ISSN: 2347-467X, Vol. 10, No. (2) 2022, Pg. 817-826

Current Research in Nutrition and Food Science

www.foodandnutritionjournal.org

Factors Affecting Muscle Mass Loss Following Laparoscopic Sleeve Gastrectomy and Laparoscopic Mini Gastric Bypass Surgeries

RANA HASSAN EMARA[1]*, DINA MAGED RAYAN[1], ALI KHAMIS AMIN[1] and MOHAMED ABDULLAH SHARAAN[2]

[1]Department of Nutrition, High Institute of Public Health, Alexandria University, Egypt.
[2]Department of General Surgery, Faculty of Medicine, Alexandria University, Egypt.

Abstract

Excessive muscle mass loss is common following bariatric surgery due to decreased protein intake. Therefore, this study aimed to examine factors associated with muscle mass loss after three months in patients who underwent Laparoscopic Sleeve Gastrectomy (LSG) and Mini-gastric bypass (MGB) in a bariatric surgery centre in Alexandria, Egypt. An observational study was performed on 50 patients, 25 of whom underwent LSG,whereas 25 underwent MGB. At baseline and after three months, physical activity level, and energy and protein intakes were assessed. Bioelectric impedance analysis assessed the body composition preoperatively and after three months. The current study demonstrated that LSG and MGB three months postoperatively lost -17.3 ± 2.8% and -18.5 ± 3.1 %, respectively, of their weight. Nevertheless, in MGB, patients lost more muscle mass (-17.2±12.4 %) compared to LSG (-11.5 ± 5.6 %) (p=0.063). In MGB, females lost -23.5 ± 11.6 % of their muscle mass compared to -7.9 ± 6.6 % in males (p<0.05). Muscle mass loss in < 60 g protein eaters was higher in MGB than LSG (M ± SD= 20.3 ± 12.5 % vs -13.0 ± 5.3 %, p=0.033). While muscle mass loss in ≥ 60 g protein eaters was -5.6± 1.5% in LSG and 7.4± 5.9 % in MGB. In conclusion, females in MGB lost more muscle mass than males after three months. Protein intake ≥ 60 g/day during the first three months postoperative is associated with low muscle mass loss. High preoperative HbA1c correlates with muscle mass loss in MGB especially in females. High preoperative Hba1c and protein intake of < 60 g/d are associated with muscle mass loss in LSG.

Article History
Received: 29 September 2021
Accepted: 11 June 2022

Keywords
Bariatric Surgery;
Laparoscopic Sleeve Gastrectomy;
Mini-Gastric Bypass;
Muscle Mass Loss;
Protein Intake.

CONTACT Rana Hassan Emara ranaemara@alexu.edu.eg Department of Nutrition, High Institute of Public Health, Alexandria University, Egypt.

Doi: http://dx.doi.org/10.12944/CRNFSJ.10.2.33

Introduction

In morbidly obese patients, bariatric surgery (BS) has proven to be a more effective therapy than lifestyle intervention and pharmacotherapy. Weight loss after BS is maintained over the long term, helping to control obesity-associated comorbidities such as type-2 diabetes, dyslipidemia, and hypertension.[1] Current guidelines recommend BS for patients with BMI greater than40 kg/m^2 or above 35 kg/m^2 with obesity associated comorbidities.[2] In the first few months after bariatric surgery, rapid weight loss causes losses in fat mass (FM) and lean body mass (LBM). During any weight loss program, LBM has been recommended to account for nearly one-fourth of total weight loss, with FM accounting for the remaining three-fourths.[3,4] Excessive LBM loss- which is mainly composed of Muscle Mass (MM)- causes a drop in resting energy expenditure (REE), which reduces the rate of weight loss and may predispose to weight regain in the long term following the surgery.[5] In addition, because skeletal muscles are involved in blood glucose uptake and thus protect against insulin resistance, excessive loss of MM may expose the individual to functional and metabolic impairments.[6]

Following the surgery, BS patients are advised to consume adequate protein, obtained by eating high protein foods or taking protein supplements to avoid significant LBM losses. Recent guidelines for the nutritional management of the BS patient postoperatively suggest a protein intake (PI) of 60- 80 g/d or 1.1-1.5 g/kg /d of ideal body weight (IBW).[7,8] In order to achieve these recommendations, the consumption of high protein sources of foods (e.g., lean meat, fish, eggs, low-fat dairy, and legumes) should be encouraged over carbohydrates or fatty foods.[9]

