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Original article

The Impact of Obesity on the Reliability of Serum Ferritin in Evaluating Iron Stores among Young Women: A Cross-Sectional Study

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Abstract
Ferritin is considered the primary indicator for iron stores; in addition, ferritin is an acute-phase reactant upregulated by obesity-related persistent inflammation. Thus, high ferritin levels in individuals with higher Body Mass Index (BMI) could lead to an overestimation of iron status and delayed iron deficiency (ID) diagnosis. This study aimed to compare iron status markers across BMI categories in young females and to assess the impact of ferritin variation in the study subjects on the most common ID-related symptoms (fatigue and hair loss), as well as to investigate whether this variation was associated with the key determinants of ID in young females (menstruation and diet). This study was designed as a cross-sectional study utilizing data collected from 103 young, supplement-free female medical students (aged 18–27 years) in Misurata, Libya. Demographic data, dietary habits, and menstrual severity scores were collected via structured questionnaires. Fatigue was evaluated using the Fatigue Assessment Scale (FAS), and hair loss was assessed using a modified hair shedding visual scale. Serum ferritin, hemoglobin, and C-reactive protein (CRP) were assessed; individuals with elevated CRP were excluded. Nearly half of the study subjects (48%) were overweight or obese. Serum ferritin differed significantly across BMI groups ($p < 0.05$), with the obese group exhibiting the highest ferritin median (21.6 µg/L) compared to the underweight group (5 µg/L). Conversely, hemoglobin levels did not differ significantly between BMI groups ($p > 0.05$). Unexpectedly, when participants were stratified according to ferritin status, no statistically significant differences were observed in fatigue scores, hair loss, menstrual bleeding severity, or dietary iron scores (all $p > 0.05$). Fluctuations in ferritin concentrations in this cohort are likely driven by adiposity-related inflammation rather than true iron sufficiency, as evidenced by the absence of corresponding increases in hemoglobin, ID-related symptoms, or established risk factors for iron depletion. Accordingly, reliance on ferritin alone for iron status assessment in patients with elevated BMI should be avoided, as this may lead to missed diagnoses of ID.
Keywords. Obesity, Serum Ferritin, Reliability, Iron Stores, Women.

Introduction

Iron deficiency (ID), indicated by low ferritin, is prevalent among young females, even among those without anemia [1,2]. Ferritin is the primary iron storage protein, and its serum level is the most reliable marker of body iron stores [3,4]. Although ferritin is highly specific at low levels for ID, elevated levels lack specificity because of its nature as a positive acute-phase protein [5]. Its production is upregulated by inflammatory cytokines (IL-6, TNF-α) and oxidative stress [6]. Consequently, ferritin rises during chronic inflammatory states such as obesity, in a manner that is independent of true iron stores [6,7].

Even in the absence of anemia, ID is commonly associated with a range of non-hematologic symptoms, including fatigue and hair loss. Regarding fatigue, studies have demonstrated a significant relationship between low ferritin levels and perceived weakness, with fatigue reported in 80% of patients with ID [8] and 83.33% of non-anemic iron-deficient individuals [9]. This association is explained by the essential role of iron in oxygen transport and the electron transport chain, where reduced ferritin leads to suboptimal energy production and tissue oxygenation [10]. In the same regard, Saputra et al demonstrated that iron supplementation has been shown to reduce work fatigue and improve reaction speed [11]. Similarly, hair loss has been frequently linked to low iron stores. One study reported that 86% of affected patients had ferritin levels ≤40 µg/L [12]. Additionally, Raichur et al. have examined 40 women aged 15 to 54 with chronic diffuse hair loss and found that 57.5% had serum ferritin levels below 12 µg/L, while 15% had levels between 13 and 20 µg/L. These findings further support the likelihood of a link between hair loss and iron deficiency [13].

