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Inadequate protein intake after laparoscopic sleeve gastrectomy surgery is associated with a greater fat free mass loss

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Abstract

Background: Low postoperative protein intake may represent a modifiable risk factor that leads to fat free mass (FFM) loss postlaparoscopic sleeve gastrectomy (LSG), but data concerning this phenomenon is scarce.
Objectives: To evaluate the association between daily protein intake and relative FFM loss at 6 (M6) and 12 (M12) months after LSG surgery.
Settings: Private hospital and university hospital.
Methods: A prospective cohort study with 12 months follow-up of 77 patients who underwent LSG surgery. Anthropometrics including body composition analysis measured by multifrequency bioelectrical impedance analysis, 3-day food diaries, food intolerance, and habitual physical activity were evaluated at baseline and at M3, M6, and M12.
Results: Repeated body composition measurements and food diary were available for 77 patients (45 women) at M6 and for 68 patients at M12. Mean age was 42.7 ± 9.4 years and mean preoperative body mass index was 42.2 ± 4.8 kg/m^2. A protein intake of ≥60 g/d was achieved in 13.3%, 32.5% and 39.7% of the study participants at M3, M6 and M12, respectively. FFM significantly decreased at M6 and stabilized at M12. Protein intake of ≥60 g/d was associated with a significantly lower relative FFM loss at M6 among women (8.9 ± 6.5% versus 12.4 ± 4.1%; $P = .039$) and this trend was also reported among men (9.5 ± 5.5% versus 13.4 ± 6.0%; $P = .068$). A logistic regression for the prediction of FFM loss of ≥10% at M6, indicated that protein intake ≥60 g/d is a strong protective factor (odds ratio = 0.29, 95% confidence interval .09–.96, $P = .043$).
Conclusion: Our study supports the currently recommended protein intake goal of ≥60 g/d as an efficient strategy for better preservation of FFM post-LSG. (Surg Obes Relat Dis 2016;▮:00–00.)

Keywords: Obesity; Sleeve gastrectomy; Body composition; Fat free mass; Protein intake

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Morbid obesity is highly prevalent worldwide and a major public health burden [1]. Bariatric surgery is usually considered when other treatments to lose weight have failed [2]. The main benefits of this intervention include sustained weight loss and long-term attenuation and control of

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associated co-morbidities, with consequent improvement in quality of life [3]. Laparoscopic sleeve gastrectomy (LSG) is a bariatric procedure consisting of the resection of the majority of the greater curvature that leaves a narrow stomach tube [4]. Current data provide evidence that LSG is a safe and effective procedure for the management of morbid obesity, resulting in excess weight loss (%EWL) of between 33% and 90% [5]. The total number of bariatric procedures performed worldwide during 2013 was 468,609, 37% of them were LSG surgeries [1]. In Israel, almost 9000 people with morbid obesity underwent bariatric surgery during 2014 and LSG was the leading procedure accounting for about 80% of surgeries [6].

Body mass index (BMI) is the most common parameter used to classify the weight status of individuals. However, there may be considerable variation in body composition even between individuals with the same BMI [7]. To improve the assessment of the quality of weight loss after bariatric surgery, it was suggested that body composition assessment should become an integral part of the clinical evaluation preoperatively and postoperatively [7]. Bariatric surgery markedly affects fat free mass (FFM) along with fat mass (FM) [8]. At 1 year after surgery, LSG was reported to be more effective in inducing EWL and body fat loss compared with conservative weight loss treatments, but with the cost of more pronounced FFM and protein loss [9]. The loss of FFM is a negative phenomenon, as nonadipose tissues are responsible for the majority of resting metabolic rate, the regulation of body temperature and weight maintenance [9]. Hypoalbuminemia (serum albumin level < 3.5 mg/dL) may occur especially during the first months postsurgery and it is more common in malabsorptive procedures. Suggested diagnostic methods to detect FFM loss include the determination of serum albumin and direct FFM evaluation [10]. However, blood proteins are less sensitive indicators of nutritional status [11].

The degrees of physical activity or sedentary behavior, protein intake, age, and male gender modulate the risk of FFM depletion postsurgery [8,10,12,13]. Postoperative protein intake leads to satiety induction, improves nutritional status, and reduces muscle breakdown [11]. Therefore, current consensus guidelines recommend average daily protein intake of 60–80 g or 1.1 g/kg of ideal body weight (IBW) after LSG to minimized postsurgical FFM loss [10,14], although there is no conclusive evidence to support this recommendation [12]. Only a few small studies tested the effect of protein intake on FFM change after LSG [12,15]. Therefore, the aim of the present study was to evaluate the association between daily protein intake and relative FFM loss at 6 (M6) and 12 (M12) months post-LSG surgery.

