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ORIGINAL CONTRIBUTIONS

Food Addiction and Binge Eating During One Year Following Sleeve Gastrectomy: Prevalence and Implications for Postoperative Outcomes

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Abstract

Background Food addiction and binge eating are common among individuals with obesity. However, a paucity of studies prospectively examined the prevalence and implications of food addiction before and post-bariatric surgery. We aimed to examine the prevalence of food addiction and binge eating before and after sleeve gastrectomy (SG) and to assess their associations with behavioral and weight loss outcomes.

Methods We followed at 3 (M3), 6 (M6), and 12 (M12) months postoperative, 54 women who underwent SG. Data collected including anthropometrics, nutritional intake, food tolerance, and physical activity measures. The Yale Food Addiction Scale and the Binge Eating Scale were used to characterize food addiction and binge eating, respectively.

Results The mean baseline age and BMI were 32.1 ± 11.1 years and 44.9 ± 4.9 kg/m^2, respectively. Pre-surgery, food addiction, and binge eating were identified in 40.7% and 48.1% of patients, respectively. The prevalence of food addiction decreased significantly up to M6, but increased to 29.3% at M12. The prevalence of binge eating decreased significantly through the follow-up up to 17.4% at M12. Those who met criteria for food addiction at M12 achieved significantly lower excess weight loss at M12 compared with those not meeting this criterion ($P = 0.005$). Food addiction scores at M12 negatively correlated with weekly physical activity ($r = -0.559$; $P < 0.001$) and food tolerance scores ($r = -0.428$; $P = 0.005$).

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Conclusions The reduction in food addiction observed at M6 was not maintained at M12. Food addiction at M12 was associated with poorer weight loss, eating, and lifestyle behaviors. Clinical practice should focus on the psychological aspects associated with obesity.

Keywords Obesity · Bariatric surgery · Binge eating · Food addiction · Eating behavior

Abbreviations

BE	Binge eating
BES	Binge Eating Scale
BS	Bariatric surgery
BMI	Body mass index
EWL	Excess weight loss
IBW	Ideal body weight
PA	Physical activity
RYGB	Roux-en-Y gastric bypass
SG	Sleeve gastrectomy
TBWL	Total body weight loss
WC	Waist circumference
YFAS	Yale Food Addiction Scale

Introduction

Sleeve gastrectomy (SG) is the most common bariatric surgery (BS) type performed today; however, data on its impact on psychological outcomes and eating behaviors are scarce [1]. Obesity state is related to significant psychological difficulties including depression, anxiety disorder, emotional eating, and maladaptive eating behaviors including binge eating disorder (BED) [1]. Binge eating is highly prevalent among candidates for BS, and has been reported in the range of 6–50% [1, 2]. Presently, most data on binge eating in relation to BS are derived from studies on Roux-en-Y gastric bypass and adjustable gastric banding [3, 4], while only a few studies evaluated binge eating among individuals who underwent SG [1, 2, 5]. Most of the relevant studies published to date reported reductions in binge eating symptoms post-surgery [3, 4]; however, at longer follow-up, binge eating has been shown to revert and even return to pre-surgery levels [1]. Food addiction is characterized by craving and consumption of highly palatable foods (e.g., processed foods high in fat and sugar) [6]. Although not formally recognized by the DSM-5, food addiction (FA) has been well described in the scientific literature [7]. Food addiction shares some clinical features with binge eating and is also common among individuals with obesity [8]. Food addiction has been found to be associated with psychosocial impairment including depression, impulsivity, eating disorder psychopathology, and poorer self-control [6]. The Yale Food Addiction Scale (YFAS) is most often used to conceptualize and measure food addiction [6, 9]. The prevalence of food addiction has been reported as up to 42% in candidates for BS, and up to 57% in adults with obesity and binge eating [9, 10]. A paucity of studies examined food addiction prospectively among individuals who underwent BS, both before and following the surgical procedure [6, 10–12]. This prospective study aimed to examine the prevalence of food addiction and binge eating before and 1 year following SG surgery, and to assess possible associations of food addiction and binge eating with weight loss outcomes and eating/behavioral patterns postoperatively.