In women of reproductive age, menstruation and poor dietary habits are identified by many studies as the major contributing factors to iron depletion presented by low ferritin [14-16]. These findings align with reports on young women in Misurata, where ID (ferritin < 15 µg/L) is highly prevalent (52.4%) [17]. Notably, on the other hand, the link between obesity, as a persistent inflammation state, and compromised iron homeostasis is well-established by numerous studies [18, 19]. It was explained by increased ferritin and stimulated hepcidin action, thus reducing iron absorption and iron availability [18,20]. Several studies have shown that individuals with higher BMI have higher serum ferritin levels, but such levels are not necessarily indicative of good iron status [20,21]. This can lead to overestimation of iron stores and delayed diagnosis of ID. However, the interaction between BMI, ferritin, and iron-related symptoms has not been examined.

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This study therefore, aimed to: compare iron status markers across BMI categories in young females and assess the impact of ferritin variation in the study subjects on fatigue and hair loss, the most common ID-related symptoms, and to investigate whether this variation was associated with the key determinants of ID in young females, such as menstruation and diet.

Methods

Study design and participants

This study was designed as a cross-sectional study utilizing data collected from 103 young women aged 18–27 years. Data were collected through two approaches: laboratory investigations and a self-reported questionnaire. The questionnaire aimed to assess factors associated with low ferritin and ID-related complications.

Questionnaire Design and Scoring

Participants completed structured questionnaires assessing dietary habits, menstrual characteristics and severity, and common manifestations of ID, including fatigue, cognitive impairment, and hair loss. To ensure accurate questionnaire responses, all participants were medical students; their heightened awareness of iron importance was neutralized by excluding supplement users.

The dietary assessment questionnaire was designed based on the type of dietary iron (heme/non-heme intake). It comprised seven items covering iron sources, meal frequency, and inhibitors of iron absorption. Heme iron intake was evaluated, scoring red meat consumption as 3 points and white meat as 2 points toward the total score for heme iron.

Menstrual bleeding was evaluated using a modified version of the Aberdeen Menorrhagia Severity Scale, selecting the five most relevant questions affecting ferritin levels [22]. Each answer was scored on an ordinal scale, and total scores were converted into a percentage to create a “menorrhagia severity score” ranging from 0 to 100. According to the Aberdeen system, scores from 0–33% indicate mild menorrhagia, 34–66% moderate, and 67–100% reflect severe cases.

Furthermore, complications of low ferritin, including fatigue and cognitive impairment, were assessed using selected items from the Fatigue Assessment Scale (FAS) developed by NovoPsych. Scores less than 22 indicate 'normal', between 22 and 34 indicate mild to moderate fatigue, and 35 or more indicate severe fatigue. The total score ranges from 10 to 50, with higher scores indicating more severe fatigue [23].

Hair loss was assessed using a modified visual scale adapted from the study “The Hair Shedding Visual Scale: A Quick Tool to Assess Hair Loss in Women”. (77) Hair shedding was categorized into normal, moderate, and severe groups based on information provided by a study conducted by Springer et al., with some modification [24].

Anthropometric and Laboratory Measurements

For each participant, demographic information such as age and sex, in addition to height and weight, was recorded at the time of sampling, and then BMI was calculated. The assessed serum parameters included serum ferritin, CRP, and hemoglobin. Data and samples were collected over a relatively short time period-three weeks (July 2025)- and processed uniformly at Ibn Sena Laboratory to minimize the analytical variation that might result from different operators and reagents. Exclusion criteria included pregnancy, lactation, recent iron deficiency diagnosis, iron supplementation, and hormonal therapy. As ferritin is regarded as a positive acute-phase protein, participants with elevated CRP were also excluded.

Ethical considerations

The study protocol emphasized informed consent; questionnaires were distributed in advance, and participants were invited to visit the IBN SENA Lab to provide a blood sample if they agreed to participate in the study. Blood samples were linked only to anonymized codes, ensuring participant confidentiality.