Materials and methods

This prospective cohort study is a part of a randomized clinical trial of 6 months treatment with probiotic versus placebo and another 6 months follow-up of 100 nonalcoholic fatty liver disease patients who underwent LSG surgery during February 2014 to January 2015. Inclusion criteria were 18–65 years old, BMI > 40 kg/m^2 or BMI > 35 kg/m^2 with co-morbidities, approval of the Assuta Hospital's committee to undergo bariatric surgery, ultrasound diagnosed nonalcoholic fatty liver disease, and ability to sign an informed consent. Major exclusion criteria were excessive alcohol consumption, mental illness or cognitive deterioration, and previous bariatric surgery. Diabetic patients who were treated with antidiabetic medications other than Metformin exclusively at a stable dose for at least 6 months were also excluded. Medical history for co-morbidities was obtained from the patients' medical records.

Data of the combined treatment groups is presented in this study, since no difference between them was observed for the measurements discussed here. All procedures performed in this study were approved by the institutional review boards of both participating hospitals and all participants signed an informed consent. The study was preregistered in the NIH registration website (TRIAL no. NCT01922830).

Anthropometric measurements

Anthropometric measurements were performed following a uniform protocol at baseline, M3, M6, and M12. Weight and height were measured on a digital medical scale, and waist circumference was measured twice at the level of the umbilicus according to a uniform protocol. BMI was calculated using weight (in kilograms) divided by the height squared (in square meters). EWL percentages were calculated as follows: ([pre-operation weight − postoperation weight]/[pre-operation weight − IBW]) × 100. IBW was considered as the weight for BMI 25 kg/m^2 [16]. Percentages of total weight loss were calculated as follows: ([pre-operation weight − postoperation weight]/[pre-operation weight]) × 100.

Patients underwent measurement for body composition (%FM, FM [kg] and FFM [kg]) using a multifrequency bioelectrical impedance analysis (BIA, Inbody 200®, Biospace, Seoul, South Korea) at baseline, M6, and M12. Body composition was not measured at M3 since we anticipated that only a very small proportion of the patients will reach a recommended protein intake at this time point. Patients were evaluated after an overnight fast of 12 hours and according to the specifications from the manufacturer. BIA is a noninvasive and relatively inexpensive method that has been used for measuring body composition [7,17], and was found to be a valid alternative to assess body composition in morbidly obese patients [7]. The researcher who performed the measurements was blinded to the dietary intake records at the time of the measurement.

Relative FFM loss at M6 and M12 is presented as the percentages of FFM loss compared to FFM at baseline ($[FFM_{M0} - FFM_{Mx}]/FFM_{M0}) \times 100$ and as FFM loss as a percentage of weight loss at M6 and M12 ($[FFM_{M0} - FFM_{Mx}]/[weight_{M0}\text{-}weight_{MX}]) \times 100$.

Dietary intake evaluation

Patients filled out a detailed 3-day food diary, reporting their recent dietary composition, at baseline, M3, M6, and M12. A nutritionist reviewed the food diaries with the patients to verify that dietary intake was reported properly and to reduce underreporting.

The nutrient content of the food items was obtained from the Israeli National Nutrient Database, Food and Nutrition Administration, Ministry of Health ("Zameret" software).

Protein intake

Patients were categorized based on the accomplishment of 2 recommended daily protein intake goals: $\geq$60 g/d or $\geq$1.1 g/IBW/d. The analysis of the food diaries was performed by a researcher who was blinded to the body composition data at all time points.

Patients were not routinely recommended to consume protein supplements; however, they were encouraged to consume high-protein foods.

Questionnaires for food tolerance assessment and physical activity

Patients filled out a self-reported questionnaire for quick assessment of food tolerance after bariatric surgery with a score of 1 (lowest score) to 27 (highest score), which was previously described by Suter et al. [18]. Data on physical activity in the last 3 months were collected by an accepted questionnaire routinely used in national surveys, which was tested for face, content, and consensual validity. The questionnaire included questions about the number of training sessions per week, duration of exercise, and type. Weekly hours spent doing physical activity were calculated by the multiplication of the number of training sessions per week with the duration of exercise in hours. Questionnaires for food tolerance assessment and physical activity were filled out by patients at baseline, M3, M6, and M12.