High protein intake increases the feeling of satiation and increases the thermogenic effect of food, which aids in weight loss after surgery.[10] A one-year follow-up of patients after BS showed that most patients consume less than the recommended 60 g of protein daily.[11] Many patients reported red meat and other animal protein intolerances following surgery, contributing to inadequate protein intake.[12] In addition, both restrictive bariatric surgery as Laparoscopic sleeve gastrectomy (LSG), and malabsorptive procedures such as Laparoscopic Roux-en-Y Gastric Bypass (LRYGB) and Mini-gastric Bypass (MGB) can lead to inadequate protein digestion and absorption due to decreased secretion of HCL and pepsinogen in LSG and due to bypassed limb in LRYGB and MGB. Consequently, this research was designed to investigate the factors correlated with Muscle Mass (MM) loss in Laparoscopic Sleeve Gastrectomy (LSG) compared to Mini Gastric Bypass (MGB).

Materials and Methods

Study Participants and Setting

This prospective study included 50 adult obese patients, both males and females, who had morbid obesity (BMI ≥ 40 kg/m^2) or BMI of 35–39.9 kg/m^2 associated with comorbidities. Patients who underwent revisional bariatric surgery were excluded from the study. Twenty-five patients underwent LSG, whereas the other 25 patients underwent MGB. The present study was carried out in a bariatric surgery centre in Alexandria, Egypt.

Data Collection Methods and Tools

a) The patients' baseline laboratory investigations were obtained from their medical records. The laboratory investigations included fasting Blood glucose (FBG), HbA1c, and thyroid function tests (TSH level and free T3, free T4).

b) Patients' physical activity levels were assessed using a validated Arabic version of the short international physical activity questionnaire (IPAQ)[13] to evaluate their physical activity level, which was presented as Metabolic equivalent minutes per week (MET-min per week) available at (http://www.ipaq.ki.se/).[14] Physical activity assessment was performed prior to surgery and at three months (M3).

c) Dietary History: A 24 h dietary recall was recorded preoperatively and three months postoperatively. Patients were asked about the types and quantities of food and beverages they consumed on three different days, two weekdays and one weekend. All 24-hour recall sheets were fed into computer-based dietary analysis software modified by Elizabeth Stewart Hands and Associates (ESHA) food processor adapted to the Egyptian Foods.[15] The nutrient values of various food items were obtained from

"Food Composition Tables for Egypt," issued by the National Nutrition Institute.[16] Patients were categorized as high or low-protein eaters based on the daily protein intake recommendations of 60 g/day.

d) Anthropometric measurements: All patients were subjected to anthropometric measurements following a standard protocol 17 at baseline and third month postoperative (M3), which included the following:

- Body composition analysis (total weight, lean body mass (LBM), Muscle Mass (MM), and fat mass (FM) (kg)) was performed using a multi frequency bioelectrical impedance analysis (MF-BIA) technique using the "In-Body 720 ®" body composition analyser. Bodyweight (BW) loss, FM loss, and MM loss at three months postoperative (M3) were expressed as a percentage compared to a baseline measurement (M0) and calculated as follows: ([measurement $_{(M0)}$ - measurement $_{(M3)}$] / measurement$_{(M0)}$) x 100.
- Height was measured using a stadiometer, and BMI was calculated using weight (in kg) divided by the height squared (in m^2).

Dietary Intervention

A written manual was handed to the patients that included all dietary instructions. The patients were instructed to follow the diet manual given in the hospital after surgery based on American Association of Clinical Endocrinologists (AACE) guidelines.[7] The diet advice was presented in stages. Stage one, On days 1-2, postoperative patients were instructed to drink clear liquids. Stage two: On the third day after surgery, patients were instructed to drink full liquids such as milk and broth. In stage three, patients were instructed to eat soft, pureed food from days 10-14 post operatively, with an emphasis on protein foods. Stage four, a healthy balanced, solid diet was recommended in the range of 1,000-1,200 Kcal for women and 1,400-1,600 for men. Patients were instructed to include an adequate amount of protein either from foods (like eggs, dairy, meat, legumes, and nuts) or from protein supplements.

Ethical Approval

The ethical committee of the High Institute of Public Health approved the research, and the research followed the international guidelines for research ethics. All patients were informed about the purpose of the study, and informed consent was taken after explaining the purpose of the study. Confidentiality of the collected data was considered. No obligation was used to allow the patients to participate in the study, and any participant was free to withdraw from completing the study.

Statistical Analysis of the Data

The collected data were subjected to statistical analysis using suitable techniques to achieve the study's objectives. Data were entered into SPSS software package version 20.0. (Armonk, NY: IBM Corp) categorical data were expressed as numbers and percentages, while numerical data were expressed as mean and standard deviation for parametric data and median and interquartile ranges for non-parametric data. The significance of the attained results was judged at the 5% confidence level. The Chi-square test was used for categorical data to compare between different groups, while for normally distributed numerical variables, the Student t -test was used. To correlate between two normally distributed quantitative variables, the Pearson Coefficient test was used. For abnormally distributed quantitative variables, the Mann-Whitney test was used. Linear regression analysis was used to determine the most independent factor affecting muscle mass loss.