Statistical analysis

Questionnaires were designed to be converted into numerical scores using the Likert method. Data were organized in Excel and analyzed using GraphPad Prism 8.0.2 employing appropriate statistics based on distribution. Normality was evaluated using both the Shapiro-Wilk and the Kolmogorov-Smirnov tests.

Results

Female participants were classified into four BMI categories according to the World Health Organization criteria: underweight (<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) [25]. As illustrated in (Figure 1), the largest proportion of participants had normal weight (45%), followed by those who were overweight (25%) and obese individuals (23%), while only 7% were classified as underweight. Overall, 48% of the study population had a BMI ≥25 kg/m², indicating that nearly half of the participants were either overweight or obese.

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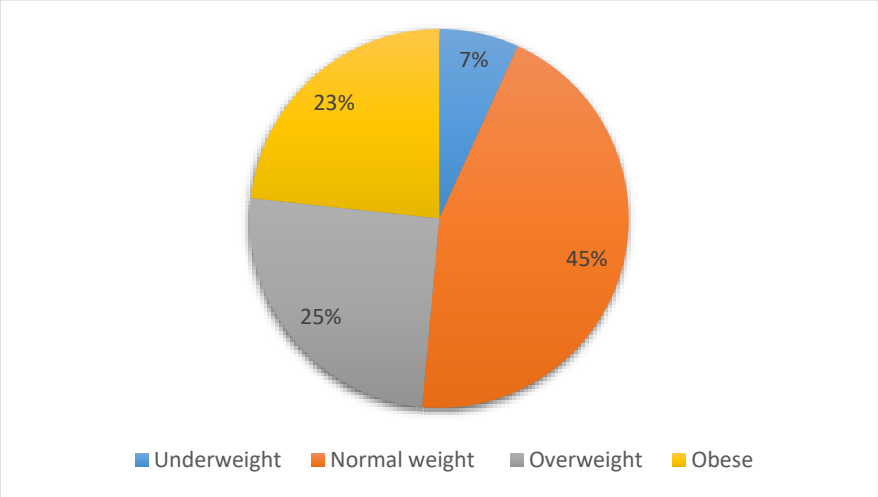

Figure1. Distribution of female participants across BMI categories

(Table 1) presents the distribution of study participants according to BMI categories and compares serum ferritin and hemoglobin levels across these groups. Based on the Kruskal-Wallis test result, a statistically significant difference was observed in serum ferritin levels across BMI groups, indicating that BMI is associated with variation in ferritin levels among the participants. In contrast, hemoglobin levels did not differ significantly between BMI groups ($p > 0.05$), despite some variation in median values and interquartile ranges.

Table 1. Differences in iron biomarkers across BMI categories

Statistic	Underweight (n=7)	Normal weight (n=46)	Overweight (n=26)	Obese (n=24)	p-value
Ferritin (µg/L) Median (Q1-Q3)	5 (2.8-10.0)	14.7 (4.9- 21.9)	10.5 (6.5-23.3)	21.6 (10.6-32.8)	<0.05
Hemoglobin (g/dl) Median (Q1- Q3)	10.7 (10.4-12.9)	12.7 (12.2- 13.5)	13.3 (12.1-13.5)	13.1 (12.3-14)	>0.05

To examine the association between ferritin level and the expected major contributors of ID (Table 2) and the most common ID-related symptoms (Table 3), participants were categorized into four groups based on their ferritin level: below15µg/L, 15-30 µg/L, 30-50 µg/L, and above50 µg/L.

