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ORIGINAL PAPER

Assessing the impact of sleeve gastrectomy on micronutrient levels and inflammatory markers – a case-control study

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ABSTRACT

Introduction and aim. Sleeve gastrectomy has become one of the most common surgical procedures in the world recently, due to its role in promoting weight loss and reducing the risk of obesity-related diseases. This study aims to determine the levels of inflammatory and nutritional factors in patients undergoing gastric sleeve surgery.

Material and methods. A case-control study was conducted including 150 patients who underwent gastric sleeve surgery and 50 healthy participants as a control group. Inclusion criteria included patients aged 45–65 years with a BMI ≥35 kg/m^2. Levels of interleukin (IL)-6, tumor necrosis factor-alpha (TNF-α), adiponectin, interferon-gamma, IL-10, IL-1β, monocyte chemoattractant protein-1, fasting blood glucose (FBG), serum amyloid A, iron, ferritin, calcium, and vitamin D3 were measured using enzyme-linked immunosorbent assay.

Results. The study revealed that the control group (22.8±3.6 kg/m^2) had a significantly reduced BMI compared to the patients who underwent sleeve gastrectomy (35.5±7.1 kg/m^2, ($p<0.001$). Elevated levels of C-reactive protein, IL-6, TNF-α, and FBG were seen in the postoperative group, although adiponectin levels were dramatically reduced ($p<0.001$). Furthermore, the postoperative patients manifested significantly reduced levels of iron, calcium, and vitamin D3, suggesting a profound insufficiency in these vital nutrients and their possible consequences on their long-term well-being.

Conclusion. The study results indicate that patients who underwent gastric sleeve surgery had significantly lower levels of iron, ferritin, calcium, and vitamin D3, compared to the control group. This is due to the effect of surgery on the absorption of nutrients, which causes a deficiency in vitamins and minerals necessary for bone and body health.

Keywords. nutrient absorption, sleeve gastrectomy, vitamin D3 deficiency

Introduction

The condition of obesity is defined by an abnormal build-up of adipose tissue. The major constituents of many disorders linked to obesity are metabolic abnormalities and chronic inflammation caused by the buildup of surplus fat.[1] Obesity has reached epidemic proportions worldwide, accounting for more than 1.9 billion overweight and approximately 650 million obese adults. There is greater morbidity and mortality in patients with severe obesity, especially classes II body mass index (BMI) 35 to 39.9

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kg/m²) and III (BMI greater than 40 kg/m²). In addition, obesity is a recognized risk factor for the development of comorbid conditions such as cardiovascular disease, type 2 diabetes mellitus (T2DM), malignancy, asthma, osteoarthritis, chronic back pain, obstructive sleep apnea, non-alcoholic fatty liver disease, and gallbladder diseases.[2] Bariatric surgery (BS), sometimes referred to as metabolic surgery, is advised for the treatment of obesity in persons who meet the specified criteria: individuals diagnosed with T2DM and having a BMI equal to or above 30 kg/m^2; those with a BMI ranging from 30 to 34.9 kg/m^2 who have not seen substantial weight loss or improvements in other health conditions after thoroughly exploring all non-surgical alternatives; and individuals with a BMI above 35 kg/m^2, irrespective of the severity of their other health conditions. Through the adoption of a basic dietary strategy (BS), overweight or obese persons can reduce the negative consequences of T2DM, high blood pressure, dyslipidemia, and non-alcoholic fatty liver disease. Indeed, there are benefits to BS that extend beyond mere reduction of body weight.[3,4] Bariatric surgery has been associated with a temporary increase in inflammatory markers as part of the immune system's response to weight loss and tissue remodeling. Empirical evidence highlights this phenomenon, with elevations observed in matrix metallopeptidase-9 (MMP-9), C-reactive protein (CRP), and proteins associated with monocyte activation. Additionally, the expression of Toll-like receptors TLR-2 and TLR-4, which recognize Gram-positive bacterial residues and endotoxins, is also affected. Nuclear factor kappa-β (NF-κB) activation is stimulated, leading to its translocation to the nucleus. Notably, cluster of differentiation (CD14) expression shows an increase following bariatric surgery, reflecting the body's adaptive inflammatory response during the post-surgical phase.[5,6] Prior studies have demonstrated that the effects of BS often lead to significant improvements within the first year, particularly in enhancing insulin sensitivity. However, inflammatory markers may initially increase following surgery due to the body's immune response to tissue injury and the metabolic stress associated with rapid weight loss. This transient rise reflects the activation of pathways involved in wound healing and tissue remodeling. In individuals with T2DM, a notable decrease in inflammatory markers and an increase in insulin sensitivity are observed over time after sleeve gastrectomy, as the inflammatory response stabilizes and metabolic improvements take effect.[7,8] Furthermore, individuals may experience a reduction in their food intake following surgery due to the following factors. The pre-meal cognitive and sensory signals that induce hunger, weight gain concerns, abdominal pain, nausea, vomiting, difficulty swallowing due to texture, and satiety have all been associated with reduced eating in individuals with Binge Eating Syndrome. Flavor exerts a direct influence on dietary patterns by altering individuals' food preferences and portion sizes. Modifications in dietary patterns following surgery might be attributed to alterations in gut-derived compounds such as hormones, nutrients, bile acids, bacteria, and neuronal signals that affect the brain's balance and pleasure-related regions.[9,10] Alterations in hormones can also influence individuals' dietary choices. This may result in feelings of anxiousness and fluctuations in mood. There exists a correlation between anxiety and excessive indulgence due to insufficient self-restraint levels. The examination of the Dutch Eating Behavior Questionnaire (DEBQ) reveals that individuals who engage in more uncontrolled or emotional eating experience greater difficulty in achieving weight loss following surgery. To the best of our understanding, no research has examined the impact of BS on individuals' moods and dietary patterns in Saudi Arabia.[11,12] prior research has demonstrated that laparoscopic sleeve gastrectomy (LSG) is a highly efficacious approach for managing morbid obesity. Although it is crucial to achieve weight loss and reduce the number of illnesses simultaneously after BS, these therapies also include difficulties and nutritional hazards. Both Roux-en-Y gastric bypass and LSG models have a restricted and inefficient capacity to absorb nutrients, potentially resulting in famine.[13,14]

