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Anthropometric, Body Composition, and Biochemical Measurements in Morbidly Obese Patients Prior to Bariatric Surgery

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ABSTRACT

Background: Obesity is the most important risk factor for occurrence of chronic diseases. Morbid obesity could be accompanied by imbalance of body composition and serum levels of nutrients. Therefore, the aim of this study was to compare body composition and serum levels of nutrients in the bariatric surgery candidates with standard values.

Methods: In this cross-sectional study, 100 morbid obese patients (22 men and 78 women) were enrolled. Their anthropometric and biochemical measurements were evaluated based on the standard protocols. Body composition was measured using the dual X-ray absorptiometry (DEXA) method. Independent t-test was used to compare the mean of quantitative variables between genders and measurements with the standard values to estimate any deficiency.

Results: Grade 3 obesity (73%), abdominal obesity (100%), abnormal waist-to-hip ratios (95%), abnormal body fat and fat-free mass percentages (100%), normal android-to-gynoid fat ratios (96%), and moderate body shape profiles (100%) were prevalent among the participants. Also, a deficiency of vitamin D (91%), vitamin B12 (19%), and iron (17% serum iron and 3% serum ferritin) was noticed. Serum levels of vitamin A (7%) and zinc (4%) were higher than normal among a part of population. There were no significant differences in the distributions of these indicators by gender.

Conclusion: People with morbid obesity had abnormal amounts of fat and muscle tissue. Also, they were deficient regarding vitamin D, vitamin B12, and iron. Moreover, vitamin A and zinc levels in some people were higher than normal. Further studies are needed to confirm these findings in larger populations.

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Introduction

Obesity as a complex multifactorial disease is one of the challengeable public health concerns in the developed and developing countries (1). Recent studies have reported 26.5% and 45% for the prevalence of obesity in the southwestern and northwestern regions of Iran (2). Evidence suggests several causes for obesity (3), but in most cases, excessive energy intake combined with inactivity is one of the most important factors (4). Those with a body mass index (BMI) ≥30 kg/m2 and a BMI≥40 or a BMI≥35 with obesity-related health conditions are considered obese and morbidly obese, according to the World Health Organization (WHO) reports (5). For patients with morbid obesity, a variety of therapeutic strategies are usually used, but bariatric surgery is also an option based on the documented guidelines (6). To optimize the management of patients' diseases during and after the bariatric surgery, a preoperative analysis of the patient's body composition and possible nutritional deficiencies is necessary.

Most epidemiologic studies have used indices such as height, weight, BMI, waist circumference (WC), and hip circumference (HC) to evaluate the prevalence of overweight and obesity and the distribution of fat in the body (7). However, these indices became updated with new ones because of their limitations (8). Recently, other indices such as a body shape index (ABSI) and the body roundness index (BRI) have been developed which consider at least two previous indices and have more validity to predict the chances of future cardio-metabolic risks related to obesity (9). Previous studies used such indices to predict cardio-metabolic risks related to obesity in patients with morbid obesity (10). Despite the aforementioned indices being suitable for the identification of metabolic risk factors in epidemiological studies, it might also be helpful to determine body composition as well. It also suggested that pre-operative body composition estimations can predict the rate of weight loss and metabolic changes after bariatric surgery (11). There are several body composition analyzer methods available, but the dual X-ray absorptiometry (DEXA) method is known as a precise method for measuring body composition in adults (12). It has been used for estimating body composition in patients undergoing bariatric surgery in some studies (13).

Nutrient imbalances are another concern among the candidates of bariatric surgeries. Nutritional assessment of morbidly obese patients is crucial because of the issues they face following bariatric surgery or during their recovery due to the nutrient deficiencies (14). However, except for prevalent vitamin D deficiency, there are inconsistent findings regarding nutrient imbalances in a morbidly obese population. Accordingly, some evidences showed that morbid obese patients are deficient in terms of vitamin A (15), vitamin B9 (16), vitamin B12 (17), Iron (18), and zinc (19). However, other studies have demonstrated that these patients have higher than normal amounts of vitamin A (20) and are not deficient in terms of vitamin B9 (18) and zinc (20). Overall, there is limited evidence regarding the estimation of anthropometric measurements using updated indices and body composition analysis using the DEXA method; as well as inconsistent findings regarding nutrient imbalances among morbid obese patients. Thus, this study aimed to compare anthropometric measurements, body composition, and biochemical parameters in morbidly obese patients prior to the bariatric surgery with standard values.

