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Relation between body mass index and iron deficiency anemia in adolescent females

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ABSTRACT

Background: Iron deficiency is widespread nutrient deficiency in adolescent females ***Aim***: the study was conducted to determine the association between body mass index and iron deficiency anemia in adolescent females. ***Methods***: Cross section study, sixty adolescent females, their ages ranged from 17 to 19 years old. There were three equal groups in number (A&B&C) according to body mass index. Group A (underweight): 20 females their BMI < 18.5, group B (normal weight): 20 females their BMI ranged from 18.5 to 24.9 and group C (overweight): 20 females their BMI ranged from 25-29.9. Also, all females in groups were subjected to analysis of hemoglobin (Hb) and serum ferritin levels (SF) by lab analysis using Cyanmethemoglobin method and Roche/Hitachi cobas c system. ***Results***: The percentage of anemic subjects with Hb less than 12 g/dL was (45%), (30) and (20%) in group A, B and C respectively with a non-statistically significant relation between weight category and the Hb deficiency category with P-value = 0. 231. As regards ferritin level, there was a statistically significant positive correlation with BMI (P-value = 0.015). ***Conclusion***: The highest prevalence of anemia was found among the underweight group followed by normal weight group while the least percentage of anemic participants was in the overweight group with no significant difference between groups, but there is a greater prevalence of iron deficiency among underweight adolescent females.

Keywords: Iron Deficiency Anemia, Body Mass Index, Adolescent Females

Introduction

Anemia is a global public health problem affecting both developing and developed countries with major consequences for human health as well as social and economic development (Tesfaye et al., 2015). It defined as a reduction in hemoglobin concentration, hematocrit, or number of red blood cells per cubic millimeter (Lanzkowsky, 2016). Iron deficiency anemia is the major adverse effect of iron deficiency. The other liabilities of iron deficiency include its effect on intellectual performance, immunity, leukocyte function, physical work capacity, growth velocity, epithelial change, fertility, malignancy, neurological function and intelligence (Igbal *et al.,* 2015).

Iron deficiency anemia is diminished red blood cell production due to low iron stores in the body. It can result from inadequate iron intake, decreased iron absorption, increased iron demand, and increased iron loss (Short and Domagalski, 2013). ID and abnormal BMI are two nutritional disorders worldwide and particularly in developing countries. Numerous dieting or constrained eating, missing meals, vegetarian eating styles, high carbohydrate meals and fast foods are all risk factors for anemia in adolescents. In spite of bigger iron needs, many adolescents, especially girls; do not take enough iron from their diets. About 75% teenage girls, do not have adequate diet, especially in bioavailability of iron foods and do not meet their dietary requirements for iron from menstrual blood loss, compared to only 17% of teenaged boys. Therefore, teenagers are prone to ID and IDA (Keikhaei *et al.,* 2012, Alquaiz *et al.,* 2013).

Body mass index is reliable indicator of health and nutritional status of human beings (Resmi *et al.,* 2017). The common interpretation is that it represents an index of an individual's fatness. It also is widely used as a risk factor for the development of or the prevalence of several health issues and widely used in determining public health policies (Nuttall, 2015). The World Health Organization defined BMI-based fatness categories of underweight (BMI < 18.5 kg/m2), normal weight (18.5–24.9 $kg/^{m2}$), overweight (25.0–29.9 kg/m2) and obese (≥30.0 kg/m2) (Sperrin *et al.,* 2016).

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Material and Methods

Participant:

A cross section study**,** a total of 60 adolescents females volunteers from the Physical Therapy Faculty, Kafr Elsheikh University, Egypt. There were three equal groups in number (A&B&C) according to body mass index. Group A (underweight): 20 females their BMI < 18.5, group B (normal weight): 20 females their BMI ranged from 18.5 to 24.9 and group C (overweight): 20 females their BMI ranged from 25-29.9**.** The females participated in the study after signing an informed consent form before data collection. The purpose and nature of the study were explained to all participants. Recruitment began after approval of the Faculty of Physical Therapy Ethics Committee.

Inclusion criteria

Participants ages ranged from 17 to 19 years, all socio economical classes, attained menarche and willing to participate in the study.

Exclusion criteria:

Uncontrolled diabetes, hypertension, liver disorders, other types of anemia such as protein deficiency anemia, pernicious anemia, sickle cell anemia, and thalassemia, iron deficiency secondary to malignancies and history of menorrhagia.