Aim

The study aims to determine the levels of inflammatory and nutritional factors in patients undergoing gastric sleeve surgery.

Material and methods

Study design and setting

Case-control study conducted at Nasiriyah General Hospital and Al-Habbobi Teaching Hospital during the period from 1/1/2023 to 1/8/2024.

Participants

Between 2023 and 2024, 150 patients had Sleeve Gastrectomy procedures. The control group comprised 50 healthy individuals with a normal BMI of 18.5 to 24.9 kg/m^2. The inclusion criteria were male and female patients aged 45 to 65 years with a BMI of 35 kg/m^2 or more who had a sleeve gastrectomy procedure between 2023 and 2024 and were monitored for one year. Excluded from consideration were pregnant women, patients who had already undergone bowel surgery, and those who had received a diagnosis of psychological illnesses. An 80% response rate was achieved in the trial. Within the original sample of 300 patients who had sleeve gastrectomy between 2023 and 2024, 50 records were removed because of duplications, while an additional 50 patients were excluded because of insufficient data or complications necessitating surgical intervention.

Blood sampling and measurement

10 mL of blood was drawn from each participant and placed in a gel tube and left at room temperature for 15 minutes until clotting. Serum was separated using a centrifuge at 3500 rpm for 15 minutes and the serum was isolated under sterile conditions and stored at -20°C until use. Levels of interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), adiponectin (Adp), interferon-gamma (IFN-γ), IL-10, IL-1β and monocyte chemoattractant protein-1 (MCP-1) were measured using enzyme-linked immunosorbent assay (ELISA) according to the manufacturer's recommendations (Bio-Techne, USA, catalog numbers: D6050, DTA00C, DY1065, DIF50, D1000B, DY201, and DCP00 respectively. Levels of fasting blood glucose (FBG), serum amyloid A (SAA), iron, ferritin, calcium and vitamin D3 were measured using a Cobas E4 11 device according to the manufacturer's recommendations (Roche, German).

Statistical analysis

Statistical analysis is often used to analyze quantitative data and provides methods for data description and simple inference for continuous and categorical data. The technique involves collecting information to assess the link between two statistical data sets. This study gives all data as the mean accompanied with standard deviation. Statistical analyses for variables with a normal distribution were performed using SPSS (version 26, IBM, Armonk, NY, USA), employing both the dependent t-test (two-tailed) and the independent t-test (two-tailed). The Mann-Whitney U test and the Wilcoxon test are utilized for variables exhibiting non-normal distribution. Statistical significance was defined as p<0.05.