Materials and Methods

This cross-sectional study included 100 morbidly obese participants (22 men, 78 women) who were referred to Ghadir Mother and Child Hospital from January 2018 to January 2021 in Shiraz City, Iran. Participants who were diagnosed as morbidly obese (a body mass index (BMI)≥40 kg/m^2) and a BMI≥35 with obesity-related health conditions (5) and aged 18-45 years old had the criteria to be included in this study. Patients were not included if they had severe physical activities, were affected with severe diseases, were pregnant, lactating, or menopausal women, and consumed nutritional supplements which affected considered biomarkers. The sample size for this study was determined based on vitamin D deficiency prevalence according to the study by Malek *et al.* (21) by considering p=0.82, d=0.1, and α=0.05. An informed consent form was signed by all participants before entering the study. The protocol of the study was in accordance with the Declaration of Helsinki and was reviewed and approved by the Ethics Committee of Shiraz University of Medical Sciences (approval number: IR.SUMS.SCHEANUT.REC.1400.108).

In the initial phase of the research, a general questionnaire was used to collect individuals' characteristics including age, gender, smoking, diet supplements, and drugs, following a weight loss regimen, and disease history. After 8-10 hours of fasting, 5 mL of venous blood was taken for biochemical assessments. After serum separation, the amount of vitamins A, vitamin D, vitamin B12, vitamin B9, iron, ferritin, and zinc were measured based on the standard protocols. Standard serum levels of vitamin A (15-60 µg/dL), vitamin D (30-100 ng/mL), vitamin B12 (200-900 pg/mL), vitamin B9 (2-20 ng/mL), iron (women=50-150 micrograms/dL and men=70-175 micrograms/dL), ferritin (women=10-150 ng/mL and men=12-300 ng/mL), and zinc (women=50-103 µg/dL and men=60-135 µg/dL) were also considered based on the previous researches (22).

Height was measured using a standard height meter; while standing bare footed and with an accuracy of 1 cm. Weight was measured using a SECA digital scale in kilograms with an accuracy of 0.01 kg. The BMI was calculated using the relate equation (BMI=weight (kg)/(height (m))^2). The WC was measured using an inflexible tape meter at the midpoint of the iliac crest and the last rib with an accuracy of 0.1 cm. The HC was measured in the largest place with a tape meter. The BRI, waist-to-hip circumference ratio (WHR), and ABSI indices were calculated based on previous studies (10, 23).

A DEXA method was used to assess body composition, such as fat mass, muscle mass, fat mass to total body weight ratio, gynoid fat mass, android fat mass, android to gynoid fat mass ratio, and limb fat mass. Standard values for obesity (grade 1=BMI of 30 to 35 kg/m^2, grade 2=BMI of 35 to 40 kg/m^2 and grade 3=BMI>40 kg/m^2) (5), body fat percentage (men (ages 20 to 39 years old=8 to 19 percent, 40 to 59 years old=11 to 21 percent and 60 to 79 years old=13 to 24 percent) - women (20 to 39 years old=21 to 32 percent, 40 to 59 years old=23 to 33 percent and ages 60 to 79 years=24 to 35 percent), body mass percentage (men=76 to 82 percent and women=69 to 75 percent) (24), WC (men=less than or equal to 102 cm and women=less than or equal to 88 cm (25), WHR (men=less than or equal to 0.9 and women=less than or equal to 0.85) (26), android to gynoid fat mass ratio (men=one or less than one and women=0.8 or less than 0.8), and body shape index (low=-0.868 to -0.272, medium=0.272 - up to +0.229, high=+0.229 to +0.798, and very high=above +0.798) (27) were considered based on the existing valid standards.