Instrumentation

*Height and Weight scale: body weight, body height, BMI was calculated by dividing the subject's weight by the square of her height, expressed in metric units: Metric: BMI = kg/ m^2, where kg is the subject's weight in kilograms and m is the subject's height in meters.
Roche/Hitachi cobas c systems for estimating serum ferritin level**.**
Hemoglobin analyzer (ERMA, JAPAN): using Cyanmethemoglobin method for estimatating hemoglobin level.

Sample size estimation:

Based on a previous study (Eftekhari *et al.,* 2009) sample size has been calculated. To avoid a type II error, a preliminary power analysis was calculated and a sample size of 18 for each group was determined. The power analysis was carried out using G*Power 3.1 soft wear with the following parameters: F tests - ANOVA: Fixed effects, omnibus, one-way Analysis: A priori: Compute required sample size Input: Effect size f = 1.1019516 α err prob = 0.05 Power (1-β err prob) = 0.95 Number of groups = 3 Output: Non centrality parameter λ = 21.8573519 Critical F = 3.6823203 Numerator df = 2 Denominator df = 15 Total sample size = 18.

Procedures:

After estimation of BMI of each female and divided them into three groups according to their BMI**,** blood samples were taken from all females for the estimation of hemoglobin and serum ferritin levels.

Three ml blood was drawn from antecubital vein by placing the tourniquet 3 to 4 inches above the selected puncture site, cleaned the area and asked the female to make afist. The needle formed a 15-30-degree angle with the arm surface, then blood was drawn into tube with EDTA for hemoglobin level analysis to prevent blood coagulation and another tube for serum ferritin level analysis.

Statistical analysis

Statistical analysis was conducted using SPSS for windows, version 25 (SPSS, Inc., Chicago, IL). Prior to final analysis, data were screened for normality assumption and presence of extreme scores. This exploration was done as a pre- requisite for parametric calculations of the analysis of difference. Descriptive analysis using histograms with the normal distribution curve and Normality test of data using Shapiro-Wilk test showed that the data of age, and BMI, each group were not normally distributed, while HB and serum ferritin are normally distributed and not violates the parametric assumption. ANOVA test was used for comparison between normally distributed variable between groups while Kruskal- Wallis H Test (non-parametric test) was used for comparison between non normally distributed variables between groups. Relationship between Hb < 12 g/dL or Hb >= 12 g/dL and weight groups was tested by Pearson Chi-square. Correlation between numerical non-normally distrusted variables was carried out by Spearman's rank Correlation. Alpha level was 0.05.

Results:

The age mean values were 18.05 ± 0.759, 18.1 ± 0.641 and 18.05 ± 0.759 years for the first, second and third group respectively ,as shown in table (1). Moreover, Kruskal-Wallis H teste (non parametric ANOVA equivalent test) revealers that there was no significant difference between the three groups regarding age factor with P-value = 0.976.

Table 1: Descriptive and ANOVA test of AGE in years of the 3 groups.

Number of patients	**Group (A) Under Weight**	**Group(B) Normal Weight**	**Group(C) Over Weight**
Mean in years	18.05	18.10	18.05
	0.759	0.641	0.759
Maximum	17	17	17
Minimum	19	19	19
Mean Rank	30.18	31.15	30.18
Kruskal-Wallis H		0.049	
P-value		0.976	
Significance		Non Significante	

As shown in table (2), the BMI mean values were 18.245 ± 0.2625, 22.85 ± 1.3249 and 27.15 ± 1.75 kg/m^2 for the first, second and third group respectively. Moreover, Kruskal-Wallis H teste (non parametric ANOVA equivalent test) revealers that there was significant difference between the three groups regarding age factor with P-value < 0.0001.

Table 2: Descriptive and ANOVA test of BMI for the 3 groups.