Ethical approval

All patients participating in this study were fully informed about its purpose and procedures, and their verbal consent was obtained prior to sample collection. The study was conducted in accordance with ethical guidelines and was approved by the Committee on Publication Ethics at the Thi-Qar Health Directorate, Al-Habboubi Teaching Hospital, No 3324 in January 1, 2023.. However, we acknowledge the potential limitations of relying solely on verbal consent and recognize the importance of ensuring comprehensive ethical compliance in future studies.

Results

Comparison of sociodemographic characteristics between gastric sleeve patients and healthy controls

The study results showed that the mean age among gastric bypass patients was 45.2±10.4 years, compared to 44.6±9.8 years in the control group, and there was no statistically significant difference between the two groups (p=0.75). The gender distribution was equal between males and females in both the patient group and the control group (p>0.999). However, the BMI was significantly higher in gastric bypass patients (35.5±7.1) compared to the control group (22.8±3.6) (p<0.001). The percentage of smokers among gastric bypass patients was 40% compared to 30% in the control group, but this difference was not statistically significant (p=0.15). In addition, the prevalence of diabetes was significantly higher among gastric bypass patients (60%) compared to 10% in the control group, with a statistically significant difference (p<0.001) as shown in Table 1.

Table 1. Sociodemographic characteristics of study participants

Variable	Patients (n=150)	Controls (n=50)	p
Age, years (mean±SD)	45.2±10.4	44.6±9.8	0.75
Gender (male/female)	75/75	25/25	>0.999
BMI, kg/m^2 (mean±SD)	35.5±7.1	22.8±3.6	<0.001
Smoking (%)	40%	30%	0.15
Diabetes mellitus (%)	60%	10%	<0.001

Inflammatory biomarker levels in gastric sleeve patients compared to healthy controls

The results of the study showed that CRP levels were significantly higher in gastric bypass patients after surgery (8.5±2.4 mg/L) compared to the control group (2.1±1.2 mg/L), with a statistically significant difference (p<0.001). IL-6 levels were significantly higher in gastric bypass patients (15.3±5.8 pg/mL) compared to the control group (5.2±2.0 pg/mL) with a statistically significant difference (p<0.001). In addition, TNF-α levels were significantly higher in gastric bypass patients (18.7±6.1 pg/mL) compared to the control group (7.3±3.4 pg/mL) with a statistically significant difference (p<0.001) as shown in Table 2.

Table 2. Analysis of CRP, IL-6, and TNF-α levels post-surgery

Group	CRP, mg/L (mean±SD)	p
Post-surgery patients	8.5±2.4	<0.001
Controls	2.1±1.2	
Group	**IL-6, pg/mL (mean±SD)**	**p**
Post-surgery patients	15.3±5.8	<0.001
Controls	5.2±2.0	
Group	**TNF-α, pg/mL (mean±SD)**	**p**
Post-surgery patients	18.7±6.1	<0.001
Controls	7.3±3.4	

Metabolic and inflammatory marker analysis in gastric sleeve patients versus healthy controls

Following surgery, individuals who underwent a gastric bypass presented with markedly elevated FBG levels (112.5±28.3 mg/dL) compared to those in the control group (89.4±14.6 mg/dL). The observed disparity was statistically significant (p<0.001). A substantial statistical difference (p<0.001) was seen in the levels of adiponectin between gastric bypass patients (5.9±2.7 μg/mL) and the control group (12.3±4.1 μg/mL). Furthermore, those who underwent gastric bypass surgery had notably elevated SAA levels (36.7±12.1 mg/L) in comparison to the control group (18.2±7.9 mg/L), and this difference was statistically significant (p<0.001) as shown in Table 3.