Statistical analysis

Statistical analyses were performed using SPSS version 21 (SPSS Inc., Chicago, IL, USA) software. Continuous variables are presented as means $\pm$ SD and dichotomous/categorical variables as proportions. The normality of the distribution of continuous variables was tested by the Kolmogorov–Smirnov test. If normality was rejected, nonparametric tests were used. The Pearson or the Spearman correlations were performed for continuous or ordinal variables, respectively. To test differences in continuous variables between 2 groups the independent-samples *t* test or the Mann-Whitney test were performed. For comparison of dichotomous or categorical variables the Pearson Chi-Square test was performed. To compare continuous variables between 2 time points the paired *t* test was performed or the Wilcoxon test when needed, and for dichotomous/categorical variables McNemar's test was performed. Binary logistic regression analysis was conducted to determine if protein intake $\geq$60 g/d is an independent predictor for relative FFM loss with a cutoff of 10% adjusted for gender, %EWL, energy intake, and hours spent in physical activity per week. $P < .05$ was considered statistically significant for all analyses.

Results

Presurgery, 96 patients had measurements for body composition and completed food diary; however, those measurements were available for 77 patients at M6 (18 lost to follow-up and 5 did not complete the measurements) and for 68 patients at M12 (5 lost to follow-up and 4 did not complete the measurements). Their mean age was 42.7 $\pm$9 .4 years (range: 22.0–63.0) with mean preoperative BMI of 42.2 $\pm$ 4.8 kg/m^2 (range: 34.7–60.0). Mean FFM was 64.1 $\pm$ 13.7 kg and mean FM was 56.9 $\pm$ 11.1 kg. Characteristics of the study participants at baseline are depicted in Table 1.

Energy and macronutrients intake

As expected after LSG, energy intake drastically decreased at M3 and slightly increased at M6 and at M12, although it did not reach baseline intake levels ($P < .05$ for both genders; Table 2). Accordingly, total absolute protein intake significantly decreased at M3 and slightly increased at M6 and at M12 in both genders. Mean protein intake was 93.5 $\pm$ 35.4 g (range: 31.7–207.3), 41.4 $\pm$ 18.5 g (range: 10.7–108.3), 51.7 $\pm$ 18.9 (range: 16.7–109.0) and 58.1 $\pm$ 22.9 g (range: 19.7–154.3) at baseline, M3, M6, and M12, respectively (Table 2).

Most of the patients did not report adequate protein intake according to the recommended goal of $\geq$60 g/d at the first 6 months after LSG (43.8% of the men and 24.4% of the women; Table 2). Moreover, only a minority of the patients achieved the protein intake goal of 1.1 g/IBW/d at M6 (n = 9, 11.7%) and at M12 (n = 8, 11.8%). Therefore, to avoid an underpowered analysis, we focused on the accepted goal of 60 g/d.

Physical activity and food intolerance score

Hours spent in physical activity per week increased significantly from baseline at all time points among both genders (Table 2). Significant negative correlation was found between hours spent in physical activity per week and percent relative FFM loss at M6 (r = −.23, $P = .046$) and at M12 (r = −.34, $P = .001$). Therefore, physical activity was adjusted for the multivariate analysis.

Table 1
Characteristics of the study participants, anthropometrics and body composition according to protein intake goal at 6 and 12 months postsurgery

