 1.96 g/dL nutritional status based on BMI, only half of the students (50.4%) maintained a healthy weight. Malnutrition was evident at both ends of the spectrum: 17.4% were underweight, while 32.2% were either overweight or obese (Class I and II).

Table 2. Clinical characteristics of the study sample (N=413).

Parameters	Classification	F	%	Mean ± SD
Hemoglobin Level	Low (Anemia)	168	40.7	13.05±1.9
	Normal	243	58.8	
	High	2	0.5	
Body Mass Index	Underweight	72	17.4	23.41±4.2
	Healthy Weight	208	50.4	
	Overweight	105	25.4	
	Obesity	28	6.8	

Source: Own authorship.

Association between BMI and Hemoglobin Levels

The primary finding of this study was the significant association between body composition and iron status. As detailed in Table 3 a highly statistically significant relationship was found between BMI categories and hemoglobin levels ($\chi^2 = 224.921$, $p<0.001$).

Table 3. Association between Hemoglobin level and body mass index.

BMI Classification	Hemoglobin Status				
	Low	Normal	High	Total	p-value
Underweight	65	7	0	72	**0.000****
Healthy Weight	12	194	2	208	
Overweight	68	37	0	105	
Obesity (Class I & II)	23	5	0	28	
Total	**168**	**243**	**2**	**413**	

**Significance calculated using Chi-Square test at $p<0.05$. Source: own authorship.

The data revealed a "U-shaped" trend in anemia prevalence, according to Figure 1.

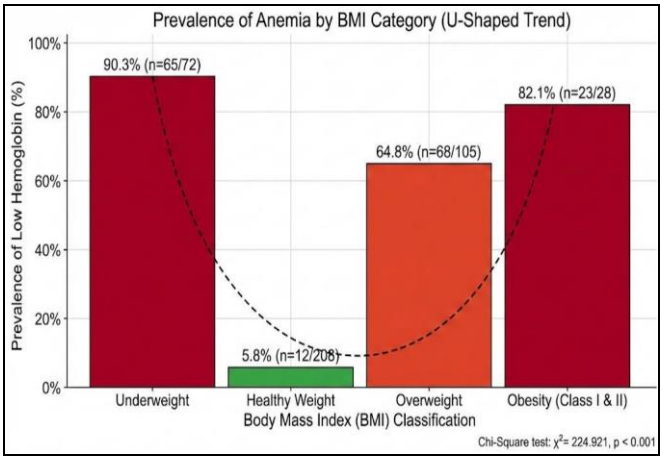

Figure 1. "U-shaped" trend in anemia prevalence. Source: Own authorship.

- **Underweight group:** Exhibited the highest rate of low hemoglobin (90.3%, 65 out of 72).
- **Overweight/Obesity group:** Also showed a disproportionately high prevalence of low hemoglobin compared to the healthy weight group.
- **Healthy Weight group:** Showed the highest proportion of normal hemoglobin levels (93.3%, 194 out of 208).

Determinants of BMI and Hemoglobin Levels

To identify significant determinants of BMI and hemoglobin levels in Multiple categorical variables, a further analysis was performed using a one-way ANOVA. Regarding BMI significant differences were observed based on dietary habits ($p<0.001$) where non-vegetarians exhibited higher BMI values compared to other dietary groups. Eating behaviors such as meal frequency ($p<0.001$), skipping breakfast ($p<0.001$) and caffeine consumption ($p<0.001$) were also significant determinants. Additionally, lifestyle factors including sleep duration ($p=0.007$) and physical exercise ($p=0.004$) showed significant associations with BMI variations. Regarding Hemoglobin (Hb) levels dietary patterns were strongly associated with Hb levels ($p<0.001$). Furthermore, unhealthy habits such as smoking status ($p<0.001$), sleep deprivation ($p<0.001$) and irregular breakfast consumption ($p<0.001$) were significant predictors of lower hemoglobin concentrations (Table 4).

Table 4. Summary of One-Way ANOVA analysis for factors influencing Body Mass Index (BMI) and Hemoglobin (Hb) levels.

Variables	BMI		Hemoglobin	
	F-value	p-value	F-value	p-value
Dietary Habits				
Dietary Pattern	2.824	**0.000****	4.848	**0.000****
Breakfast Consumption	2.336	**0.000****	4.012	**0.000****
Meals per Day	1.764	**0.000****	2.260	**0.000****
Caffeine Consumption	1.708	**0.000****	4.143	**0.000****
Emotional Eating	1.361	**0.022***	1.485	**0.009****
Lifestyle Behaviors				
Sleep Duration	1.460	**0.007****	3.732	**0.000****
Physical Exercise	1.505	**0.004****	2.000	**0.000****
Smoking Status	0.958	0.619	5.543	**0.000****
Phone use while eating	1.669	**0.000****	1.667	**0.001****

*Statistically significant at the 0.05 level. **Statistically significant at the 0.01 level. Source: Own authorship.

Discussion

Prevalence and the Dual Burden of Malnutrition

The findings of this study highlighted a significant public health concern regarding the nutritional status of (40.7%) which aligned with findings by Zefenkey in similar university settings [18]. Furthermore, malnutrition was evident in a dual form, where 17.4% of students were under weighting and 32.2% were overweight or obese. This prevalence appeared lower than the 51.3% reported in a 2019 study by Mohsein et al. [19] conducted at the same institute. This indicated that the student population is facing a "double burden of malnutrition" likely driven by the transitional nature of university life, academic stress and the adoption of sedentary habits combined with nutrient-poor and energy-dense diets.