The Kolmogorov-Smirnov test was used to determine whether the data follow the normal distribution. Quantitative data were reported as mean and standard deviation and qualitative data were reported as frequency and percentage. The independent sample t-test was utilized to compare the mean of quantitative variables between two groups. The Chi-square test was employed to compare the distribution of qualitative variables between the two groups. The results were analyzed using SPSS software (Version 22, Chicago, IL, USA) and $p<0.05$ was considered as a statistically significant level.

Results

Table 1 shows the general characteristics, anthropometric measurements, and body composition of the participants in this study. As seen, 100 people (22 men and 78 women) with morbid obesity and candidates for the bariatric surgery were enrolled. The mean age, BMI, WC, total body fat, and fat mass in these people were 36.21 years, 42.43 kg/m^2, 127.29 cm, 49.20 kg, and 61.58 kg, respectively. There was a significant difference between male and female participants considering the mean age (p=0.01), BMI (p=0.02), WC (p<0.001), HC (p=0.02), WHR (p<0.001), ABSI (p<0.001), BRI (p=0.01), total body fat mass (p<0.001), android fat (p<0.001), fat mass to body weight ratio (P<0.001), fat-free mass to body weight ratio (P<0.001) and android to gynoid fat ratio (p<0.001).

In Table 2, serum vitamin and mineral values were displayed for bariatric surgery candidates. A significant difference was found between men and women in terms of serum values of iron (p<0.001), zinc (p<0.001), vitamin D (p=0.02), ferritin (p<0.001), and vitamin B12 (p=0.002). The

Table 1: General characteristics, anthropometric measurements, and body composition of the study participants (n=100).

Variables	Total (n=100)	Male (n=22)	Female (n=78)	*P* value
Age (year)	36.21±10.59	31.00±9.60	37.68±10.44	0.01
Body mass index (kg/m^2)	42.43±4.42	44.39±4.18	41.88±4.36	0.02
Waist circumference (cm)	127.29±10.98	142.40±8.30	123.02±7.24	<0.001
Hip circumference (cm)	134.58±9.06	138.60±7.64	135.45±8.08	0.02
Waist to hip ratio	0.95±0.07	1.03±0.05	0.92±0.05	<0.001
A body shape index	0.14±0.01	0.16±0.01	0.13±0.01	0.01
Body roundness index	9.98±1.48	10.76±1.46	9.77±1.12	0.01
Fat mass (kg)	49.20±9.42	51.44±11.27	48.57±8.81	0.21
Lean body mass (kg)	61.58±14.37	82.91±11.55	55.56±7.90	<0.001
Android fat mass (kg)	4.54±1.23	5.43±1.36	4.29±1.10	<0.001
Gynoid fat mass (kg)	7.59±1.61	7.60±2.03	7.58±1.49	0.96
Limb fat mass (kg)	23.28±4.47	23.06±5.23	23.34±4.27	0.81
Lean mass to body weight ratio	0.53±0.06	0.59±0.06	0.51±0.05	<0.001
Fat mass to body weight ratio	0.43±0.06	0.36±0.06	0.45±0.05	<0.001
Android fat mass to gynoid fat mass ratio	0.60±0.13	0.72±0.10	0.57±0.11	<0.001

Data were presented as mean±standard deviation or Number (%). Independent sample t-test was used for the comparison of quantitative variables. A $p<0.05$ was considered statistically significant.

Table 2: Mean serum biomarker values of the study participants (n=100).

Variable	Total (n=100)	Male (n=22)	Female (n=78)	*P* value
Iron (µg/dL)	76.73±44.27	94.64±26.44	71.67±25.69	<0.001
Zinc (µg/dL)	83.90±16.86	98.31±21.39	79.84±12.82	<0.001
Ferritin (ng/mL)	45.28±16.26	158.30±95.48	68.18±58.87	<0.001
Vitamin A (µg/dL)	45.28±16.26	43.91±10.95	45.67±17.51	0.65
Vitamin D (ng/mL)	17.64±9.24	21.81±9.34	16.47±8.93	<0.001
Vitamin B9 (ng/mL)	9.84±2.86	9.08±2.52	10.04±2.93	0.17
Vitamin B12 (pg/mL)	222.05±6.30	256.63±96.96	212.30±42.78	0.002

Data were presented as mean±standard deviation or number (%). Independent sample t-test was used for comparison of quantitative variables. A *p*<0.05 was considered statistically significant.