Table 3. Evaluation of fasting blood glucose, adiponectin, and serum amyloid A levels gastric sleeve patients versus healthy controls

Group	FBG, mg/dL (mean±SD)	p
Post-surgery patients	112.5±28.3	<0.001
Controls	89.4±14.6	
Group	**Adiponectin, μg/mL (mean±SD)**	**p**
Post-surgery patients	5.9±2.7	<0.001
Controls	12.3±4.1	
Group	**SAA, mg/L (mean±SD)**	**p**
Post-surgery patients	36.7±12.1	<0.001
Controls	18.2±7.9	

Cytokine and chemokine profiles in gastric sleeve patients compared to healthy controls

A statistically significant difference was seen in IFN-γ levels between gastric bypass patients after surgery (22.5±8.9 pg/mL) and the control group (10.8±4.3 pg/mL) with a significance level of p<0.001. A statistically significant difference (p<0.001) was seen in the levels of IL-10 between the gastric bypass patients (7.2±2.9 pg/mL) and the control group (3.5±1.8 pg/mL). Significantly higher IL-1β levels were seen in gastric bypass patients (14.9±5.7 pg/mL) compared to the control group (6.4±3.1 pg/mL), with a statistically significant difference (p<0.001). The levels of MCP-1 were markedly elevated in patients who underwent gastric bypass (265.4±92.6 pg/mL) compared to the control group (145.3±58.2 pg/mL), creating a statistically significant disparity (p<0.001) as shown in Table 4.

Table 4. Assessment of IFN-γ, IL-10, IL-1β, and MCP-1 levels profiles in gastric sleeve patients compared to healthy controls

Group	IFN-γ, pg/mL (mean±SD)	p
Post-surgery patients	22.5±8.9	<0.001
Controls	10.8±4.3	
Group	**IL-10, pg/mL (mean±SD)**	**p**
Post-surgery patients	7.2±2.9	<0.001
Controls	3.5±1.8	
Group	**IL-1β, pg/mL (mean±SD)**	**p**
Post-surgery patients	14.9±5.7	<0.001
Controls	6.4±3.1	
Group	**MCP-1, pg/mL (mean±SD)**	**p**
Post-surgery patients	265.4±92.6	<0.001
Controls	145.3±58.2	

Iron and ferritin levels in gastric sleeve patients versus healthy controls

The study showed a significant decrease in iron levels in gastric bypass patients after surgery (55.2±15.3 μg/dL) compared to the control group (85.7±20.4 μg/dL), with a statistically significant difference (p<0.001). Ferritin levels, an indicator of body iron stores, were also significantly lower in gastric bypass patients (22.5±8.6 ng/mL) compared to the control group (55.3±12.7 ng/mL) with a significant difference (p<0.001). These results indicate a significant decrease in iron stores in patients after gastric bypass surgery as shown in Table 5.

Table 5. Serum iron and serum ferritin levels in gastric sleeve patients versus healthy controls

Group	Iron, μg/dL (mean±SD)	p
Post-surgery patients	55.2±15.3	<0.001
Controls	85.7±20.4	
Group	**Ferritin, ng/mL (mean±SD)**	**p**
Post-surgery patients	22.5±8.6	<0.001
Controls	55.3±12.7	

Calcium and vitamin D3 levels in gastric sleeve patients compared to healthy controls

The study results showed a significant decrease in calcium levels in gastric bypass patients after surgery (8.4±0.9 mg/dL) compared to the control group (9.5±0.7 mg/dL), with a statistically significant difference (p<0.001). Vitamin D3 levels were also significantly lower in patients after surgery (18.6±7.3 ng/mL) compared to the control group (30.2±10.5 ng/mL), with a significant difference (p<0.001). These results indicate a significant deficiency in both calcium and vitamin D3 in patients after gastric bypass surgery, which may affect their bone and psychological health in the long term as shown in Table 6.

Table 6. Post-surgery nutritional deficiencies in calcium and vitamin D3

Group	Calcium, mg/dL (Mean±SD)	p
Post-surgery patients	8.4±0.9	<0.001
Controls	9.5±0.7	
Group	**Vitamin D3, ng/mL (Mean±SD)**	**p**
Post-surgery patients	18.6±7.3	<0.001
Controls	30.2±10.5	