Parameter[†]	Pre-surgery	M6		M12[‡]	
	N = 77	Protein intake < 60 g/d N = 52	Protein intake ≥60 g/d N = 25	Protein intake < 60 g/d N = 41	Protein intake ≥60 g/d N = 27
Age (years)	42.7 ± 9.4	42.3 ± 9.6	43.4 ± 9.1	43.0 ± 9.3	43.3 ± 9.4
Gender (men)	41.6	34.6	56.0	26.8	66.7[*]
Co-morbidities					
Type 2 diabetes (%)[§]	11.7	13.5	8.0	12.2	7.4
Sleep apnea (%)[§]	10.4	5.8	20.0	7.3	14.8
Hypothyroidism (%)[§]	11.7	9.6	16.0	17.1	7.4
Current smoker (%)[§]	6.5	7.7	4.0	7.3	0.0
Anthropometrics					
Height (m)	1.69 ± 0.09	-	-	-	-
Weight (kg)	121.4 ± 18.9	90.3 ± 14.5	93.1 ± 10.2	78.8 ± 12.2	89.9 ± 12.1[*]
BMI $_{M0}$[§] (kg/m2)	42.2 ± 4.8	42.5 ± 5.0	41.7 ± 4.4	41.8 ± 4.3	42.3 ± 5.4
BMI (kg/m2)	42.2 ± 4.8	31.9 ± 3.8	31.5 ± 2.8	28.4 ± 3.3	29.9 ± 2.9
WC (cm)	124.7 ± 12.5	100.3 ± 10.8	101.9 ± 8.5	91.9 ± 10.1	98.0 ± 8.3[*]
Body composition					
FFM $_{M0}$[§] (kg)	64.1 ± 13.7	62.6 ± 14.3	67.3 ± 11.9	59.4 ± 12.6	71.5 ± 13.4[*]
FFM (kg)	64.1 ± 13.7	54.4 ± 12.0	60.9 ± 10.1[*]	51.2 ± 10.7	62.8 ± 11.4[*]
FM (kg)	56.9 ± 11.1	35.5 ± 9.4	31.5 ± 7.1	26.9 ± 7.5	26.4 ± 6.9
FM (%)	47.2 ± 6.4	39.5 ± 8.1	34.2 ± 7.0[*]	34.5 ± 8.1	29.7 ±7.2[*]
FM/FFM	0.9 ± 0.2	0.7 ± 0.2	0.5 ± 0.2[*]	0.5 ± 0.2	0.4 ± 0.2[*]
EWL (%)	-	62.4 ± 14.1	61.7 ± 10.1	80.7 ± 19.2	72.7 ± 12.7
Total weight loss (%)	-	24.8 ± 5.0	24.2 ± 4.8	31.8 ± 8.1	29.0 ± 6.3
Relative FFM loss (%)	-	12.8 ± 4.8	9.3 ± 5.8[*]	13.6 ± 6.0	11.9 ± 4.7
Relative FFM loss ≥10%	-	71.2	44.0[*]	80.5	66.7
FFM loss/weight loss (%)	-	26.5 ± 8.0	20.0 ± 12.8[*]	21.5 ± 8.4	23.1 ± 9.6
FFM loss/weight loss ≥20%		80.8	52.0[*]	58.5	51.9
FFM loss/weight loss ≥30%		36.5	16.0	12.2	22.2
FM loss (%)	-	38.6 ± 8.7	43.2 ± 9.0[*]	51.6 ± 12.9	51.8 ± 9.4
Energy intake, physical activity and food tolerance					
Energy intake (kcal/d)	2117.6 ± 920.9	948.4 ± 327.6	1433.4 ± 508.2[*]	1008.2 ± 248.0	1734.2 ± 459.1[*]
NPC:N[¶]	122.7 ± 45.0	120.7 ± 41.8	95.4 ± 27.6[*]	123.7 ± 38.5	112.8 ± 37.1
Physical activity (hr/wk)	0.8 ± 1.6	2.7 ± 2.5	2.9 ± 2.5	1.8 ± 1.7	3.0 ± 2.4[*]
Food tolerance (score)	-	21.4 ± 3.8	22.4 ± 3.5	21.4 ± 3.9	23.1 ± 3.5

BMI = body mass index; EWL = excess weight loss; FFM = fat free mass; FM = fat mass; N = nitrogen; NCP = noncalories protein; WC = waist circumference.
[†]Values expressed as the average ± SD, unless otherwise stated.
[*]$P < .05$ between the cutoff for the protein intake goal (60 g/d).
[‡]At M12, 9 participants lost to follow up, thus 68 patients had full data for this time point.
[§]Represents baseline values for all comparisions.
[¶]NPC:N = nonprotein calories to nitrogen ratio was calculated as follows: total nonprotein calories/grams of nitrogen consumed per day (1 gr N = 6.25 g protein).

Food tolerance score was significantly improved from M3 to M6 and to M12 ($P < .05$ for both genders; Table 2). There was a significant positive correlation between protein intake and food tolerance score at M6 for men (r = .39, $P = .028$), but not for women (r = −.15, $P = .315$). No association was noted between the food tolerance score and FFM loss at M6.

Protein intake and relative FFM loss at 6 and 12 months follow-up

Table 1 presents postsurgery changes in anthropometric and body composition parameters at M6 and M12 by achievement of the recommended protein intake goal of 60 g/d. For both genders, FFM significantly decreased at M6 and then stabilized at M12 (Fig. 1A), whereas FM continued to decrease during all the 12 months follow-up (Fig. 1B). There was a significant inverse correlation between daily protein intake as a continuous variable and relative FFM loss at M6 (r = −.39, $P = .008$ for women and r = −.40, $P = .023$ for men; Fig. 2A), but not at M12 (r = −.30, $P = .06$ for women and r = −.11, $P = .569$ for men).

