J Biochem Tech (2019) 10(2): 12-17
ISSN: 0974-2328

Association between the Iron Status and Body Mass Index of Female Students in the Faculty of Science of King Abdulaziz University

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Received: 21 October 2018 / Received in revised form: 22 March 2019, Accepted:27 March 2019, Published online: 10 April 2019

Abstract

Anemia is a major health problem. Being overweight has been a risk factor of iron deficiency (ID). The aim of the present study was to examine the possible correlation of obesity with the level of serum iron among young female students attending King Abdulaziz University, Jeddah, Saudi Arabia**.** This cross-sectional study included 164 young female students aged 18–25 years. The students were recruited between December 2017 and April 2018. All the participants underwent routine body measurements and blood collection for analysis of iron and different metabolic parameters. Students were divided in four groups according to BMI measurements. The results revealed increased glucose, cholesterol, HDL, SBP, DPB, uric acid levels and WBC counts in the group with a BMI > 25 kg/m². The serum levels in the elevated BMI and reduced BMI groups were lower (77.22 ± 6.40 μg/dL and 49.37 ± 5.27 μg/dL, respectively) than those of the students in the normal-weight group (90.94 ± 7.91 μg/dL). In the overweight students, a high waist circumference (≥88 cm) was significantly associated with reduced serum iron levels. Our results point to an association between an elevated BMI and defects in iron homeostasis in young women.

Keywords: Iron, Body Mass Index, Young Female.

Introduction

Anemia is defined as a decrease in the total amount of red blood cells or hemoglobin levels or both (Abbaspour, Hurrell and Kelishadi, 2014). Anemia affects quality of life and has health, social, and economic consequences (Kalyanshetti, 2016).
The recommended daily allowance of iron for an adult man is 10 mg/day, whereas it is 18 mg/day for an adult, but not pregnant woman. Iron deficiency anemia (IDA), which is the most common type of anemia, is the result of an insufficient iron supply to produce red blood cells. According to the latest prevalence statistics on anemia from the World Health Organization, anemia affects more than 2 billion people worldwide, 43% of whom are females (Camaschella, 2015; Auerbach and Adamson, 2016). Anemia affects quality of life and has health, social, and economic consequences (Kalyanshetti, 2016).

Iron deficiency anemia (IDA), which is the most common type of anemia, is the result of an insufficient iron supply to produce red blood cells. Anemia occurs in most of the world's population, with the main cause being iron deficiency. Anemia is characterized by symptoms of chronic fatigue, disturbance of intelligence and disrupts health (Hasimun, et al., 2018). Many factors can lead to the development of anemia. These include inadequate iron intake, excessive blood loss, and an increased iron demand (Aigner, Feldman and Datz, 2014).

Obesity and overweight are other causative factors shown to be correlated with IDA (Qin et al., 2013; Zhao et al., 2015; Meydani and Dao, 2013). According to a survey of 10,735 Saudis in 2013, 28.7% of the participants (females: 33.5%; males: 24.1%) were classified as patients with obesity according to their body mass index (BMI) measurements (Memish et al., 2014). Body Mass Index is an explanatory factor of self-perceived quality of life (Antony & Azeem, 2019). This finding may be linked to increased food intake, the type of food consumed, and a low level of physical activity. Health promoting behavior is a major criterion for determining health and its ultimate goal is to make decisions regarding health and to prepare for desirable behaviors (Darkhor et al., 2018).The study will help in increasing the awareness and knowledge among young students to start thinking about considering a healthy life style to avoid latter complications. The aim of the present study was to examine the possible correlation of obesity with the level of iron in serum among young female students attending King Abdulaziz University (KAU), Jeddah, Saudi Arabia**.**

Methodology

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Study population

This cross-sectional study was conducted between December 2017 and April 2018 at KAU. The inclusion criterion was female science students aged between 18 and 25 years. Participants were excluded if they were receiving iron therapy or consuming dietary supplements or vitamins containing iron. Additional exclusion criteria were chronic or hematological diseases, such as diabetes or hypertension, and menstrual or postnatal periods.

Ethics and approval

The General Directorate of Health Affairs of the College of Medicine, KAU and biomedical ethics unit at the Faculty of Medicine, KAU approved this study. All the participants provided signed informed consent prior to the commencement of the study, and the study was conducted in accordance with the guidelines of the Helsinki Declaration.