Number of patients	**Group (A) Under Weight**	**Group(B) Normal Weight**	**Group(C) Over Weight**
Mean in kg/m2	18.245	22.850	27.150
± SD	0.2625	1.3249	1.75
Minimum	17.3	21.0	25.2
Maximum	18.4	24.9	29.9
Mean Rank	10.50	30.50	50.50
Kruskal-Wallis H		52.746	
P-value		0.0001	
Significance		Significante	

As shown in table (3): the HB mean values were 12.165 ± 0.809, 12.45 ± 1.465 and 12.615 ± 0.5566 g/dL for the first, second and third group respectively. Moreover, ANOVA teste revealers that there was no significant difference between the three groups regarding age factor with F-value = 0.999 and P-value =0.374. Moreover, as shown in table (4) and figure (1), frequency and percentage of subjects with Hb less than 12 g/dL was 9 (45%), 6 (30) and 4 (20%) in group A, B and C respectively, so the total count of subjects with Hb less than 12 g/dL was 19 with percentage of (31.67%). Chi square test showed that there was a non-statistically significant relation between weight category (under, normal or over weight) and the Hb deficiency category (Hb < 12 g/dL or Hb >= 12 g/dL) with P-value = 0.231.

As regard to Results of the serum ferritin level between the three study groups, as shown in table (5): the serum ferritin mean values were 29.055 ± 23.103, 31.375 ± 28.887 and 67.47 ± 43.234 ng/mL for the first, second and third group respectively. Moreover, ANOVA teste revealers that there was significant difference between the three groups regarding serum ferritin factor with F-value = 22.967 and P-value < 0.0001.

Moreover, as shown in table (6) and figure (2), frequency and percentage of subjects with S. ferritin < 12 ng/mL was 7 (35%), 6 (30%) and 0 (0%) in group A, B and C respectively, so the total count of subjects with iron deficiency was 13 with percentage of (21.67%). Chi square test showed that there was a statistically significant relation between weight category (under, normal or over weight) and the S. ferritin deficiency category (S. ferritin < 12 ng/mL or S. ferritin >= 12 ng/mL) with and P-value = 0.015.

Table 3: Descriptive and ANOVA test of HB in g/dL of the 3 groups.

Number of patients	Group (A) Under Weight	Group(B) Normal Weight	Group(C) Over Weight
Mean in g/dL	12.165	12.450	12.615
± SD	0.8093	1.4652	0.5566
Minimum	10.5	9.2	11.6
Maximum	14.1	14.8	13.7
F-value		0.999	
P-value		0.374	
Significance		Non Significante	

Table 4: Frequency and percentage of subjects with Hb < 12 g/dL or Hb >= 12 g/dL in each group.

Weight Group	Hb < 12 g/dL		Hb >= 12 g/Dl	
	Frequency	Percent	Frequency	Percent
Under Weight (n=20)	9	45.0	11	55.0
Normal Weight (n=20)	6	30.0	14	70.0
Over Weight (n=20)	4	20.0	16	80.0
Total (n=60)	19	31.67	41	68.33
Pearson Chi-Square		2.927		
P-value		0.231		

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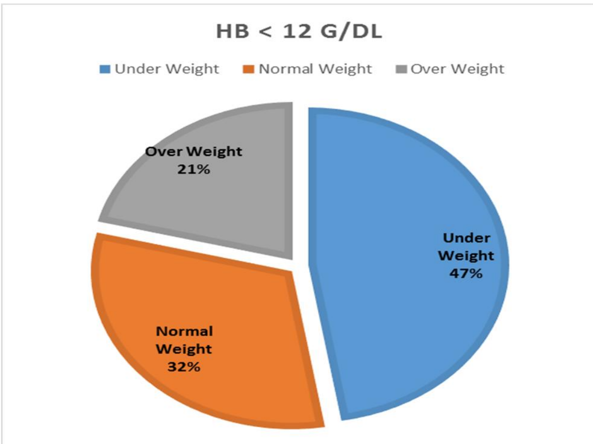

Fig. 1: Pie chart for percentage of subjects with Hb < 12 g/dL in each group.

Table 5: Descriptive and ANOVA test of Serum ferritin in ng/mL of the 3 groups.

Number of patients	Group (A) Under Weight	Group (B) Normal Weight	Group (C) Over Weight
Mean in years	21.665	22.850	61.885
± SD	11.3474	11.4614	31.5321
Minimum	4.2	5.9	18.1
Maximum	46.2	39.1	105.3
F-value		25.054	
P-value		0.0001	
Significance		Significante	

Table 6: Frequency and percentage of subjects with S ferritin < 12 ng/mL or S ferritin >=12 ng/mL in each group.