Protein intake of ≥60 g/d was associated with a significantly lower relative FFM loss than protein intake of < 60 g/d at M6 among women (8.9 ± 6.5% versus 12.4 ± 4.1%; $P = .039$) and this trend was also found among men (9.5 ± 5.5% versus 13.4 ± 6.0%; $P = .068$; Fig. 2B). Furthermore,

Table 2
Reported daily energy and macronutrient intake, food tolerance score and physical activity performance at baseline and 3, 6, and 12 months postsurgery

	All participants				Men				Women			
Parameter[†]	Pre-surgery	M3	M6	M12	Pre-surgery	M3	M6	M12	Pre-surgery	M3	M6	M12
	N = 77	N = 77	N = 77	N = 68	N = 32	N = 32	N = 32	N = 29	N = 45	N = 45	N = 45	N = 39
Energy intake (kcal/d)	2117.6 ± 920.9	838.9 ± 348.5*	1105.9 ± 453.7*	1296.5 ± 496.5*	2441.2± 1136.5	979.2 ± 398.5*	1280.3 ± 555.8*	1571.6 ± 551.4*	1889.7 ± 655.5	740.1 ± 271.9*	981.8 ± 316.2*	1091.9 ± 331.5*
Carbohydrates (g/d) (%kcal)	222.2 ± 125.8 (40.8)	90.8 ± 47.0* (42.8)	121.1 ± 67.2* (42.6)	142.3 ± 69.8* (43.4)	250.1 ± 164.3 (38.3)	103.8 ± 55.4* (41.9)	147.3 ± 85.3* (44.4)	174.4 ± 86.6* (43.4)	202.5 ± 86.5 (42.6)	81.7 ± 38.2* (43.4)	102.5 ± 42.8* (41.4)	118.3 ± 41.1* (43.4)
Fats (g/d) (% kcal)	90.4 ± 43.9 (38.4)	32.7 ± 16.9* (35.1)	43.9 ± 19.4* (36.1)	52.4 ± 22.6* (36.3)	104.8 ± 51.3 (39.1)	38.5 ± 21.0* (35.3)	49.0 ± 23.1* (34.9)	63.8 ± 24.5* (36.6)	80.3 ± 34.9 (37.8)	28.7 ± 11.9* (34.9)	40.3 ± 15.5* (36.9)	44.0 ± 17.0* (36.0)
Proteins (g/d) (% kcal)	93.5 ± 35.4 (18.7)	41.4 ± 18.5* (20.2)	51.7 ± 18.9* (19.6)	58.1 ± 22.9* (18.4)	113.7 ± 35.8 (20.6)	49.8 ± 22.0* (20.9)	57.8 ± 20.5* (19.3)	69.3 ± 24.1* (18.4)	79.3 ± 27.8 (17.4)	35.5 ± 12.9* (19.8)	47.4 ± 16.5* (19.7)	49.8 ± 18.1* (18.5)
NCP:N[§]	122.7 ± 45.0	107.1 ± 36.6*	112.5 ± 39.4*	119.4 ± 38.0	111.0 ± 42.6	103.5 ± 36.5	114.7 ± 36.8	119.8 ± 37.9	130.9 ± 45.2	109.6 ± 37.0*	110.9 ± 41.5*	119.0 ± 38.6
Patients achieving a protein intake ≥60 g/d (%)	84.0	13.3*	32.5*	39.7*	96.8	29.0*	43.8*	62.1*	75.0	2.3*	24.4*	23.1*
Patients achieving a protein intake ≥1.1 g/kg IBW/d (%)	65.3	2.7*	11.7*	11.8*	71.0	6.5*	15.6*	13.8*	61.4	0.0*	8.9*	10.3*
Food tolerance (score)	-	20.0 ± 4.1	21.7 ± 3.7‡	22.2 ± 3.8‡	-	19.9 ± 4.2	21.4 ± 4.0‡	22.0 ± 3.9‡	-	20.1 ± 4.1	21.9 ± 3.6‡	22.3 ± 3.7‡
Physical activity (hr/wk)	0.8 ± 1.6	2.5 ± 2.3*	2.7 ± 2.5*	2.2 ± 2.1*	1.4 ± 2.2	2.7 ± 2.1*	3.2 ± 2.6*	3.0 ± 2.4*	0.4 ± 0.7	2.4 ± 2.4*	2.4 ± 2.4*	1.7 ± 1.6*

IBW = ideal weight; N = nitrogen; NCP = noncalories protein.
*$P < .05$ compared with baseline.
†Values expressed as the average ± SD, unless otherwise stated.
‡$P < .05$ compared with M3.
§NPC:N = nonprotein calories to nitrogen ratio was calculated as follows: total nonprotein calories/grams of nitrogen consumed per day (1 g N = 6.25 g protein).