Data collection

Blood samples were randomly collected from 164 students, and all the participants completed a general questionnaire. The questionnaire included a brief description of the purpose of the research and questions on several anthropometric and physical parameters, such as age, weight, pregnancy status, dietary type, fast food consumption, caffeine consumption, pharmaceutical consumption, sport, and smoking. Blood samples (5 ml of venous blood) were collected in EDTA tubes (for hemoglobin measurements) and then transferred into plain test tubes and centrifuged (4,500 rpm for 10 min) to separate the serum. The samples were then stored at -20 °C for later analysis of iron levels.

A complete blood count (CBC) was obtained using a hematoanalyzer (Sysmex). Iron profiles were determined using the chromazurol B (CAB) method and a photometric colorimetric test, with a lipid clearing factor **(11-13)**. Following the iron kit procedure (Human, Germany), iron (Fe^{3+}) reacts with CAB and cetyltrimethylammonium-bromide to form a colored ternary complex, with an absorbance maximum at 632 nm. The intensity of the color produced is directly proportional to the concentration of iron in the sample. The iron concentration was measured using the following equation: concentration = 100 (ΔA sample)/(ΔA standard) (micrograms per deciliter). Total cholesterol, triglycerides (TGs) low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), uric acid, and glucose were assessed using commercially available enzymatic colorimetric kits (Human Gesellschaft for Biochemica and DiagnosticambH, Germany).

Statistical analysis

The data were coded and entered using the statistical package SPSS version 15. The quantitative variables were expressed by mean ± standard deviation (SD). Significance between normal and individuals with obesity was made using unpaired student “t” test for parametric parameters and Chi-Square test for non-parametric parameters. Significance between groups was made using One-way ANOVA test for parametric parameters and Chi-Square test for non-parametric parameters. Pearson correlation coefficient test was performed for correlation analysis of biochemical variables and BMI. P value less than or equal to 0.05 were considered statistically significant, while P value less than or equal to 0.01 were considered highly significant.

Results

In total, 164 female students aged 18–25 years completed the study and divided as follows: BMI < 18.5 (kg/m²): underweight 15.3% (32 students); BMI between 18.6 and 24.9 (kg/m²): normal weight 48.4% (80 students); BMI between 25 and 29.9 (kg/m²): overweight 20.2% (29 students) and a BMI ≥ 30 (kg/m²): people with obesity 16.1% (23 students). The mean age in the normal-weight group was 22.56 ± 1.38 years. The mean age in the group with obesity was 20.66 ± 0.19. The mean body mass index (BMI) in the normal group was 20.11 ± 0.22 kg/m², whereas the mean BMI in the group with obesity was 30.52 ± 0.87 kg/m².

In this study, anemia was classified as a hemoglobin level lower than 11.9 g/dL in accordance with the WHO in 2011 classification of anemia in non-pregnant adult women. According to this classification system, the participants were classified into four BMI groups, as follows: a BMI < 18.5 (kg/m²): underweight; BMI between 18.6 and 24.9 (kg/m²): normal weight; BMI between 25 and 29.9 (kg/m²): overweight and a BMI ≥ 30 (kg/m²): people with obesity.

The prevalence of anemia in the total sample was 33.1%. According to the data, 36.8% of the underweight students (n = 32) had anemia, whereas 15.6% had iron deficiency (ID). Among the normal-weight students (80/164), 10% (8 students) were considered iron deficient. In the overweight and group with obesity, 6.9% (2 students) and 4.3% (1 students) of the students, respectively, were ID. Among smokers, only 4 of 77 participants (who only answered this question) were anemic (hemoglobin ≤ 12 g/dL), and 1.05% had ID.(one of the smokers was in normal group, two were people with obesity and the final one was overweight group)

The comparison of the anthropometric measurements of the obesity and normal groups normal revealed a highly statistical significant difference in terms of weight (P< 0.001), BMI (P< 0.001), waist circumference (P< 0.001), hip circumference (P< 0.001), systolic blood pressure (SBP) (P< 0.020), and diastolic blood pressure (DPB) (P< 0.009) (Table 1).

Table 1: Comparison between demographic characteristics and CBC parameters between obese and normal persons.