Materials and Methods

Subjects This prospective cohort study is a part of a randomized clinical trial of 2-month treatment with preoperative vitamin administration vs. standard pre-surgery care and 12-month follow-up, aimed to assess bone density among 62 women who were candidates for SG. The data presented in this study are for the combined treatment groups, since differences between them were not observed for the measurements discussed here. Inclusion criteria were age 18–65 years and BMI ≥ 40 kg/m^2 or BMI ≥ 35 kg/m^2 with comorbidities. Major exclusion criteria included untreated mental illness or unstable mental state, pregnancy, lactation, chronic conditions affecting bone metabolism and previous BS. All the procedures performed in this study were approved by the institutional review boards of the participating hospital (Hadassah Ein Kerem Medical Center) and all the participants signed an informed consent. The study was pre-registered in the NIH registration website (identifier: NCT02483026). Participants were evaluated during January 2018 to January 2019 at baseline (2 months preoperatively, M0), 3 (M3), 6 (M6), and 12 (M12) months postoperatively.

Anthropometrics Weight was measured on a digital medical scale; height was measured by a stadiometer and waist circumference was measured twice according to a uniform protocol. BMI was calculated by weight (in kilograms) divided by the height squared (in square meter). Percentages of excess weight loss (% EWL) were calculated as follows: [(preoperative weight-postoperative weight) / (preoperative weight-ideal weight)] × 100. Ideal body weight (IBW) was considered the weight for BMI 25 kg/m^2. Percentages of total body weight loss (TBWL) were calculated as follows: ([preoperative weight-postoperative weight] / [preoperative weight]) × 100.

Dietary Intake, Food Tolerance, and Physical Activity Evaluation Participants filled a 3-day food diary to assess macronutrient and micronutrient consumption from food. This was computed with the Israeli nutritional software "Zameret." Participants were asked to complete a physical activity (PA) diary that assessed the frequency, type, and duration of each activity, for a 7-day period [13]. Additionally, patients filled a questionnaire for quick assessment of food tolerance after BS, with a score of 1 to 27 (a high score represented high food tolerance) [14]. Translated versions of this questionnaire have been used in studies in Israel [15].

Binge Eating Scale and Food Addiction Assessment The Binge Eating Scale (BES) [16, 17] is a 16-item instrument that is widely used as a self-report measure of binge eating severity [18]. In the context of individuals who underwent BS, the instrument showed high internal consistency (Cronbach's alpha = 0.90) [19], as well as high sensitivity and adequate specificity in classifying persons with and without binge eating [18]. For the purpose of this study, a frequent previously used adaptation was used, in which a score greater than 17 classifies "binge eaters" [17]. Food addiction was assessed by the YFAS, a 25-item self-report measure that assesses symptoms of food addiction [9]. The YFAS is scored both dimensionally (a "symptom" score, based on the number of symptoms endorsed) and dichotomously (a "diagnosis," by endorsing three or more symptoms and clinically significant impairment or distress) [3, 9]. The YFAS has demonstrated validity and reliability in bariatric candidates and post-surgical patients [20]. Hebrew and Arab translations of the original validated BES questionnaire and the YFAS were attained in steps, according to developed methodologies [21].

Statistical Methods All the statistical analyses were performed using SPSS version 25.0. If normality was rejected by the Kolmogorov–Smirnov test, nonparametric tests were used. Continuous variables are presented as means ± SD or median and IQR, as appropriate; and dichotomous/categorical variables as proportions. 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. For dichotomous/categorical variables, McNemar's test was performed. A mixed-model repeated-measures analysis was conducted to examine associations of anthropometrics and other variables with weight loss and behavioral outcomes.