Table 3: Comparison of anthropometric measurements and body composition of the participants with standard values (n=100).

Variable	Total (n=100)	Male (n=22)	Female (n=78)	*P* value
Obesity				0.22
Grade 1	6 (6.0)	0 (0)	6 (7.7)	
Grade 2	21 (21.0)	3 (13.6)	18 (23.1)	
Grade 3	73 (73)	19 (86.4)	54 (69.2)	
Abdominal obesity				---
Normal	---	---	---	
Abnormal	100 (100)	22 (100)	78 (100)	
Waist to hip ratio				0.22
Normal	5 (5.0)	0 (0)	5 (6.4)	
Abnormal	95 (95.0)	22 (100)	73 (93.6)	
Body fat percent				---
Low	0 (0)	0 (0)	0 (0)	
Normal	0 (0)	0 (0)	0 (0)	
Higher than normal	100 (100)	22 (100)	78 (100)	
Lean body mass percent				---
Low	100 (100)	22 (100)	78 (100)	
Normal	0 (0)	0 (0)	0 (0)	
Higher than normal	0 (0)	0 (0)	0 (0)	
Android fat mass to gynoid fat mass ratio				0.27
Normal	96 (96.4)	22 (100)	74 (94.6)	
Abnormal	4 (4.0)	0 (0)	4 (5.4)	
A body shape index				---
Low	0 (0)	0 (0)	0 (0)	
Moderate	100 (100)	22 (100)	78 (100)	
High	0 (0)	0 (0)	0 (0)	
Very high	0 (0)	0 (0)	0 (0)	

Data were presented as number (%). Chi-square test was used to compare the distribution of qualitative variables between two groups. A *p*<0.05 was considered statistically significant.

values of anthropometric measurements and body composition of the study participants were compared to the standard values and presented in Table 3. Among the participants, 73%, 100%, 95%, 100%, 96%, and 100% had grade 3 obesity, abdominal obesity, abnormal waist-to-hip ratios, abnormal body fat and fat-free mass percentages, normal android-to-gynoid fat ratios, and moderate body shape profiles, respectively; although, the distribution of these indicators did not differ significantly between the two genders (*p*>0.05). Table 4 shows the comparison of the mean serum vitamins and minerals of the participants with standard values. Accordingly, a deficiency of vitamin D (91%), vitamin B12 (19%), and iron (17% serum iron and 3% serum ferritin) in this population was observed. Also, serum levels of vitamin A (7%) and zinc (4%) were higher than normal in a part of this population. There were no significant differences in the distributions of these indicators by gender (*p*>0.05).

Discussion

This cross-sectional study was conducted to compare the levels of anthropometric, biochemical,

Table 4: Comparison of mean serum biomarker values of the participants with standard values (n=100).

Variable	Total (n=100)	Male (n=22)	Female (n=78)	*P* value
Iron				0.74
Low	17 (17.0)	4 (18.2)	13 (16.7)	
Normal	81 (81.0)	18 (81.8)	63 (80.8)	
High	2 (2.0)	0 (0)	2 (2.6)	
Zinc				0.88
Low	0 (0)	0 (0)	0 (0)	
Normal	96 (96.0)	21 (95.5)	75 (96.2)	
High	4 (4.0)	1 (4.5)	3 (3.8)	
Ferritin				0.88
Low	3 (3.0)	1 (4.5)	2 (2.6)	
Normal	87 (87.0)	19 (86.4)	68 (87.2)	
High	0 (0)	2 (9.1)	8 (10.3)	
Vitamin A				
Low	0 (0)	0 (0)	0 (0)	
Normal	93 (93.0)	21 (95.5)	72 (92.3)	
High	7 (7.0)	1 (4.5)	6 (7.7)	
Vitamin D				0.09
Low	91 (91.0)	18 (81.8)	73 (83.6)	
Normal	9 (9.0)	4 (18.2)	5 (6.4)	
High	0 (0)	0 (0)	0 (0)	
Vitamin B9				----
Low	0 (0)	0 (0)	0 (0)	
Normal	100 (100)	22 (100)	78 (100)	
High	0 (0)	0 (0)	0 (0)	
Vitamin B12				0.91
Low	19 (19.0)	4 (18.2)	15 (19.2)	
Normal	81 (81.0)	18 (81.8)	63 (80.8)	
High	0 (0)	0 (0)	0 (0)	