The Association Between BMI and Hemoglobin

The most critical finding of this study was the highly significant association between BMI and hemoglobin levels ($p<0.001$) which demonstrated a "U-shaped" trend as shown in Table 3. Underweight students exhibited the highest rate of low hemoglobin (90.3%) a result consistent with Khan et al. [20], who attributed this to direct caloric and micronutrient deficiencies. Paradoxically, the study also showed a high prevalence of anemia among overweight or obese students. This finding supported the hypothesis of "inflammatory anemia" proposed by Eon et al. [8], according to which excess adipose tissue induces the production of inflammatory cytokines leading to an overproduction of hepcidin and thus inhibiting iron absorption despite ample food intake.This observation confirmed that a healthy weight is a protective factor against anemia as evidenced by the high proportion of normal-weight hemoglobin levels (93.3%) in the normal-weight group.

Dietary Determinants: Breakfast, Caffeine, and Patterns

Dietary practices were found to be important statistically significant variables influencing both body mass index and hemoglobin levels. In particular, skipping breakfast was found to be significantly related to a reduction in health status ($p<0.001$). This is in line with what Khatun et al. have argued, who have noted that skipping breakfast led to a nutritional gap that was seldom filled later in the day, resulted in weight changes and iron deficiency [21]. Moreover, excessive caffeine intake was found to be significantly related to a reduction in hemoglobin levels ($p < 0.001$). As Mahra and others have argued, frequent tea and coffee consumption, particularly with meals, prevented the absorption of non-heme iron due to the presence of tannins [22]. In addition, students with a non-vegetarian diet had better hemoglobin levels than others ($p < 0.001$), which Sari et al. ascribed to the improved bioavailability of heme iron in animal sources [23].

Impact of Lifestyle Behaviors

In addition to dietary factors, lifestyle factors contributed significantly to the health variables of the students. Lack of sleep was shown to have a strong relationship with a higher body mass index and a lower hemoglobin level ($p<0.001$). Utomo et al. **[24]** clarified that the lack of sleep caused the body to have an improper secretion of metabolic hormones and could impair the process of red blood cell production due to increased oxidative stress. On the other hand, eating while distracted, such as eating while using phones, was shown to have a significant relationship with body mass index ($p<0.001$). This practice weakened the body's satiety signals, resulting in unconscious overeating **[25]**. Contrary to what one would expect, smoking did not have a significant relationship with body mass index, but it did have a significant relationship with hemoglobin level ($p<0.001$). The increased hemoglobin level of smokers indicated a compensatory physiological response to a lack of oxygen, and it was not an indicator of better health **[26]**.

Limitations of the Study

The primary limitation of this study lay in the utilization of a non-probability purposive sampling technique. This methodological approach was deliberately selected to prioritize internal validity over external validity. Given the unavailability of comprehensive official medical records for the student population, a purposive approach was indispensable to rigorously apply strict exclusion criteria and effectively control for confounding variables that could skew the hematological outcomes. To mitigate the potential limitations regarding generalizability, a substantial sample size of 413 participants was recruited to ensure high statistical power and the reliability of the findings.

Conclusion

On the basis of the results obtained from the current study, the following conclusions can be made about the findings, which indicated a serious health issue prevalent among university students: the double burden of malnutrition. The results indicated a strong U-shaped correlation with lower hemoglobin levels as frequently observed in underweight or overweight students. This suggested the possible presence of occult anemia in obese students, an anemia that studies showed to be due to mechanisms associated with inflammation. Besides body composition the results suggested that university life was closely linked to health. In particular, irregular eating habits such as skipping breakfast, excessive caffeine consumption, lack of sleep and a sedentary lifestyle were identified as important factors associated with poor blood health.

Recommendations

In light of the results of the study following recommendations are made:

1. The study recommends that university health services offer comprehensive anemia screening to all students regardless of their weight. University administrations should also ensure that students from diverse socioeconomic backgrounds have access to nutritious and affordable food.
2. Educational programs should be introduced to raise students' awareness of the importance of a healthy breakfast, appropriate caffeine consumption and a healthy sleep schedule. These programs will help to mitigate the negative effects of university-related stress on metabolic health.
3. Future studies should focus on longitudinal studies and research on specific inflammatory biomarkers such as hepcidin and interleukin-6 to clinically confirm the causal relationship between obesity and anemia and to investigate the effects of lifestyle factors in more detail.

CRediT

Author contributions: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Project administration; Supervision; Writing - original draft; Writing-review & editing- Marwa Hussein Kadhim, Riyadh Saad Atshan Al Khafaji.

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Ethical Approval

The study protocol was reviewed and approved by the Scientific Research Ethical Committee at the College of Health and Medical Technologies, Al-Furat Al-Awsat Technical University, Kufa/Iraq. Informed verbal and written consent were obtained from all participants prior to data collection in accordance with the Declaration of Helsinki.

Informed Consent

It was applicable.

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Data Sharing Statement

The datasets generated and analyzed during the current study are not publicly available due to participant privacy and institutional ethical restrictions but are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

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