Parameters	Normal subjects BMI ≤ 25 (n =80)	Subjects with obesity BMI ≥ 25 (n= 52)	*P* value
Age (years)	22.53±1.78	20.65±0.19	0.394
Height (m)	1.59±0.01	1.59±0.01	0.999
Weight (kg)	53.32±0.64	77.33±0.2.06	0.001

BMI (kg/m2)	21.18±0.19	30.80±0.83	0.001
Waist (cm)	70.66±1.01	89.33±1.98	0.001
Hips (cm)	93.74±1.18	112.55±2.43	0.001
Waist/ hip ratio	0.76±0.02	0.81±0.03	0.143
SBP (mmHg)	104.89±1.10	109.22±1.53	0.020
DBP (mmHg)	70.53±0.95	74.80±1.39	0.009
Smoking (no.)	1 (1.20%)	3 (5.80%)	0.321
Number of exercise	1.94±0.23	1.14±0.24	0.025
Sleeping hours (no.)	6.89±0.22	6.86±0.28	0.933
WBC (X 10^3/uL)	6.06±0.20	7.18±0.28	0.001
MCV (fl)	83.94±0.84	81.94±1.25	0.174
MCH (pg)	27.18±0.39	26.77±0.35	0.452
RDW (%)	13.89±0.25	13.64±0.38	0.578
HB (gram/dl)	12.50±0.16	12.45±0.16	0.857

Data were expressed as mean +/- standard error of mean. Significance between normal and obese individuals was made using unpaired student “t” test for parametric parameters and Chi-Square test for non-parametric parameters.

In terms of the CBC results, normal white blood cells (WBCs) were significantly higher in the group with obesity as compared with those in the normal group (P < 0.001), but there was no significant difference normal in the hemoglobin levels of the two groups (P < 0.857) (Table 1). As regards the iron profile results, no significance correlation was detected between the groups, although the iron levels in the group with obesity were lower than those in the normal group (P < 0.232)**.**

Regarding lipid profiles, TG and HDL cholesterol levels in the group with obesity were significantly higher than those in the normal group (P < 0.035 vs. P < 0.048, respectively.

In addition, there was a significant difference in the glucose and uric acid levels in the people with obesity and normal groups (P < 0.001; P< 0.002, respectively) (Table 2).

Table 2: Comparison between demographic characteristics and CBC parameters between obese and normal persons.

Parameters	Normal subjects BMI ≤ 25(n =80)	Subjects with obesity BMI ≥ 25 (n= 52)	*P* value
Age (years)	22.53±1.78	20.65±0.19	0.394
Height (m)	1.59±0.01	1.59±0.01	0.999
Weight (kg)	53.32±0.64	77.33±0.2.06	0.001
BMI (kg/m2)	21.18±0.19	30.80±0.83	0.001
Waist (cm)	70.66±1.01	89.33±1.98	0.001
Hips (cm)	93.74±1.18	112.55±2.43	0.001
Waist/ hip ratio	0.76±0.02	0.81±0.03	0.143
SBP (mmHg)	104.89±1.10	109.22±1.53	0.020
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Smoking (no.)	1 (1.20%)	3 (5.80%)	0.321
Number of exercises	1.94±0.23	1.14±0.24	0.025
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RDW (%)	13.89±0.25	13.64±0.38	0.578
HB (gram/dl)	12.50±0.16	12.45±0.16	0.857

Data were expressed as mean +/- standard error of mean. Significance between normal and obese individuals was made using unpaired student “t” test for parametric parameters and Chi-Square test for non-parametric parameters.

Table 3: Comparison between results of lipid profile and iron status between normal and persons with obesity.

Parameters	Normal subjects (n =111)	Subjects with obesity (n= 55)	P value
Cholesterol (mg/dl)	203.04±11.62	224.18±12.99	0.227
Triglyceride (mg/dl)	153.01±11.83	191.76±13.81	**0.035**
HDL-C (mg/dl)	60.20±5.48	87.47±16.16	**0.048**
LDL-C (mg/dl)	130.57±12.60	157.46±10.63	0.108
Uric acid (unit)	5.82±0.33	8.26±0.48	**0.001**
Glucose (unt)	95.27±2.47	109.63±4.08	**0.002**
Anemia (no.)	20 (18.00%)	12 (22.60%)	0.103
Iron (ug/dl)	80.29±6.45	69.39±4.17	0.232

Data were expressed as mean +/- standard error of mean. Significance between normal and patients was made using unpaired student “t” test for parametric parameters and Chi-Square test for non-parametric parameters.

The mean serum iron level in the normal-weight BMI group (90.94µg/dL) was higher than that in the overweight group (62.62µg/dL) and group with obesity (77.22 µg/dL) (Figure 1). The lowest serum iron level was found in the underweight group (49.37µg/dL), with a significant difference (P < 0.003) (Table 3).