Data were presented as number (%). Chi-square test was used to compare the distribution of qualitative variables between two groups. A $p<0.05$ was considered statistically significant.

and body composition indicators with standard levels in patients with morbid obesity before the bariatric surgery. The results showed that 73%, 100%, 95%, 100%, 96%, and 100% of the participants had grade 3 obesity, abdominal obesity, abnormal waist-to-hip ratios, abnormal body fat and fat-free mass percentages, normal android-to-gynoid fat ratios, and moderate body shape profiles, respectively. Also, the findings indicated a deficiency of vitamin D (91%), vitamin B12 (19%), and iron (17% serum iron and 3% serum ferritin) in this population. In addition, this study demonstrated that serum levels of vitamin A (7%) and zinc (4%) were higher than normal in a part of this population.

According to the findings of this study, candidates of bariatric surgery had abnormal anthropometric profiles and body compositions. In line with these results, some studies have examined anthropometric and body composition measurements before the bariatric surgery, as well as their relationship to short- and long-term outcomes after the surgery (28). The results of those studies were similar to the current study; however, some similarities and differences should be noted between them. For example, unlike the present study, a study conducted with Brazilian participants revealed that the fat mass percentage was greater than the fat-free mass percentage, mainly because all participants had grade 3 obesity.

Also, in that study, the researcher measured the fat-free mass using the bioelectrical impedance analysis (BIA) device (29). In addition, a study conducted on American obese individuals used underwater weighing and body density measurements to assess body composition, and the sample size was smaller than ours (30). Moreover, the same results were found by Zamaniour *et al.*, while they assessed body composition using a BIA device. Interestingly, they reported that women had higher body fat percentages than men, and their population was almost four times that of men, as in the present study (10).

Similar to this study, a limited number of studies have examined body composition in morbidly obese patients using the DEXA method (31). Accordingly, in a study conducted in France on 114 bariatric surgery candidates, the researcher found similar results to the current study using this method. There was a similar ratio of women to men in that study, however, the higher body fat in that study may be caused by the majority of the participants having grade 3 obesity (31). Also, a study was conducted in Brazil to investigate body composition changes after one year of bariatric surgery on 50 participants (32). Compared to the present study, the BMI, body fat mass, and WC were higher, and fat-free mass was lower than the present study. In that study, anthropometric profiles and body composition before surgery were not compared between the genders, but the changes in these parameters after surgery did not differ significantly between them. That study's results might be affected by the higher number of women (41 people) compared to men (6 people). Therefore, the comparison of the previous studies with the recent study indicates that the differences in body composition in obese people before the bariatric surgery in different studies can be explained by the differences in gender, sample size, or measurement methods.

The use of new indicators, such as ABSI, to evaluate the relationship between anthropometric measurements and cardiovascular risk factors and mortality has increased in the recent years. This index, which can be calculated from WC, BM, and height, is related to some metabolic conditions. The results of the present study showed that all the participants had moderate values of this index. It has also been used in limited studies to investigate anthropometric conditions in morbidly obese patients (10, 33). In a cross-sectional study conducted on 776 Iranian obese participants, the researcher observed a significant positive correlation between this index and the serum levels of vitamin D. Since this index was low in that population, it may not be related to cardio-metabolic factors (10). Comparing the results of the two studies shows that the participants in the studies had almost the same range of fat and fat-free mass, and the ABSI was moderate in both studies. In another study conducted on 101 American candidates of the bariatric surgery, the researchers investigated the effect of bariatric surgery on the improvement of ABSI after 3 years of surgery. The mean ABSI in that study before surgery was 0.08 $m^{11/6}kg^{-2/3}$. After 3 years, this indicator has decreased to 0.08 $m^{11/6}kg^{-2/3}$ (33). Therefore, the results of that study indicated that even though the body mass profile decreased significantly after the bariatric surgery, this surgery did not have much effect on the ABSI.