Weight Group	S ferritin < 12 ng/mL		S ferritin >= 12 ng/mL	
	Frequency	Percent	Frequency	Percent
Under Weight (n=20)	7	35.0	13	65.0
Normal Weight (n=20)	6	30.0	14	70.0
Over Weight (n=20)	0	0	20	100.0
Total (n=60)	13	21.67	47	78.33
Pearson Chi-Square	8.445			
P-value	0.015			

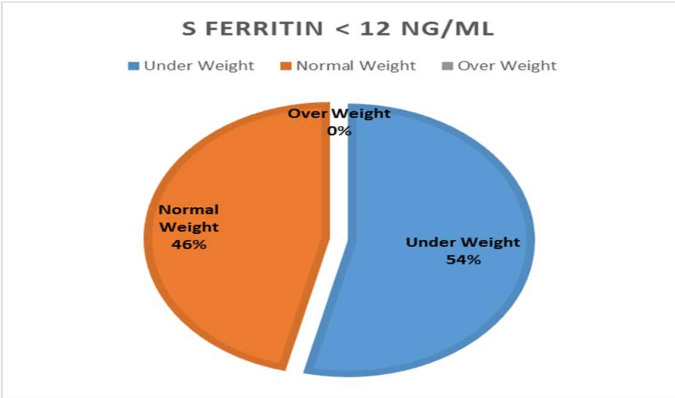

Fig. 2: Pie chart for percentage of subjects with S ferritin < 12 ng/mL in each **group.**

Table 7: Correlation between BMI and Hb and between BMI and S. ferritin

		Hb	S. ferritin
BMI	Correlation Coefficient	0.244	0.503**
	P-value	0.061	0.000
	N	60	60
	**. Correlation is significant at the 0.01 level (2-tailed).		

Discussion

Anemia is a global public health problem which is worse in developing countries mainly because of malnutrition, infectious disease and parasitic infections (Durrani, 2018). Iron deficiency is the most common and widespread nutritional disorder, recognized as a problem mainly in developing countries, it is also an enormous public health problem in the world (Urrechaga *et al.,* 2016). Poor quality of diet consumed during early childhood and early onset of menarche, can lead to depletion of iron stores (Shaka and Wondimagegne, 2018). IDA is a global health problem. Although it occurs at all age and involves both the sexes, adolescent girls are more prone to iron deficiency and anemia due to increased requirement of iron which in turn is caused by abrupt increase in lean body mass and total blood volume, and menstrual blood loss (Kumari *et al.,* 2017)

In the current study, the highest prevalence of anemia was found among the underweight group (45%) followed by normal weight group (30%) while the least percentage of anemic participants was in the overweight group (20%) which was statistically non-significant (p > 0.05). The prevalence of anemia with respect to the BMI in our study is compatible with multiple other studies which stated that the prevalence of anemia is lower in those with high BMI than normal weight while those with low BMI are more likely to be anemic than others, such as the study performed by (Gupta *et al.,* 2011) who stated that the prevalence of anemia was higher in females with low BMI (91%) , 83.6% in those with normal BMI and 73.7% in females with high BMI, also Pal et al., 2011 highlights the facts that the prevalence of anemia was high in individuals having low BMI as he stated that the prevalence of anemia was the lowest in the overweight females (25%) and higher prevalence was noted in normal groups (62%) and underweight group (80%). Also, these finding was in agreement with Qin *et al.,*

(2013) who observed that overweight Chinese women population were less likely to be anemic as compared to normal weight women.

Our study found that anemia is more prevalent among underweight females rather than among overweight and normal weight females, this in agreement with previous studies shown the association between the higher prevalence of anemia and a low BMI (Gupta *et al.,* 2011and Sumarmi *et al.,* 2016) (Ramachandra and Kasthuri, 2008 and Sunita and Kallur 2016) , The higher prevalence of anemia among underweight females in our study may be due to dietary deficiency and poor dietary patterns in adolescent females who depend on junk food away from home which high in energy, fat and sodium content and low in vitamins, calcium and iron content. (Sumarmi *et al.,* 2016) found that there was significant associations between energy intake level and iron depletion and the multiple logistic regression analysis of his study indicated that after adjustment for dietary intake (energy, total fat, folic acid, vitamin C, iron and zinc), underweight showed significant association with iron depletion.