Results

Table 1 shows the sample's baseline data, where females constituted most of the cases (60 %) in both LSG and MGB groups. The mean age of the LSG group was significantly lower than that of the MGB group (M ± SD = 32.9 ± 11.2 and 41.9 ± 9.1 years, respectively). In the sleeve group, 28 % of patients had HbA1c in the prediabetic range (5.7-6.4), and 24 % of patients in the bypass group. With regard to cases with diabetes (diagnosed with HbA1c > 6.4), there were 20 % in the MGB group compared to only 8 % in the LSG group. There was no statistically significant difference between the two groups. Five cases in the sleeve group and two in the bypass group were accidentally discovered to have an abnormally high level of TSH without a previous diagnosis of hypothyroidism.

Table 1: Comparison between the two studied groups regarding baseline characteristics

Baseline characteristics	Sleeve (n = 25)		Bypass (n = 25)		Test of Sig.	P
	N	%	N	%		
Gender						
Male	10	40	10	40	X^2=0.000	1.000
Female	15	60	15	60		
Age (years)	32.9 (11.2)		41.9 (9.1)		t=3.139**	0.003*
FBG (mg/dl) †	90 (85 – 96)		95 (90– 107)	U=216.5	0.062	
Normal (<100)	22	88	16	64	X^2=4.61	^{MC}p= 0.112
Pre diabetic (100 – 125)	1	4	6	24		
DM (≥126)	2	8	3	12		
HbA1c† 5.6 (5.1 – 5.8)	5.6 (5.3 – 6.4)		U=280.0	0.527		
Normal (<5.7)	16	64	14	56	X^2=1.46	^{MC}p= 0.523
Pre diabetic (5.7 – 6.4)	7	28	6	24		
DM (>6.4)	2	8	5	20		
TSH (mIu/ml) †	1.8 (1.6 – 3.6)	1.7 (1.4 – 2.9)		U=266.5	0.372	
Normal (0.4 – 4.5)	20	80	23	92	X^2= 1.49	^{FE}p= 0.417
Abnormal > 4.5	5	20	2	8		
Free T3 (pg/ml) †	2.40 (1.2 – 3.1)		2.7 (2.4-3.0)	U=282.50		0.56
Low (<2.3)	9	36	4	16	X^2=3.23	^{MC}p= 0.195
Normal (2.3 – 4.1)	16	64	20	80		
High (>4.1)	0	0	1	4		

Data are presented as mean (SD) unless otherwise stated †: Data are presented as median (IQR)
t: Student t-test, U: Mann Whitney test, X^2:Chi-square test, MC: Monte Carlo, p:p-value for comparing between the studied groups, *: Statistically significant at p ≤ 0.05
FBG: Fasting blood glucose, HbA1c: Haemoglobin A1c, TSH: Thyroid-stimulating hormone

Table 2: Comparison between LSG and MGB groups according to baseline body composition analysis, dietary intake, and MET-min/week

Baseline characteristics	Sleeve (n = 25)	Bypass (n = 25)	Test of Sig	p
Weight (Kg)	121.0 (13.8)	122.0 (11.9)	t=0.27	0.782
BMI	42.4 (3.1)	43.4 (3.7)	t=0.99	0.327
Fat mass (Kg)	53.7 (7.3)	58.7 (9.4)	t=2.08*	0.042*
Muscle Mass (Kg)	35.0(7.7)	34.3 (5.1)	t=0.3	0.703
Energy Intake (Kcal/d)	2682.9 (778.8)	3121.0 (819.0)	t=1.938	0.058
Protein Intake (g/d)	96.7 (37.0)	113.1 (35.2)	t=1.60	0.116
Fat Intake (g/d) †	99.6 (82.5-128.0)	130.6 (107.6-138.3)	U=176.00*	0.008*
Carb. Intake (g/d) †	313.4 (276.6-363.8)	337.1 (287.7-402.4)	U=239.00	0.154
MET-min/week †	297.0 (198.0-528.0)	132.0 (99.0-198.0)	U=92.00*	<0.001*

Data are presented as mean (SD) unless otherwise stated †: Data are presented as median (IQR)
t: Student t-test, U: Mann Whitney test,p:p-value for comparing between the studied groups,
*: Statistically significant at p ≤ 0.05,
Carb.: Carbohydrate, MET: Metabolic Equivalent of the activity.