No significant correlation was detected between the BMI and iron level, but a positive significant correlation was detected between the BMI and waist circumference (P = 0.001). There was a negative correlation between waist circumferences and iron levels, although the relation was statistically significant (Table 4).

Table 4: Relationship between body mass index status and iron deficiency.

Parameters	Underweight (*n* = 32)	Normal (*n* = 80)	Overweight (*n* = 29)	Subjects with obesity (*n* = 23)	*P* value
Hemoglobin level (g/dL).	12.30 ±0.36	12.50 ±0.16	12.63 ±0.25	12.23 ±0.17	0.675
Anemia (no.)	4 (12.50%)	16 (20.00%)	6 (20.70%)	6 (26.10%)	0.136

Serum iron level (µg/dL)	49.37 ±5.27	90.94 ±7.91	62.62±5.43	77.22 ±6.40	**0.003**
Iron status					**0.006**
Low (<37 ug/dl)	5 (15.6%)	8 (10.00%)	2 (6.90%)	1 (4.34%)	
Normal (37-145 ug/dl)	15 (46.90%)	38 (47.5%)	23 (79.31%)	18 (78.26%)	
High (>145 ug/dl)	-	13 (16.25%)	3 (10.34%)	2 (8.70%)	
Missing	12 (37.5%)	21(26.25 %)	1 (3.44%)	2 (8.70%)	

Data were expressed as mean +/- standard error of mean or number (%) as appropriate. Significance between groups was made using One-way ANOVA test for parametric parameters and Chi-Square test for non-parametric parameters.

Table 5: Correlation between serum iron levels, BMI and waist circumference in all participants.

Parameters	BMI (kg/m^2)	Waist (cm)
Iron (ug/dl)	0.028 (P= 0.759)	-0.135 (*P*= 0.154)
BMI (kg/m^2)	-	**0.763 (*P*= 0.001)**

Data are expressed as correlation coefficient (r) and significance (P). Significance was made using Person correlation.

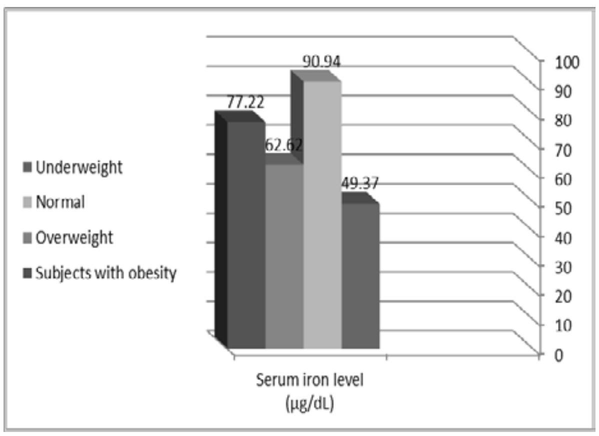

Figure 1: Comparison between the different BMI groups regarding iron level.

Discussion

As anemia is a major disease worldwide, especially among children and young adults, and affects quality of life, it is important to identify its causes and implement treatment. Various factors lead to the development of different types of anemia, with IDA considered the most common type. Although the primary cause of IDA is generally considered a micronutrients deficiency as a result of insufficient dietary intake, many studies have pointed to a possible association of obesity with IDA. In the present study, we assessed the possible causative role of an elevated and reduced BMI lower than 18 (kg/m²) or higher than 25 (kg/m²) in the development of anemia, particularly IDA among adult non-pregnant students at KAU.

As the analysis of the data proved, obesity significantly increased the level of various metabolic parameters, such as glucose, uric acid, cholesterol, HDL, SBP, DBP, and WBC counts. Other important parameters, such as waist and hip circumferences, were high in the group with obesity. As reported in previous research, high waist and hip measurements increase the possibility of the development of chronic diseases, including cardiovascular diseases and diabetes type 2 (Zheng et al., 2016). Previous research highlighted the importance of both BMI and waist circumference measurements, as the BMI measures the height to weight ratio and provides a measure of general obesity, whereas the waist circumference can be considered a measure of central obesity (i.e., abdominal fat accumulation (Lim and Meigs, 2013). An increase in waist circumference can be the result of subcutaneous or visceral fat accumulation, which is hard to discriminate (Díaz-Santana et al., 2016). In the present study, although there was no statistically significant difference in the waist to hip ratio of the people with obesity and normal groups, the ratio tended to increase in the students with obesity. This finding pointed to increased abdominal obesity in young girls due to visceral fat accumulation. As reported in previous studies, visceral fat can lead to increased secretion of inflammatory mediators, such as cytokines and chemokines, thereby leading to a general inflammatory response associated with obesity (Savastano et al., 2015; Tchkonia et al., 2013; Soundarya and Suganthi; Coimbra, Catarino and Santos-Silva, 2013).