On the other hand, (Ugwuja *et al.,* 2015) concluded that BMI was not correlated with HB concentration p=0.985.

In contrast to the positive correlation result obtained in our study between BMI and HB (r=244), Saxena *et al.* (2011) found that there was a negative association of BMI to HB level among overweight girls (r -0.59, p= 0.24). Also, there was a negative association among underweight girls and girls within normal BMI in the study done by Khakurel *et al.* (2017) who explained that it may be due to the decrease in levels of estrogen binding protein with increasing BMI. So the free estrogen rises which suppresses the process of erythropoiesis in females.

The overall prevalence of anemia in our study was found to be 31.67% which is not far from the estimated global prevalence of anemia in Egypt (35% for non-pregnant females) (World Health Organization, 2015) and it is relatively lower than that documented by Mousa *et a*l. (2016) who found that 39.9% of the Egyptian girls participated in her study were anemic. Our lower incidence of anemia could be related to the high educational level of university students in our study who are more aware about healthy dietary habits whereas participants in (Mousa *et al.,* 2016) were prepatory schools girls living in rural areas in upper Egypt in which low socioeconomics prevails and lower-income households could have limited access to iron-rich foods and are more prone to parasitic infection which increase likehood to develop IDA.

As regards ferritin level among participants in the current study, there was a statistically significant positive correlation with BMI (p<0.05 r=0.503). This is in line with multiple previous researches which documented a significant positive correlation between body mass index and ferritin level as (Jamali *et al.*, 2017, Huang et al., 2015 and Alam *et al.,* 2015).

Among many diagnostic tests for assessment of iron status in the body, serum ferritin measurement has been proposed as an accurate test because of its high sensitivity and specificity (Zaribaf *et al.,* 2014, Uen and Ling, 2005). The World Health Organization also clearly states that ferritin is positively correlated with body iron stores (World Health Organization, 2011). Some papers even indicate that serum ferritin was the best single indicator for assessing body iron store (Ren&Walczyk, 2014 , Patidar *et al.*, 2013). Thus, a low ferritin level reflects depleted iron stores. The highest ferritin level in the current study was found in the overweight group (mean 61.8) followed by normal weight group (mean=22.8) while those in underweight group had the lowest level of ferritin (mean+21.665).Elevated ferritin levels observed in the obese group along with a positive correlation with BMI is compatible with multiple other studies which revealed that obese females less likely to have low serum ferritin such as that performed by Alam *et al.,* (2015) who found the highest ferritin level was in the obese and overweight groups whereas it decreased in normal weight group. Also, Huang *et al.* (2015) stated that, the proportion of participants in adolescent females with low ferritin level decreased progressively from underweight to overweight and obese groups.

The elevated ferritin level associated with obesity may be due to the fact that the chronic inflammatory reaction caused by obesity is associated with increase in serum ferritin level being one of the acute phase reactants (Zafon *et al.,* 2010). Ferritin's role as an acute-phase protein. C-reactive protein (CRP) and α1-acid glycoprotein (AGP) are commonly used to measure the acute-phase response caused by inflammation. Both of these indicators have been positively associated with obesity and elevated serum ferritin. CRP has been frequently used to measure inflammation in overweight and obese populations (Wendt *et al.,* 2015). Also Jamieson *et al.* (2013) showed that higher long-chain polyunsaturated fatty acid status is associated with reduced risk of iron depletion.

On the other hand, the as-associated decreased ferritin level among underweight subjects, a possible explanation for this might be the important role of fat mass in the production of CRP (Alquaiz *et al.,* 2013).

This result was not in agreement with a study by Eftekhari *et al.,* (2009) which demonstrated serum ferritin levels to be decreased in obesity, they explained this by diverse hypotheses as urbanization that has taken place in recent decades has obliged children and adolescents to spend their free time on sedentary activities such as television watching, electronic games and computers together with the greater consumption of foods with high energy and low iron content to result in an epidemic increase in obesity and Fe deficiency in children and adolescents in addition to increased Fe requirements in obese adolescents because of their increased growth and body surface area.

Conclusion

The highest prevalence of anemia was found among the underweight group followed by normal weight group while the least percentage of anemic participants was in the overweight group with no significant difference between groups but there is a greater prevalence of iron deficiency among underweight adolescent females.

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