Discussion

BS is widely considered the most efficacious method for weight loss. The weight loss during BS can be ascribed to several variables, including as hormonal fluctuations, reduced food intake, reduced absorptive capacity and gastrointestinal secretions, and adverse effects associated with operations, including food aversion and frequent vomiting. The above provided data demonstrates a significant disparity in BMI, smoking habits, and diabetes mellitus between patients with gastric sleeve and healthy individuals. These findings align with other studies.[15-17] In order to achieve their long-term weight and health objectives, individuals undergoing gastrectomy must meticulously adhere to their dietary and lifestyle recommendations. Varying degrees of compliance with the dietary recommendations provided by the nutritionists to the participants of the study were observed. Furthermore, the participants shown a strong will to avoid calorie-dense items by strictly adhering to the instructions. Adopting such practice will significantly impact their overall health and body weight.[18] An underlying factor contributing to the unexpectedly high degree of treatment adherence is the relatively brief duration following the surgery, which lasted only 12 months. Given the current knowledge, patients are highly inclined to adhere to the guidelines about their diet and lifestyle both prior to and immediately following surgery. Nevertheless, the level of devotion diminishes with time.[19] Furthermore, studies have demonstrated that about one to two years following surgery, individuals typically exhibit reduced eating habits, lower hunger levels, and reduced mental health issues. Additionally, adherence to a diet, use of supplements, and overall improvement in overall well-being tend to improve.[20] The data presented in Table 2 highlights a significant elevation in CRP levels among post-surgery patients (8.5±2.4 mg/L) compared to the control group (2.1±1.2 mg/L), with a $p<0.001$, indicating statistical significance. These findings align with studies documenting an initial surge in inflammatory markers following bariatric surgery. For example, Radi S et al. A similar pattern was observed by Hentilä et al. who attributed the increased CRP levels to an acute-phase inflammatory response of the body as a consequence of transition to tissue injury and metabolic stress in the postoperative recovery phase. In contrast, long-term studies, exemplified by the work of Randell et al., noted a progressive decline in CRP levels at six months to one year after surgery, which was associated with reduced adiposity and systemic inflammation. This seems to indicate that though there is an acute inflammatory response from bariatric surgery, the long-term weight loss and metabolic benefits outweigh any adverse effects. Other researchers noted that the difference in short- and long-term studies is possibly due to the timing in tissue repair and the effect of other external factors like diet and stress. For the impact of inflammatory markers after bariatric surgery, this highlights the need to examine both short and longer-term outcomes.[21,22] The analysis shows significantly higher IL-6 levels in post-surgery patients (15.3±5.8 pg/mL) compared to controls (5.2±2.0 pg/mL, $p<0.001$), consistent with studies like Smidowicz et al., that attribute this rise to the acute-phase response and tissue repair following surgery. However, long-term studies, such as Ko et al., report decreased IL-6 levels six to twelve months post-surgery, correlating with reduced visceral fat and systemic inflammation. This suggests that while IL-6 elevation is a natural post-operative response, it is transient and decreases as metabolic health improves over time.[23,24] Alterations in diet can also modify the composition of gut microbiota and the equilibrium between pro-inflammatory and anti-inflammatory gut microbiota groups, therefore exacerbating inflammation. The potential impact of BS on the gastrointestinal axis may result in reduced consumption of fruits and vegetables among our participants, therefore influencing their overall nutritional intake.[25,26] Patients who underwent gastrointestinal surgery exhibited elevated levels of TNF-α and SAA, as well as increased levels of IFN-γ, IL-10, IL-1, and MCP-1, in comparison to healthy controls.[27] Post-surgery patients had significant nutritional deficiencies of calcium and vitamin D3 levels ($p<0.05$) comparing to controls, as demonstrated in Table 6. Calcium levels post-surgery were significantly lower than in controls (8.4±0.9 mg/dL vs. 9.5±0.7 mg/dL, $p<0.001$). Likewise, vitamin D3 status was markedly poorer in patients post-surgery (18.6±7.3 ng/mL) than in controls (30.2±10.5 ng/mL, $p<0.001$). This is in accordance with studies like Steenackers et al. which stated that bariatric surgery may result in malabsorption or altered nutrient metabolism due to decreased intestinal surface area and dietary restrictions. Prolonged deficiency in these areas can lead to effects on the bones as well as immune function, making it very important to evaluate and assess with regularity whether supplementation and/or post-surgical nutrition is appropriate.[28] That study also noted a marked increase in calcium at the 1- and 12-month follow-ups for the LSG group, which mirrors the findings of our study. The effect may be due to the activation of bone remodeling during BS, which may alter calcium homeostasis. The increase in participants can be attributed to the fact most people now adhere upper to guideline vitamin and mineral supplementation, along with supplementation with daily 600 mg calcium carbonate tablets.[29] Moreover, our results provided evidence that the concentration of plasma levels of vitamin D were significantly higher, in comparison to pre-operative levels, at the 3- and 12-months postoperative time-points. Preoperative vitamin D deficit and insufficiency were highly prevalent during the trials with levels from 33.1 (23.9) nmol/L at recruitment to 57.1 (23.1) nmol/L 12 months after the operation when they were regularly supplemented. It is advised to take a daily supplement of vitamin D3 to prevent vitamin D deficiency post- SG, which can be around 2000 to 4000 IU. During a period of just eight weeks, every single one of the patients in our investigation with either a deficiency or insufficiency of vitamin D was given 50,000 IU of vitamin D3 dietary supplements.[30,31] Data indicates dramatic drops in iron and ferritin levels for patients after surgery, relative to controls. Iron levels were significantly decreased after surgery (55.2±15.3 μg/dL) compared to controls (85.7±20.4 μg/dL, p<0.001). Ferritin levels were also found to be significantly lower in post-surgery patients (22.5±8.6 ng/mL) when compared to controls (55.3±12.7 ng/mL, p<0.001). Similar studies including Ahmed et al. and Gudzune et al., who linked impaired iron absorption after bariatric surgery to low gastric acid production and altered gastrointestinal anatomy. This suggests that post-surgery patients need to receive complementary nutritional assessment and supplementation on a regular basis to prevent anemia, and its related health problems.