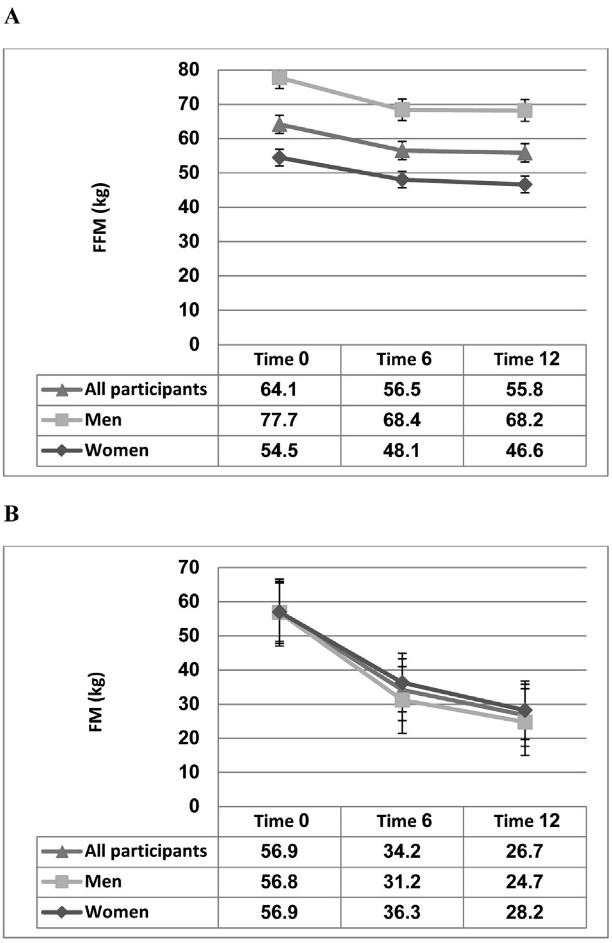

Fig. 1. Changes in FFM (A) and FM (B) from baseline at 6 and 12 months postsurgery by gender. FFM = fat free mass; FM = fat mass. n = 77 at M0 and M6 (n = 32 for men and n = 45 for women), n = 68 at M12 for all participants (n = 29 for men and n = 39 for women).

protein intake of ≥60 g/d was associated with a significantly lower percent of patients with clinically significant FFM loss of ≥10% (Fig. 2C).

Multivariate analysis for the prediction of FFM loss

A logistic regression for the prediction of FFM loss of ≥10% at M6 was performed, adjusting for all variables that were significantly different between the protein intake categories (Table 2) and may be potential confounders. As depicted in Table 3, a protein intake ≥60 g/d was a strong independent protective factor from ≥10% FFM loss at M6 (odds ratio [OR] = .29, 95% confidence interval [CI] .09–.96, P = .043). Percent EWL was associated with increased odds for FFM loss of ≥10% at M6 (OR = 1.06, 95% CI 1.01–1.11, P = .015; Table 3).

Discussion

This study supports the currently recommended daily protein intake of ≥60 g/d, which was associated with a