Table 3: Postoperative changes in body composition, dietary intake, and Metabolic equivalent in the two groups in relation to gender

Parameter	Total Sleeve	Sleeve (n = 25)		Total Bypass	Bypass (n = 25)	
		Male (n = 10)	Female (n = 15)		Male (n = 10)	Female (n = 15)
Weight M3 (Kg)	100.2(12.9)	110.0 (9.3)	93.8(10.9)[c]	99.4(10.6)	106.0 (9.9)	95.0 (8.9)[c]
Weight change (%)	-17.3 (2.8)	-17.1 (2.5)	-17.4 (3.0)	-18.5(3.1)	-17.8 (1.1)	-19.0 (3.8)
Fat M3 (Kg)	40.9 (7.5)	38.4 (7.4)	42.5 (7.3)	44.2 (8.9)	43.8 (9.9)	44.6 (8.5)
Fat change (%)	-24.2 (6.4)	-25.7 (5.4)	-23.2 (7.0)	-25.0 (4.3)	-25.2 (3.5)	-24.9 (4.9)
MM M3 (Kg)	30.9 (6.9)	37.4 (5.0)	26.6 (4.0)[c]	28.3 (6.2)	33.4 (6.8)	25.0 (2.3)[c]
MM change (%)	-11.5(5.6)	-10.3 (3.8)	-12.3 (6.6)	-17.2 (12.4)	-7.9 (6.6)	-23.5(11.6)[cb]
BMI M3	34.8 (3.4)	35.2 (3.2)	34.5 (3.6)	35.6 (3.7)	36.9 (4.3)	34.8 (3.2)
BMI change (%)	-18.0 (4.5)	-17.8(4.4)	-18.1 (4.8)	-18.0 (2.9)	-17.30 (3.1)	-18.5 (2.8)
Energy intake M3	612.7(179.3)	613.9 (165)	611.93(194)	627.8(168.6)	676.8(215.1)	595.2(127)
Protein intake M3	38(14.5)	39.4(14)	37 (15.2)	42.2(14.8)	46.7(16)	39.3 (13.6)
< 60 g/d (no./%)	20(80%)	8 (80%)	12 (80%)	19(76%)	6 (60%)	13 (86%)
≥ 60 g/d (no./%)	5(20%)	2 (20%)	3 (20%)	6(24%)	4 (40%)	2 (13%)
Fat intake M3†	21.6(16.6-27.4)	22.7(18.4-27.4)	20.0(16.5-27.9)	24.7(20.4-27.8)	25.3(19.6-36.6)	23.3(21.2-26.7)
Carb. intake M3†	55.8(49.1-81.4)	53.4(48.6-85.2)	56.7(50.3-79.3)	58.0(44.9-62.9)	52.7(40.0-62.9)	59.1(46.6-63.0)
MET-min/week M3†	594(330-1,485)	1246.5(378-1,488)	594(308-980)	792(445-1,229)	1,089(594-1,278)	685.50(417-902)

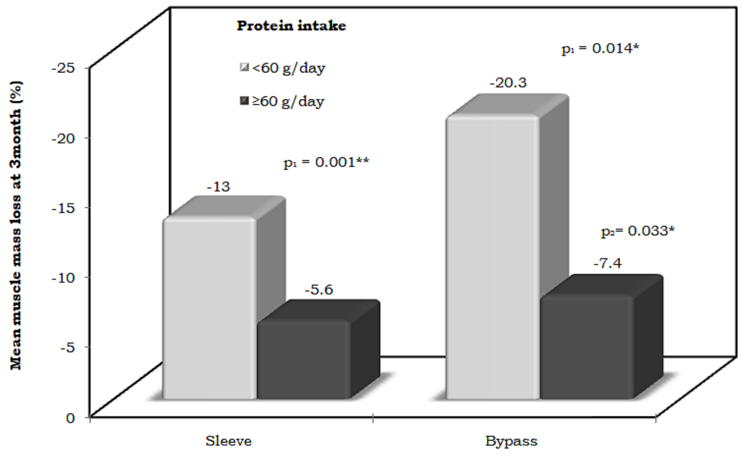
Data are presented as mean (SD) unless otherwise stated †: Data are presented as median (IQR)
MM: muscle mass, BMI: Body mass index, Carb.: Carbohydrate, MET: Metabolic equivalent (min/week), M3: after threemonths
a: Significant between the two groups in males'sample, b: Significant between the two groups in females'sample, c Significant between males and females in the same group, statistically significant at $p \leq 0.05$.