[32,33] Visceral fat presents a susceptibility to insulin resistance, and gastric bypass results in early and also significant decrease in body weight. In addition, it shrinks this tissue. The short-term increase in serum adiponectin levels can be attributed to the reduction in visceral fat mass occurring post-surgery, an organ that produces low levels of adiponectin. But then, as the loss of weight progresses and the body adjusts to the fresh state of affairs, blood adiponectin levels may start to diminish smoothly as part of a new homeostasis of fat metabolism. This reduction could also be attributed to variations in insulin sensitivity and the improved inflammatory status of the organism in the post-surgery period.[34] The data show major changes in adiponectin and serum amyloid A (SAA) levels after surgery as compared to controls. Post-surgery patients had significantly decreased adiponectin levels (5.9±2.7 μg/mL) compared to controls (12.3±4.1 μg/mL, p<0.001), whilst SAA levels were significantly higher in post-surgery patients (36.7±12.1 mg/L) compared to controls (18.2±7.9 mg/L, p<0.001). These results align with studies like Barron et al. and Stoica et al. to indicate that the decrease of adiponectin can be explained by the acute metabolic alterations and transient inflammation that occur after surgery. In contrast, higher levels of SAA demonstrate an inflammatory acute-phase response, found most frequently in post-surgical settings. This reflects the complex relationship between inflammation and metabolic adaptations that occurs in the post-operative recovery phase.[34,35] After gastric surgery, the vitamin deficiencies are well documented. Generally, BS-induced signs of hunger are represented by protein-energy imbalances and deficiencies of micronutrients including cobalamin, folate, calcium, iron, transferrin, and fat-soluble vitamins. Because bipolar disorder decreases gastric acid, it also reduces the bioavailability of iron. This situation is further complicated by the patient's insufficient vitamin intake.[36] Thus, compliance with the dietary recommendations given after surgery to avoid deficits and maximize the chance for the success immediately is paramount. Below are thorough guidelines for determining a diet, food selection, supplementation, nutrition therapy, and treatment of common GI disorders.[37] Iron deficiency can occur due to decreased absorption hence the need for supplementation to prevent nutritional deficiencies. To reduce the risk of iron deficiency post-operatively, all of our patients were given oral ferrous sulphate in a 190 mg dose every 12 hours. According to Lefebvre et al., the transferrin IBC ratio was 62.7 at baseline and decreased to 61.8 after 12 months. Moreover, soybean meal seems to be the initial feed component with the highest concentration of factors that were considered detrimental to Fe absorption, with a previous study showing an initial prevalence of iron insufficiency in serum at 29.8% decreasing to 15.6% after a year 10.[38,39] The data in this table reflects major changes in some of the main inflammatory responses after bariatric surgery. In particular, higher expression levels of IFN-γ, IL-10, IL-1β and MCP-1 were found in post-surgery patients compared to the control group, maintaining an inflammatory response after surgery, which might be related to the physiological changes that occur after surgery. Post-surgery patients had significantly higher levels of IFN-γ (22.5±8.9 pg/mL) than control patients (10.8±4.3 pg/mL, p < 0.001). IFN-γ: a cytokine central to the Th1 immune response, elevated in inflammatory conditions and during infection. This rise in IFN-γ may also be a reflection of the acute-phase inflammatory response induced by surgery.[40] Anti-inflammatory cytokine IL-10 was elevated in the post-surgery patients (7.2±2.9 pg/mL) compared with the controls (3.5±1.8 pg/mL, p<0.001). Although IL-10 is mainly involved in limiting inflammatory responses to prevent immune-mediated damage to tissues, the increase in IL-10 that we observed post-surgery could potentially function as a mechanism to compensate for the increased inflammatory state triggered by surgery. Li et al. also showed a comparable response, suggesting that the acute inflammation immediately following surgery is paired with an increase in IL-10, which might represent a regulatory response aimed at dampening inflammation and preventing chronic damage.[41] Moreover, significantly elevated concentrations of IL-1β (14.9±5.7 pg/mL in postsurgery patients, vs 6.4±3.1 pg/mL in controls, p<0.001) is consistent with this premise. IL-1β is proinflammatory cytokine and its increase after surgery correlates with results of Trahtemberg et al., this coincides with increased levels of IL-1β early post-operatively as a result of tissue damage and follow-up inflammation. The increased IL-1β is linked with many metabolic and immune changes that may includ insulin resistance which can have implications for post-injuncture metabolic health.[42] MCP-1 (265.4±92.6 pg/mL in post-surgery patients vs. 145.3±58.2 pg/mL in controls, p<0.001) was significantly upregulated, as has also been reported by Salman et al. who reported that MCP-1 levels are increased by bariatric surgery. MCP-1 is important in recruiting monocytes to sites of inflammation and its elevation indicates ongoing processes of inflammation. This increase may participate in adipose tissue remodeling and may be involved in the reprogramming of the immune system during rapid weight loss.[43] Additionally, some visceral fat may remain after surgery, which is an important source of these inflammatory proteins, contributing to their continued elevation. MCP-1 also plays a role in attracting immune cells to promote wound healing after surgery, while SAA is elevated as part of the inflammatory response and altered metabolism in the body during the recovery period. These changes are usually transient and levels gradually return to normal with full recovery.[44,45] A small number of people in the study showed a low level of emotional eating, but about 64.4% of them showed an average level of this behavior. Most of the people who took part (58.1%) displayed a low level of external eating, while 41.9% displayed a moderate level of this habit. Many research studies have shown that stress, grief, and disappointment have a big effect on both emotional and outward eating habits.[46] Questioned about whether they felt depressed or hopeless along with the urge to eat, 45% of the people who took part said "occasionally." Along with this, there is a strong link between higher DEBQ scores linked to emotional and external eating and weight loss plans not working as well.[47] A person's psychological eating habits may affect their ability to adapt to changes in their food after surgery, which can either help or hurt their weight loss efforts. Several factors affect how people eat after surgery, which is a complicated process.[48] Dietary changes after bariatric surgery depend on factors like gender, type 2 diabetes, genetics, and the specific type of surgery. It is also thought that the signaling routes between the gut and the brain affect how people eat differently after having gut surgery.[49]