Results

Characteristics of the Participants Of the 62 women who enrolled in the study, 4 eventually did not undergo SG surgery and 4 did not complete the 12-month follow-up post-surgery. Therefore, the final sample included 54 women who had anthropometric measurements at the M12 follow-up visit, and the dropout rate was considered 12.9%. Preoperative characteristics according to diagnosis of food addiction and binge eating at baseline are described in Table 1.

Table 1 Characteristics of women who underwent sleeve gastrectomy according to food addiction (FA) and binge eating (BE) status at baseline (n = 54)

Parameter†	Non-FA n = 32	FA n = 22	P value	Non-BE n = 28	BE n = 26	P value
Age (years)	32.9 ± 11.4	30.8 ± 10.8	0.499	32.1 ± 11.9	32.1 ± 10.4	0.992
Weight (kg)	114.4 ± 12.1	119.2 ± 17.3	0.227	114.1 ± 12.6	118.8 ± 16.2	0.235
BMI (kg/m^2)	44.9 ± 4.4	44.9 ± 5.6	0.974	45.1 ± 4.6	44.7 ± 5.3	0.825
Type 2 diabetes (%)	4 (12.5%)	2 (9.1%)	0.695	3 (10.7%)	3 (11.5%)	0.923
Hypertension (%)	2 (6.3%)	4 (18.2%)	0.170	2 (7.1%)	4 (7.4%)	0.336
Education (% with academic degree)	7 (21.9%)	5 (22.7%)	0.941	4 (14.2%)	8 (30.7%)	0.145
Marital status (% married)	14 (43.8%)	7 (31.8%)	0.377	14 (50.0%)	7 (26.9%)	0.082
Monthly income (% > national average)	13 (40.6%)	7 (31.8%)	0.491	11 (39.2%)	9 (34.6%)	0.644
Current smoker (%)	1 (3.1%)	5 (22.7%)	*0.024*	1 (3.5%)	5 (19.2%)	0.067
BES total score	12.0 (9.0, 17.0)	23.0 (19.7, 28.3)	*< 0.001*	12.0 (8.0, 14.0)	23.0 (20.0, 29.7)	*< 0.001*
FA total score	2.0 (1.0, 3.0)	5.5 (4.0, 7.0)	*< 0.001*	2.0 (1.0, 3.0)	5.0 (3.0, 6.3)	*< 0.001*

†Values are expressed as the mean ± SD or median (IQR) according to the variable

BES Binge Eating Scale, *BMI* body mass index

Prevalence of Food Addiction and Binge Eating Categorization Before and After SG Before SG surgery, food addiction was identified in 22 (40.7%) and binge eating in 26 (48.1%) participants. All patients with food addiction at baseline ($n = 22$) have also met the criteria for binge eating; thus, 40.7% of the preoperative sample presented both features. Following SG, food addiction was reduced at M3 (10.2%) and M6 (6.7%); however, at M12, 29.3% of the women met the criteria for food addiction ($P > 0.05$ compared with baseline). The prevalence of binge eating was significantly lower at all post-SG time points compared with baseline, and was 17.4% at M12 ($P < 0.05$ compared with baseline) (Fig. 1). At M12, 14.3% of the women met the criteria for both food addiction and binge eating. Moreover, food addiction and binge eating were resolved at M12 among 66.7% and 86.4% of women who met the criteria for food addiction and binge eating at baseline, respectively.

Anthropometrics, Physical Activity, and Dietary Intake According to Binge Eating and Food Addiction Categorization at Baseline Table 2 presents anthropometric and lifestyle parameters at baseline and at M3, M6, and M12, according to the presence of food addiction and binge eating before SG. BMI was significantly lower at M12 than at baseline, for women with and without food addiction at baseline, with no differences between these groups (P time*group = 0.405). However, BMI was stabilized at M6 among women with food addiction at baseline, while it continued to decrease from M6 to M12 among those without food addiction (Table 2). The same trend was noted for BMI during the postoperative year, comparing women with and without binge eating at baseline. The reported hours spent in weekly PA increased significantly from baseline at all time points among women without food addiction and women without binge eating. However, those with food addiction or binge eating at baseline reported significantly less time in PA at M12 ($P = 0.041$, $P = 0.006$, respectively). The mean food tolerance score decreased significantly from baseline to M3, M6, and M12 for all the participants. However, scores were significantly lower at M12 among those with than without food addiction, and with than without binge eating at baseline ($P = 0.020$, $P = 0.024$, respectively).