In Table 2, there were no statistical differences in baseline weight, BMI, and muscle mass (MM) between the two groups. Fat mass (FM) in MGB group was significantly higher than LSG group (M ± SD = 58.7 ± 9.4 and 53.7 ± 7.3 kg respectively) (p=0.042). At baseline, the two groups showed no statistical differences concerning energy, protein, and carbohydrate intakes, but the median fat intake in the LSG group (Median =99.6, IQR= 82.5-128.0 g/d) was higher compared to the MGB group (Median =130.6, IQR= 107.6-138.3 g/d) (p= 0.008). Additionally, the LSG group was more physically active than the MGB group (Median=297.0 MET –min /week vs. 132.0 MET –min /week, p<0.001). (Table 2)

Table 3 demonstrates that after three months following the operation, both LSG and MGB groups lost comparable percentages from their previous weight (M± SD = -17.3 ± 2.3 %, -18.5 ± 3.1 %, respectively), and their fat mass (-24.2 ± 6.4, -25.0 ± 4.3). Nevertheless, the MGB group lost more percent of their MM (-17.2 ±12.4 %) compared to the sleeve group (-11.5 ±5.6 %), with no significant difference between both groups (p= 0.063). Females from both groups lost more MM than males, which is significant only in the MGB group. In MGB group females significantly lost almost quarter (-23.5 ± 11.6 %) of their MM compared to -7.9 ± 6.6 % in males (p=0.001).

The energy intake of the LSG group decreased dramatically from 2,682.9 ± 778.8 Kcal/d (table 2) to 612.7± 179.30 kcal at M3 (Table 3). In the MGB group, the energy intake decreased from 3,121.0 ± 819.0 Kcal/d to 627.8±168.6 Kcal/d. Protein intake in the LSG group decreased from 96.7 ± 37.0 g/d preoperative (Table 2) to only 38.0 ± 14.5 g/d (table 3) at M3, and in the MGB group, protein intake dropped from 113.1 ± 35.2 to 42.23± 14.8 g/d at M3, and this difference between two groups was not significant.

After three months post operatively, the majority of patients (80%) in LSG and 76 % of the MGB group reported protein intake of ≤ 60 grams/day, with no significant difference between the two groups. In both groups, the percentage of MM loss at M3 was significantly higher in patients consuming < 60 g/d of protein (Figure 1). Regarding LSG, the mean MM loss in those who consumed < 60 g protein was -13.0 ± 5.3 % compared to -5.6± 1.5 % in those who consumed > 60 g protein daily (p=0.001). In MGB patients who consumed < 60 g of protein lost a mean of -20.3 ± 12.5 % compared to only a loss of -7.4± 5.9 % in > 60 g protein eaters (p=0.014) (Figure 1).



p1: significant between PI<60 g/d and PI≥60 g/d in each sleeve and bypass groups,
p2: significant between PI<60 g/d in sleeve compared to bypass group
Fig. 1: Relation between protein intake at three months postoperative with percent muscle mass loss

Table 4 shows the variables associated with percent MM loss in both sleeve and bypass groups. In the LSG group, age showed a positive intermediate direct association with MM loss (r= 0.53), whereas protein intake at three months was strongly and inversely correlated with MM loss in the sleeve group (r= -0.81) and showed an intermediate inverse relation in bypass group (r=-0.57). The degree of impaired glycemia expressed by HbA1c showed a strong direct correlation with MM loss in the sleeve group (r= 0.79) and a moderate direct relation in the bypass group (r= 0.68). In addition, higher TSH levels were moderately directly associated with MM loss but only in the bypass group (r= 0.41). As measured by MET min/week, the amount of exercise done after surgery had a moderately inverse association with MM loss in both sleeve (r=0.57) and bypass groups (r=0.49).

Table 4: Correlation between the percentage of muscle mass loss and different variables in the LSG and MGB groups

Parameter	Muscle mass loss %			
	Sleeve (n =25)		Bypass (n =25)	
	r	p	r	p
Age (years)	0.53**	0.006*	-0.03	0.868
Energy intake M3 (kcal/d)	0.47*	0.017*	-0.19	0.362
Protein intake M3(g/d)	-0.81***	<0.001*	-0.57**	0.003*
FBG M0 (mg/dl)	-0.22	0.290	-0.03	0.856
HbA1c M0	0.79***	<0.001*	0.68***	<0.001*
HOMA-IR M0	0.16	0.442	-0.31	0.121
TSH (mIu/ml) M0	0.12	0.550	0.41*	0.039*
MET-min/week M3	-0.53**	0.006*	-0.42*	0.037*

r: Pearson coefficient,*: Statistically significant at p ≤ 0.05, **: Statistically significant at p ≤ 0.01, ***: Statistically significant at p ≤ 0.001.
FBG: Fasting blood glucose, HbA1c: Hemoglobin A1c, TSH: Thyroid-stimulating hormone, MET: Metabolic equivalent (min/week), HOMA-IR: Hemostatic model assessment of insulin resistance, M0: baseline values, M3: after three months.