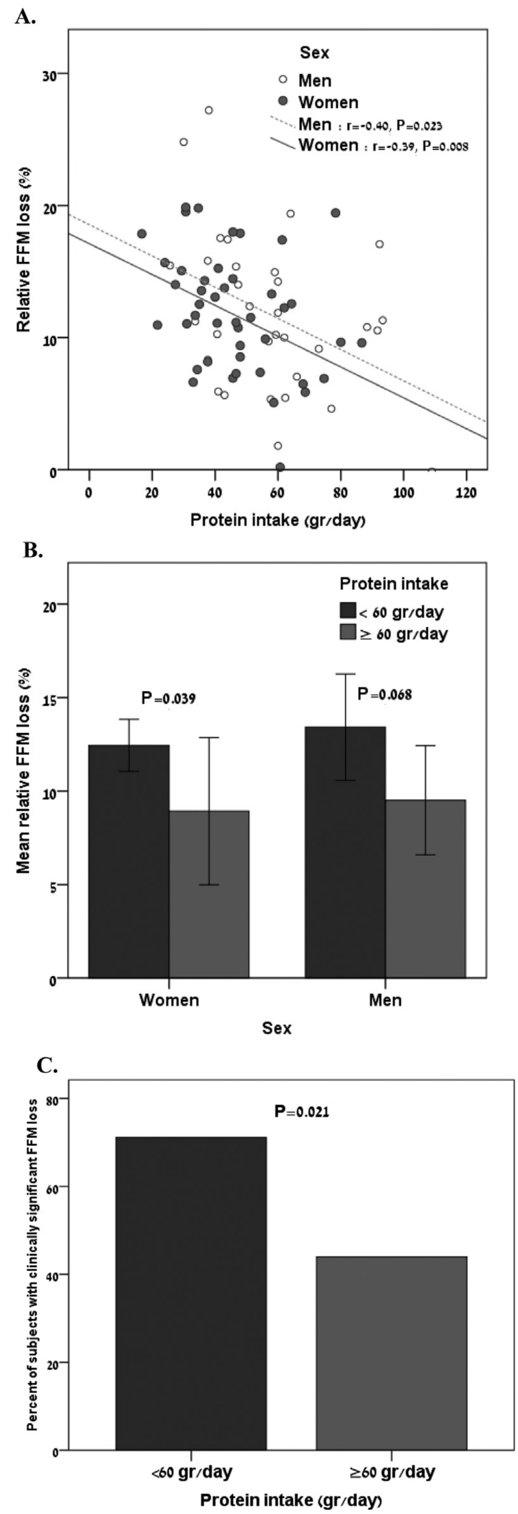

Fig. 2. Relative FFM loss from baseline according to daily protein intake goal at 6 months postsurgery; correlation between relative FFM loss and daily protein intake (A), relative FFM loss (mean ± SE) according to daily protein intake goal of 60 g/d (B), percent of patients with clinically significant FFM loss (≥10%) by daily protein intake goal of 60 g/d (C). FFM = fat free mass; IBW = ideal weight. n = 77 (n = 32 for men and n = 45 for women). All participants: n = 52 for < 60 g protein intake/d and n = 25 for ≥60 g protein intake/d. Men: n = 18 for < 60 g protein intake/d and n = 14 for ≥60 g protein intake/d. Women: n = 34 for < 60 g protein intake/d and n = 11 for ≥60 g protein intake/d.

Table 3
Multivariate analysis for the prediction of relative FFM loss ≥10% at 6 and 12 months postsurgery

Parameter	OR (95% CI)	*P* value
6 months postsurgery		
Gender (men)	1.26 (.41–3.88)	.691
EWL $_{M6}$ (%)	1.06 (1.01–1.11)	.015
Protein intake ≥60 $_{M6}$ (g/d)	.29 (.09–.96)	.043
Energy intake $_{M6}$ (kcal/d)	1.00 (1.00–1.00)	.839
Physical activity $_{M6}$ (hr/wk)	.90 (.73–1.11)	.319
12 months postsurgery		
Gender (men)	2.19 (.45–10.63)	.330
EWL (%) $_{M12}$	1.06 (1.01–1.11)	.025
Protein intake ≥60 $_{M12}$ (g/d)	2.68 (.35–20.68)	.344
Energy intake $_{M12}$ (Kcal/d)	1.00 (1.00–1.00)	.152
Physical activity $_{M12}$ (hr/wk)	.52 (.34–.79)	.002

CI = confidence interval; EWL = excess weight loss; FFM = fat free mass; OR = odds ratio.

significantly lower relative FFM loss 6 months after LSG. In addition, our study identified protein intake of < 60 g/d as an independent and useful predictor for relative FFM loss of at least 10%, 6 months after LSG. Interestingly, at 12 months after LSG protein intake was no longer associated with FFM loss. This lack of association can be explained by the fact that FFM loss was not significant between 6 to 12 month after LSG, implying that the critical period for adequate protein intake to prevent FFM loss is within the first 6 months postsurgery.

In our study, a low compliance with the recommended protein intake was found; 37.9% of the men and as much as 76.9% of the women consumed < 60 g/d of protein, and the vast majority (86.2% of the men and 89.7% of the women) had protein intake of <1.1 g/IBW/d at M12. Similarly, Andreu et al., Moizé et al., and Verger et al. reported protein intake under the recommended value of 60 g/d in a high proportion of LSG patients 12 months postsurgery [12,15,19]. This gap between recommendations and practice can be explained by the postoperative reduced gastric volume, intolerance to high protein-containing foods and vomiting [11]. We found a significant positive association between protein intake and food tolerance score at M6 among men, an association that can explain, at least in part, the low protein intake postsurgery.