Anemia was found in approximately 33.1% of the participants in this study, and it was more common among the students with a high BMI. There was no significant difference in the hemoglobin levels in this group as compared with those in the other groups, and the iron level in most of the individuals (79%) in this group was in the normal range (37–145 ug/dL), indicating that factors other than ID a contributed to the development of anemia. As reported earlier, an imbalanced diet and genetic factors can result in the development of anemia caused by factors other than ID (Coimbra, Catarino and Santos-Silva, 2013). In the present study, although the students with a high BMI tended to have low iron levels as compared with those in the other groups, this finding was not statistically significant. However, this finding serves as an important indicator of the possible association between fat accumulation and an iron level imbalance.

As the correlation data indicated, waist circumference measurements showed a significant association with low iron levels but not with BMI measurements in the students with obesity. This finding points to the possible role of abdominal fat in metabolic alterations of iron, with an inflammatory state leading to a low iron level, as confirmed by the elevated WBC count in the students with obesity. Many studies showed that inflammation resulted in increased production of liver hepcidin, which interferes with iron absorption, and the authors of these studies suggested that this may explain the low iron level associated with a high BMI (Ghadiri-Anari, Nazemian and Vahedian-Ardakani, 2014; Guglielmi et al., 2015; Kordas et al., 2012).

The findings of the present study on the possible association of an elevated BMI with anemia, as well as with an increased risk of low iron levels, are in agreement with those of many recent studies on BMI, which used plasma ferritin and serum iron levels as diagnostic tests for IDA. These studies demonstrated that BMI was a risk factor for reduced serum iron levels but not reduced plasma ferritin levels (Meydani and Dao, 2013; Memish et al., 2014; Zheng et al., 2016). Thus, the literature points to the role of inflammatory mediators in a low iron level in obesity.

In contrast, some studies found no association between anemia or ID and obesity (Eckhardt et al., 2008; Datz et al., 2013). In a recent study on Colombian women, the authors found a low likelihood of anemia and IDA in women with a high BMI. The authors suggested that the iron-rich nature of the food consumed in the Colombian diet may explain the null association of obesity and anemia (Kordas et al., 2012). Other studies conducted among Mexican, Egyptian, and Peruvian populations reported the same results, finding no association of obesity with overweight or anemia. Given the insufficient intake of micronutrients in developing countries, the authors attributed this finding to iron in a high-energy diet lowering the risk of anemia in women with obesity (Eckhardt et al., 2008).

In the present study, low serum iron concentrations were associated with elevated glucose and uric acid levels and increased body fat (high LDL and TG), especially visceral fat (waist circumference), in addition to high blood pressure, all of which are considered obesity indicators. It is also thought to indicate impaired iron homeostasis (Sri et al., 2016).

In the present study, ID was more prevalent among the underweight young women with a low BMI, which was in agreement with the findings of other studies (Sharif, Madani and Tabatabaie, 2014)**.** This could be explained by an unhealthy lifestyle. According to the results of the survey, these students consumed an imbalanced diet, which was low in nutrients, and they had a low level of physical activity. It is noteworthy that, the prevalence of anemia in this group was lower than that found in the normal-weight and group with obesity's. ID, with or without anemia, due to a nutrient-poor diet is a risk factor for serious complications, especially among young girls of reproductive age, with the risk of excessive blood loss during the menstrual cycle. To prevent complications associated with low iron levels, medical advice should be sought, with possible iron supplementation. As our data demonstrated, both a high and low BMI increased the risk of ID. Thus, parents and educational institutes should encourage young girls to consume a balanced diet and adopt a healthy lifestyle.

In conclusion, the results of the present study suggest that anemia is common among young female students, a finding that may be associated with rapid lifestyle changes as type of food and low physical activity. They also indicate that both high and low BMI measurements are associated with low iron levels in the absence of IDA. Future studies should include investigations of iron factors, as well as important inflammatory mediators, including ferritin and transferrin, that could contribute.

Conflicts of interest:

All contributing authors declare no conflicts of interest.

Acknowledgements

We are grateful to the Science Research & Innovation Unit at the Faculty of Science, King Abdulaziz University in Jeddah, Saudi Arabia and Mawakeb Alajer who supported this study.

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