Body composition and anthropometric measurements in obese people can also be useful to predict the chance of occurrence of cardiovascular diseases, as well as to assess their relationship with complications after the bariatric surgeries. In a study conducted on 155 Swedish people (108 women and 47 men), the researcher investigated the relationship between BMI and sagittal abdominal diameter (SAD) and cardiovascular risk factors. The results of that study showed BMI had a positive correlation with the levels of inflammation (CRP) and triglyceride in people with morbid obesity before the surgery. It was also seen that SAD not only had a positive correlation with the above factors; but also had a positive and significant correlation with blood sugar profiles (fasting blood sugar and hemoglobin A1c) and systolic blood pressure. Therefore, the review of the available evidence shows that the use of anthropometric and body composition measurements can be effective in controlling, managing, or predicting the risks associated with a disease, especially in people with morbid obesity and candidates for bariatric surgery. Despite the limitations of this study and the limited studies that have especially used new indices such as ABSI, it seems necessary to conduct more studies in this field.

Regarding nutritional deficiencies, the high prevalence of vitamin D deficiency in obese people seems to be one of the most important challenges related to their disease management. In this study, 93 % of the participants had low levels of vitamin D ,which was confirmed by the previous researches with reported prevalence between 53.6% and 97.5% (16, 18, 19, 22). Meanwhile, a study conducted by Gillon *et al.*, on 336 Norwegian adults indicated that the prevalence of vitamin D deficiency was 20.4% (34). The difference in the percentage of vitamin D deficiency among the studies is probably due to differences in ethnic-racial groups, climatic differences, and differences in food intake, especially the enriched type. It seems that the high prevalence of vitamin D deficiency in morbidly obese individuals is partly due to a diet poor in vitamin D, rapid weight loss before the bariatric surgery, and retention of vitamin D in the adipose tissue. However, some evidence states that the increase in body mass in obese people and the subsequent volume expansion of the person can lead to a decrease in the serum level of vitamin D. Although the serum levels of this vitamin increase somewhat after a weight loss diet, it is not enough to compensate the deficiency. Other reasons for low levels of vitamin D in obese people include reduced exposure to sunlight due to the low mobility and social isolation due to a person's body shape (35).

In the present study, the serum levels of iron and ferritin were lower than the normal level in a part of population, which indicates possible deficiency of this micronutrient in this population. To date, many studies have investigated the status of iron deficiency in obese people, which indicated the prevalence of iron deficiency ranging from 1.9% to 29.3% (16, 18, 19, 22). The comparison of the present study with another study conducted in Iran indicates that the prevalence of iron deficiency was low, which may be because of the high intakes of animal proteins in this group (36). However, these results are significantly different from those conducted in other developing countries such as Kuwait and Singapore, which can indicate the low intake of iron sources in those populations and the lack of food enrichment with minerals such as iron. Nevertheless, the low sample size of the current study indicates uncertainty in the conclusion, which necessitates a study with a larger sample size. The imbalance in iron status in the obese population appears to be due to inflammation and high levels of hepcidin. Evidence shows that high levels of hepcidin prevent intestinal absorption of iron and also reduce the amount of iron released from macrophages. It was also seen that the expression of genes related to hepcidin should be increased not only in the liver but also in the adipose tissue (37). Finally, the observations showed that the synthesis of inflammatory factors from the inflamed fat tissue also stimulates the secretion of hepcidin, which leads to the accumulation of iron in tissues such as the liver, spleen, and macrophages, and as a result, decreases the plasma level of iron (37).

The results of the present study indicated normal levels of vitamin B9 and insufficient levels of vitamin B12 in the studied population. Similarly, a study conducted on the Kuwaiti population showed that vitamin B9 deficiency was not common in that population and about 16.4% of that population had vitamin B12 deficiency (18). In contrast, studies conducted in various populations indicated a moderate to severe deficiency of vitamin B9 (28.8% to 63.2%) in candidates for bariatric surgery (16, 22). Since all the reviewed studies have used the serum folate levels to check the folate deficiency status, and have considered both men and women genders, it seems that the differences can be caused by low intake of vitamins or genetic differences related to folic acid metabolism.