Adequate protein intake after bariatric surgery is of utmost importance to prevent the patients from experiencing FFM loss, hair loss, poor wound healing, and also, rarely, protein-calorie malnutrition [19,20]. To achieve the protein intake recommendation of at least 60 g/d, protein-rich foods (e.g., lean meat, fish, dairy products, eggs, soya products and legumes) should be preferentially consumed over foods high in carbohydrates or fats [11]. The quality and composition of protein sources are also very important, particularly with respect to the quantity of leucine, which helps maintain muscle mass, and thus is particularly important for this patient group [11]. Patients who fail to consume at least 60 g/d of protein in their diet may need to increase protein intake through protein supplements. A recent published randomized clinical trial indicated that protein supplementation post-LSG helped reaching the recommended goal for protein intake without negative impact on renal function [21].

We observed a significant decrease in FM and in FFM at M6 and M12 after surgery; however, at M6, FFM loss slowed down whereas FM continued to decrease at M12. This result is in accordance with previous studies that assessed body composition change post LSG [4,5,9,19]. However, the spectrum of FFM loss in weight loss interventions is unknown [22] and no "gold standard" exists for a "reasonable" FFM loss postbariatric surgeries. Our results found at M12 a mean FFM loss/weight loss of 22.3 ± 8.8%. Those results are similar to those of Damms-Machado et al., which reported FFM loss/weight loss of 25.4% at 12 months post-LSG [5]. The mean %EWL at M12 in our study was 76.7%, which is higher than that reported in other studies [23,24], but similar to a recent published study on 3003 LSG patients from Israel [25].

One plausible explanation to the favorable effect of adequate protein intake on the lower relative FFM loss post-LSG can be a relatively low nonprotein calories to nitrogen (NPC:N) ratio. Although there is no recommendation for a certain value of NPC:N ratio for the bariatric patients, we found that daily protein intake of ≥60 g/d was associated with significant lower NPC:N ratio than daily protein intake of <60 g/d at M6. This finding can be related to the better preservation of FFM among patients who consumed more protein at a catabolic state [26].

Only a few studies examined the association between protein intake and the changes in body composition after LSG. Andreu at al. reported that a daily protein intake of <60 g/d was associated with a greater loss of FFM at 4 months post-LSG, but only among men [12]. Moizé et al. found that protein intake ≥60 g/d or ≥1.1 g/IBW/d was associated with lower FFM loss at 4 and 12 months post-LSG among both men and women [15]. Both of those studies did not assess habitual physical activity among the bariatric surgery patients, which may be an important confounder. We found that the number of weekly hours spent in physical activity increased significantly from baseline and was a negatively correlated with relative FFM loss at M6 and M12. However, adjustment for physical activity did not attenuate the association between protein intake and FFM loss.

Our study has several limitations. First, we used BIA and not the dual-energy X-ray absorptiometry (DXA) for body composition measurement. However, DXA is expensive and has a weight limit (in most cases, 120 kg), whereas the multifrequency BIA was found to be a valid alternative to assess body composition in morbidly obese patients with comparable results to DXA [7]. Second, we used a 3-day food diary for all time points rather than a 7-day food diary to estimate daily protein intake. This option was chosen since previous studies indicated that the 7-day food diary may lead to misreporting due to participant fatigue and that the use of shorter recording periods (3 days) may help to optimize overall participation because of the lower burden [27]. Although food diaries are considered a reliable method for the evaluation of food intake since it relies less on recall, the possibility of a report bias, especially underreporting as frequently observed in obese patients [28], still exists. To reduce this potential bias, the nutritionist reviewed the food diaries with the patients at all time points. Importantly, any misclassification bias in either nutritional intake or FFM measurement is expected to be nondifferential and thus can only lead to underestimation of the observed associations. Third, the small number of patients who achieved the protein intake goal of 1.1 g/IBW/d did not allow sufficient statistical power to test the association with FFM loss postsurgery. Fourth, we did not differentiate different protein sources or proteins with different biological value, a refinement that will have to be performed in future studies, most probably with a larger sample size.

Our study is one of the largest studies testing the novel association between protein intake and changes occurring in body composition after LSG, and the only one that examined in parallel protein intake, habitual physical activity, food intolerance, and body composition. A future study with a longer follow-up to the point when weight loss is stabilized or there is weight regain is needed to determine if protein intake and body composition are stable after LSG and if FFM loss is associated with a reduction in functional strength.

Conclusion

A large proportion of the patients during the first year after LSG, do not meet the currently recommended daily protein intake of at least 60 g/d. Our data emphasize the importance of an adequate protein intake after LSG and supports the currently recommended protein intake goal of $\geq$60 g/d as an efficient strategy to better preserve FFM post-LSG.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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