Table 2. Assessment of known contributors to iron status across ferritin categories

Statistic	Below15µg/L (n=54)	15-30 µg/L (n=31)	30-50 µg/L (n=12)	Above50 µg/L (n=6)
Menstruation score % Median, $\bar{X}$ (Q1- Q3)	55.6, 57.5 (50- 66.7)	55.6, 57.5 (50- 61.1)	52.8, 55.1 (45.8-59.7)	58.3, 55.6 (48.6-63.9)
Dietary score Median, $\bar{X}$ (Q1- Q3)	8.5, 8.7 (6- 12)	8, 8.1 (6-10)	9, 8.9 (6.3- 10.8)	9.5, 9.5 (7.5-11.5)

Table 3. Assessment of common health complications associated with low ferritin across ferritin categories

Statistic	Below15µg/L (n=54)	15-30 µg/L (n=31)	30-50 µg/L (n=12)	Above50 µg/L (n=6)
Fatigue score Median, $\bar{X}$ (Q1- Q3)	31.6, 33.2 (27.3- 39.0)	37.3, 35.0 (27.8- 43.3)	31.6, 32.5 (26.4- 41.0)	31.3, 30.5 (23.4- 36.8)
Hair loss score Median, $\bar{X}$ (Q1-Q3)	7, 6.5 (5-8)	7, 6.5 (4-8)	8, 6.9 (4.25-9)	5, 5.7 (5-6.5)

Differences among groups presented in (Tables 2 and 3) were assessed using ANOVA or the Kruskal–Wallis test, as appropriate. No statistically significant differences were observed between groups (all $p > 0.05$).

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Discussion

In general, participants in the higher BMI groups tended to exhibit altered ferritin concentrations compared with those with lower BMI. These findings align with previous studies showing that ferritin levels are influenced not only by iron status but also by adiposity-related inflammation, as ferritin functions as an acute-phase reactant [18-21]. This notion is further supported by the absence of a statistically significant difference in hemoglobin because ferritin and hemoglobin are physiologically linked, as under conditions of true iron sufficiency, increases in iron stores reflected by ferritin would typically be associated with maintenance or improvement of hemoglobin levels. Consequently, elevated ferritin concentrations in individuals with higher BMI may reflect inflammation-related upregulation rather than improved iron status. Therefore, ferritin concentrations should be interpreted with caution in individuals with BMI > 25 kg/m², as elevated levels may overestimate iron stores and conceal underlying iron deficiency.

Unexpectedly, when participants were stratified according to ferritin status, no significant differences were observed in clinical manifestations commonly associated with ID, including hair loss scores and total fatigue scores. This finding provides further support for the interpretation that ferritin concentration may reflect the underlying inflammatory state rather than true iron stores. If variations in ferritin level reflected true differences in iron status, participants with lower ferritin levels would be expected to exhibit a greater prevalence of ID-related symptoms. The lack of corresponding differences suggests that the observed variation in ferritin may not be indicative of clinically significant alterations in iron status.

A similar pattern was observed when established determinants of low ferritin were examined. Menstrual blood loss and poor dietary habits, both well-recognized contributors to iron depletion, did not differ significantly across ferritin-defined groups. In contrast to prior studies, where these factors were strongly linked to reduced iron stores, this further suggests that the variation in ferritin concentrations observed in this cohort may not be primarily driven by differences in iron loss or intake.

Taken together, these findings support the interpretation that ferritin concentrations in this study may have been influenced by factors other than iron status, particularly BMI.

Conclusion

This study highlights that elevated ferritin concentrations observed in individuals with higher body mass index (BMI) are largely attributable to obesity-related inflammation rather than genuine iron sufficiency. The lack of parallel increases in hemoglobin, iron-deficiency symptoms, or established risk factors for iron depletion underscores the risk of misclassification when ferritin alone is used to assess iron status in overweight or obese patients. Accordingly, clinicians should avoid reliance on ferritin as a sole diagnostic marker in this population. For individuals with BMI >25 kg/m², iron status evaluation should incorporate markers less influenced by inflammation, such as transferrin saturation and soluble transferrin receptor, alongside ferritin. Adjustment of ferritin values using inflammatory markers (e.g., C-reactive protein) may further improve diagnostic accuracy. Importantly, BMI category should be considered when interpreting ferritin thresholds to ensure timely and accurate identification of iron deficiency or insufficiency.

Conflict of interest. Nil

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