Table 5: Multivariate linear regression analysis for the variables affecting the percentage of muscle mass loss in LSG and MGB groups

	#Multivariate			
	Sleeve group (n = 25)		Bypass group (n = 25)	
	p	B (95%C.I)	p	B (95%C.I)
Age (years)	0.160	-0.062(-0.151 – 0.027)		
Gender (Female)			0.006*	9.691(3.09 – 16.286)
Protein intake M3 (g/d)	<0.001*	-0.211(-0.288 – -0.134)	0.131	-0.191(-0.445 – 0.062)
HbA1c M0	<0.001*	2.794(2.003 – 3.585)	0.027*	6.092(0.760 – 11.424)
TSH (mIu/ml) M0			0.702	0.460(-2.014 – 2.933)
MET-min/week M3	0.240	-0.001(-0.002 – 0.001)	0.912	0.001(-0.008 – 0.008)

B: Unstandardized Coefficients, C.I: Confidence interval, #: All variables with p<0.05 was included in the multivariate,*: Statistically significant at p ≤ 0.05,
HbA1c: Haemoglobin A1c, TSH: Thyroid-stimulating hormone, MET: Metabolic equivalent (min/week), M0: baseline values, M3: after three months.

In the LSG group, the multivariate model in Table 5 shows that although the significant associations with age and level of physical activity disappeared, the only significant factors that affected MM loss % were lower protein intake (B= -0.21, p<0.001) and higher HbA1c at baseline (B=2.79, p<0.001). Concerning the MGB group, the multivariate analysis revealed that the only significant factors that affected MM loss % at three months were being a female (B= 9.69, p=0.006) and having high HbA1c at baseline (B=6.09,p=0.027).

Discussion

Females represent the majority of cases (60%) in both sleeve and bypass groups in current study. According to the literature, it is evident that women undergoing bariatric surgery are more than men.[18,19] The present study showed a gender difference regarding body composition changes at three months post operatively. This discrepancy in MM loss was only significant in the bypass group, where females lost almost a quarter of their baseline MM. Furthermore, being a female continued to be a significant factor affecting the degree of muscle mass loss at three months post operatively in the univariate and multivariate regression in the MGB group. A similar result was found in a five-year follow-up study[20] that investigated the changes of LBM and MM following RYGB. Females lost a high percentage of FFM in the first year as skeletal muscle (96.7%) which was significantly higher than males (92.0%). Age was found to have a positive intermediate direct relation to MM loss in the sleeve group (r= 0.53), but this significance was not detected in the multivariate logistic regression. Age was reported to have a significant direct effect on MM loss post BS (p<0.01). Younger patients could lose more weight and preserve FFM after RYGB, which can be attributed to increased mobility and lower comorbidity rates.[20]

The current study reported inadequate protein intake in both LSG and MGB, which was significantly related to MM loss. Protein intake at three months was inversely associated with MM loss in the sleeve group (r= -0.817) and demonstrated an inverse association in the bypass group (r=-0.571). This correlation was also significant in the multivariate model of the LSG group but not in the multivariate model of the MGB group. Likewise, a study on LSG patients illustrated that patients with protein intake <60 gm/day lost a higher percentage of relative LBM than patients with protein intake >60 gm/day (M±SD1= 2.8±4.8% vs. 9.3±5.8%, respectively) at six months postoperatively.[21] A 2017 systematic review showed a wide range of lean body mass loss ranging from 10.5 to 27.7 % at six months post-LSG.[22] Inadequate protein intake during the weight-loss period might potentiate the development of sarcopenia. Consequently, supplementation with powdered or liquid protein supplements helps a better weight loss while preventing muscle mass loss, even though poor adherence to protein supplements was also reported.[23]

A 36-month observational follow-up study[24] revealed that a rapid body weight loss was correlated with lean body mass loss during the first three months and up to 12 months after RYGB, which stabilized at 36 months. The mean protein intake was 46 ± 3 and 57 ± 3 g/day at 12- and 36-months after the surgery, respectively, significantly lower than baseline and lower than the recommended intake. In a 12-month cohort study,[10] using BIA, data was collected from 427 consecutive BS patients. Results showed that patients compliant with protein dietary intake (PDI) of > 1g/kg/day at 12 months post-RYGB had a greater % EWL and a higher percentage of lean mass. Moreover, in a randomized controlled study that lasted for six months, it was reported that the control group lost a higher percentage of LBM than the protein supplemented group (27% vs. 21%) at six months post BS.[25] Using the multilinear regression showed that inadequate protein intake is a causative factor of a high percentage of LBM loss (p =0.017),[26] which is consistent with the results of our study.