Conclusion

The study results indicate that gastric sleeve surgery results in a significant decrease in iron, ferritin, calcium, and vitamin D3 levels in patients compared to the control group. This may be explained by the effect of surgery on reducing the absorption of these important nutrients, which increases the risk of mineral and vitamin deficiencies essential for bone health and general body functions. Therefore, patients after surgery need close nutritional monitoring and nutritional supplements to compensate for this deficiency and avoid future health problems.

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Declarations

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Author contributions

Conceptualization, O.A.M.; Methodology, N.H.N.; Software, O.A.M.; Validation, A.H.F., O.A.M. and A.M.A.; Formal Analysis, O.A.M.; Investigation, O.A.M.; Resources, A.M.A.; Data Curation, N.H.N.; Writing – Original Draft Preparation, N.H.N.; Writing – Review & Editing, O.A.M.; Visualization, A.H.F.; Supervision, A.H.F.; Project Administration, O.A.M.; Funding Acquisition, O.A.M.

Conflicts of interest

There is no conflicts of interest.

Data availability

Data supporting the findings of this study are available upon request from the corresponding author.

Ethics approval

The study was conducted in accordance with ethical guidelines and was approved by the Committee on Publication Ethics at the Thi-Qar Health Directorate, Al-Habboubi Teaching Hospital, No 3324 in January 1, 2023.. However, we acknowledge the potential limitations of relying solely on verbal consent and recognize the importance of ensuring comprehensive ethical compliance in future studies.

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