Previous research showed a relatively low to moderate prevalence of vitamin B12 deficiency in morbidly obese individuals (17). However, until now, no known mechanism has been identified for the occurrence of vitamin B12 deficiency in obese people. But it appears that vitamin B12 deficiency in this population may be due to the gastrointestinal disorders (malabsorption) and the use of medications such as metformin, potassium pump blockers, and anti-acids (17). In general, the comparison of nutrient deficiencies in people with obesity in different populations indicates that the different prevalence of deficiencies in populations may be due to the difference in the sample size of the studies, the diversity of people's food cultures in different societies, and various environmental factors (for example, the effect of sunlight on the serum levels of vitamin D in different societies), and the difference in food enrichment in different regions.

In the present study, serum levels of vitamin A and zinc were higher than the normal level in 4 and 8% of the population. In a study conducted on 407 obese Dutch people, it was seen that 72.0% of the participants had serum levels of vitamin A higher than normal (20). Contrary to these results, several studies have also reported the prevalence of vitamin A deficiency in the bariatric surgery candidates (38). Perhaps the difference in food intake or access to vitamin precursors consumed in different regions is one of the causes of these differences. Therefore, it seems that more studies are necessary to determine whether the process of obesity leads to deficiency or increased levels of vitamin A to make a more precise statement in this field, and the results of this study should be interpreted with caution.

Regarding serum zinc levels, the results of previous studies were not in line with the findings of this study. In a study conducted on 407 Dutch people with morbid obesity, serum zinc levels were normal in all participants (20). Also, Asghari *et al.* reported a 38% prevalence of zinc deficiency among Iranian candidates of the bariatric surgery (19). In addition, the results of other studies have shown a low to high prevalence of zinc deficiency (between 2.9% and 73.9%) in the obese population with morbid obesity (39). In general, the review of the available evidence indicates that the issue of zinc deficiency is more challenging than its high serum levels. The reason that the results of this study are different from other studies can be due to the small sample size of this study. Although the main mechanism of decreased zinc levels in the obese population is unknown, it seems that inflammation caused by excessive accumulation of adipose tissue is one of the most important reasons in this regard. Studies showed that inflammatory conditions created in obese people can lead to increased expression of metallothionein and zinc-copper carriers on liver and fat cells. The expression of these proteins subsequently leads to an increase in the accumulation of zinc in the liver and fat cells and a decrease in the serum levels of this micronutrient. Also, insufficient zinc intake from foods may be a cause of its deficiency in obese people (39). Therefore, it is better to carry out more detailed studies to check zinc status in obese people and use better indicators to check its status.

One of the most important strengths of this study is the examination of body composition using the DEXA method as a gold standard for body composition assessment. Also, comparing the measured values with the standard levels is a perspective to identify the deficiency or excess of nutrients to eliminate the possible deficiency. However, this study had a low sample size, which necessitates the need for more studies. The lack of information on dietary intake is also one of the limitations of this study, and the presence of this information could possibly provide us a better view of the relationship between dietary intake and blood indices. Moreover, the cross-sectional nature of this study makes it impossible to find cause-and-effect relationships.

Conclusion

The results of this study showed that people with morbid obesity had abnormal amounts of fat and muscle tissue. It was also seen that the deficiency of some micronutrients such as vitamin D was prevalent in this population; as well as others such as iron and vitamin B12 had a moderate prevalence. In addition, the results of this study demonstrated that a percentage of people have higher than normal levels of vitamin A and zinc. However, it is necessary to conduct more studies with a larger sample size and a prospective perspective, especially by assessing the nutrient intakes at the same time to better elucidate the relationships and changes.

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Authors' Contribution

MKH: Research idea, Study design, Data collection, and writing and drafting the manuscript. NH: Research idea, study design, data interpretation, and critical revision of the manuscript. YJ: Study design, data interpretation, writing and drafting the manuscript, and critical revision of the manuscript. MZ: Research idea, study design, data analysis and interpretation, and critical revision of the manuscript. ZS: Research idea, study design, data interpretation, and critical revision of the manuscript.

Conflict of Interest

None declared.

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