A strong negative correlation was detected between physical activity and MM loss in the univariate linear regression of both LSG and MGB groups. Habitual physical activity among BS patients could be an important protective factor against LBM loss. A significant inverse correlation has been found between hours spent in physical activity per week and LBM and MM loss at six months (r = 0.23, p =0.046) and 12 months (r = 0.34, p = 0.001) following surgery.[21] Another study has revealed that physical inactivity in BS patients caused decreased muscle strength by 33% and was associated with significant MM loss during the first year after laparoscopic gastric bypass surgery.[27]

It has been suggested that BS patients' glycaemic profile and muscle mass are interrelated. Patients with a controlled glycaemic profile experienced less MM loss than patients with poor glycaemic control,[28] which is mainly due to the vital role of MM in insulin sensitivity which eventually modulates plasma glucose level. Similarly, it has been noted that changes in %MM were inversely correlated with fasting plasma glucose (FPG) and haemoglobin A1c (HbA1c), and patients with less muscle mass loss experienced better glycaemic profile improvements after BS.[29] There was a significant positive correlation between baseline plasma TSH levels and MM loss in our study Morbid obesity is associated with higher TSH concentrations compared to control subjects.[30] A possible explanation of this association would be that a higher TSH level is associated with insulin resistance and higher HbA1C in obese subjects, which is indirectly associated with more MM loss.

Conclusion

Excessive MM loss must be avoided during the rapid weight loss caused by bariatric surgery. Following BS, nutrition advice should emphasise protein intake of at least 60 grams/day following BS, particularly for female patients undergoing MGB or other malabsorptive procedures. Preoperative glycaemic profile assessment should be carried out on all patients, and patients with prediabetes should ensure adequate protein intake (from diet or supplements or both) and physical exercise after BS to prevent excessive MM loss.

Acknowledgements

We would like to thank dietitian NHD for analysing the 24-hour-recall of the study participants.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interests

The Authors declare that there is no conflict of interest and that they did not receive any specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Abelson P, Kennedy D. The obesity epidemic. *Science*. 2004;304(5676):1413.
2. Hubbard VS, Hall WH. Gastrointestinal Surgery for Severe Obesity. *Obes Surg*. 1991;1(3):257-265.
3. Heymsfield SB, Thomas D, Nguyen AM, *et al*. Voluntary weight loss: systematic review of early phase body composition changes. *Obes Rev*. 2011;12(5):e348-61.
4. Heymsfield SB, Gonzalez MC, Shen W, Redman L, Thomas D. Weight loss composition is one-fourth fat-free mass: a critical review and critique of this widely cited rule. *Obes Rev*. 2014;15(4):310-21.
5. Faria SL, Kelly E, Faria OP. Energy expenditure and weight regain in patients submitted to Roux-en-Y gastric bypass. *Obes Surg*. 2009;19(7):856-9.
6. Ma J, Hwang S-J, McMahon GM, *et al*. Mid-adulthood cardiometabolic risk factor profiles of sarcopenic obesity. *Obesity.* 2016;24(2):526-534.
7. Mechanick JI, Apovian C, Brethauer S, *et al*. Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures - 2019 update: cosponsored by American Association of Clinical Endocrinologists/American College of Endocrinology, The Obesity Society, American Society for Metabolic & Bariatric Surgery, Obesity Medicine Association, and American Society of Anesthesiologists. *Surg Obes Relat Dis.* 2020;16(2):175-247.
8. Sherf Dagan S, Goldenshluger A, Globus I, *et al*. Nutritional Recommendations for Adult Bariatric Surgery Patients: Clinical Practice. *Adv Nutr.* 2017;8(2):382-394.
9. Faria SL, Faria OP, Buffington C, de Almeida Cardeal M, Ito MK. Dietary protein intake and bariatric surgery patients: a review. *Obes Surg*. 2011;21(11):1798-805.
10. Raftopoulos I, Bernstein B, O'Hara K, Ruby JA, Chhatrala R, Carty J. Protein intake compliance of morbidly obese patients undergoing bariatric surgery and its effect on weight loss and biochemical parameters. *Surg Obes Relat Dis.* 2011;7(6):733-42.
11. Moizé V, Geliebter A, Gluck ME, *et al*. Obese patients have inadequate protein intake related to protein intolerance up to 1 year following Roux-en-Y gastric bypass.

Obes Surg. 2003;13(1):23-8.

12. Moreira Mde A, Espínola PR, de Azevedo CW. Food intolerances and associated symptoms in patients undergoing Fobi-Capella technique without gastric ring. *Arq Bras Cir Dig*. 2015;28(1):36-9.
13. Garashi N, Kandari J, Ainsworth B, Barac-Nieto M. Weekly Physical Activity from IPAQ (Arabic) Recalls and from IDEEA Activity Meters. *Health.* 2020;12(6):598-611.
14. Hagstromer M. IPAQ_Arabic(Saudi-Arabia)_selfadmin_short.doc. https://sites.google.com/site/theipaq/questionnaire_links. Accessed April 15 2019,
15. Tayel DI, Aboudeif NM, Mohamed NS, Amine EK. Evaluation of Dietary Intake Analysis Using Egyptian Modified Food Processor Software and Traditional Method: A Comparative Study. *Canadian Journal of Clinical Nutrition* 2020 8(1):36-53.
16. Institute NN. Food Composition Tables for Egypt. second edition.Cairo, Egypt: *National Nutrition Institute*; 2006.
17. Gibson RS. Principles of Nutritional Assessment. second edition.New York: Oxford University Press; 2005.
18. Miller-Matero LR, Tobin ET, Clark S, Eshelman A, Genaw J. Pursuing bariatric surgery in an urban area: Gender and racial disparities and risk for psychiatric symptoms. *Obes Res Clin Pract*. 2016;10(1):56-62.
19. Khalil O, Mansy W, Abdalla W, Baiomy T. Laparoscopic sleeve gastrectomy with loop bipartition versus laparoscopic sleeve gastrectomy in treating obese people with type II diabetes mellitus: a prospective randomized comparative study. Original Article. *The Egyptian Journal of Surgery*. 2019;38(3):610-617.
20. Davidson LE, Yu W, Goodpaster BH, DeLany JP. Fat-Free Mass and Skeletal Muscle Mass Five Years After Bariatric Surgery. 2018;26(7):1130-1136.
21. Sherf Dagan S, Tovim TB, Keidar A, Raziel A, Shibolet O, Zelber-Sagi S. Inadequate protein intake after laparoscopic sleeve gastrectomy surgery is associated with a greater fat free mass loss. *Surg Obes Relat Dis.* 2017;13(1):101-109.
22. Ito MK, Gonçalves VSS, Faria S, *et al*. Effect of Protein Intake on the Protein Status and Lean Mass of Post-Bariatric Surgery Patients: a Systematic Review. *Obes Surg*. 2017;27(2):502-512.
23. Nicoletti CF, de Oliveira BA, Barbin R, Marchini JS, Salgado Junior W, Nonino CB. Red meat intolerance in patients submitted to gastric bypass: a 4-year follow-up study. *Surg Obes Relat Dis.* 2015;11(4):842-6.
24. Giusti V, Theytaz F, Di Vetta V, Clarisse M, Suter M, Tappy L. Energy and macronutrient intake after gastric bypass for morbid obesity: a 3-y observational study focused on protein consumption. 2016;103(1):18-24.
25. Schollenberger AE, Karschin J, Meile T, Küper MA, Königsrainer A, Bischoff SC. Impact of protein supplementation after bariatric surgery: A randomized controlled double-blind pilot study. *Nutrition*. 2016;32(2):186-92.
26. Moizé V, Andreu A, Flores L, *et al*. Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-En-Y gastric bypass in a mediterranean population. *J Acad Nutr* Diet. 2013;113(3):400-410.
27. Campanha-Versiani L, Pereira DAG, Ribeiro-Samora GA, *et al*. The Effect of a Muscle Weight-Bearing and Aerobic Exercise Program on the Body Composition, Muscular Strength, Biochemical Markers, and Bone Mass of Obese Patients Who Have Undergone Gastric Bypass Surgery. *Obes Surg*. 2017;27(8):2129-2137.
28. Vaurs C, Diméglio C, Charras L, Anduze Y, Chalret du Rieu M, Ritz P. Determinants of changes in muscle mass after bariatric surgery. *Diabetes & Metabolism.* 2015;41(5):416-421.
29. Ozeki Y, Masaki T, Yoshida Y, Okamoto M, Anai M, Gotoh K. Bioelectrical Impedance Analysis Results for Estimating Body Composition Are Associated with Glucose Metabolism Following Laparoscopic Sleeve Gastrectomy in Obese Japanese Patients. 2018;10(10)
30. Janković D, Wolf P, Anderwald CH, *et al*. Prevalence of endocrine disorders in morbidly obese patients and the effects of bariatric surgery on endocrine and metabolic parameters. Obes Surg. 2012;22(1):62-9.