Characteristics of Women Who Met Criteria for Food Addiction and Binge Eating at 12-Month Postoperative Characteristics of the cohort are presented in Table 3 and Fig. 2, according to meeting the criteria of food addiction and binge eating at M12. Women who met the criterion of

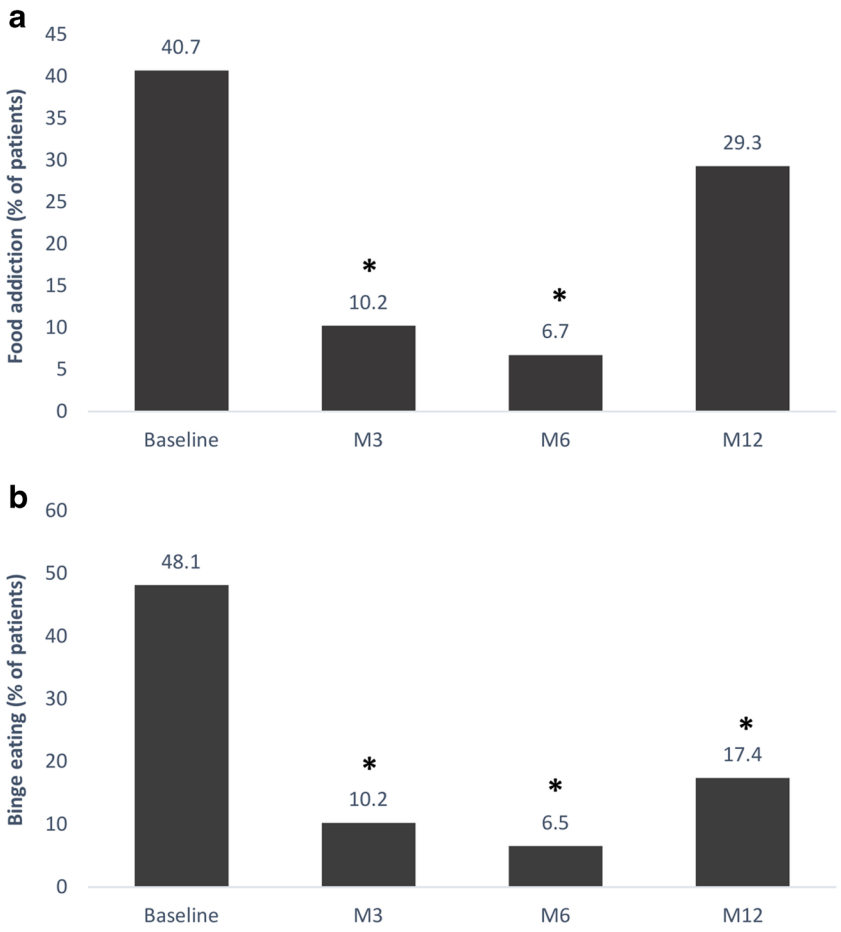

Fig. 1 Prevalence of food addiction and binge eating before sleeve gastrectomy, and at 3, 6, and 12 months (M3, M6 and M12) postoperative. Food addiction measured by the Yale Food Addiction Scale (YFAS) (**a**) and binge eating measured by the BES (**b**). *Significantly different from baseline, $P < 0.05$. Food addiction was measured by the Yale Food Addiction Scale (YFAS) and was available for: $n = 54$ at baseline, $n = 49$ at M3, $n = 45$ at M6, and $n = 41$ at M12. Binge eating was measured by the BES questionnaire and was available for: $n = 54$ at baseline, $n = 49$ at M3, $n = 46$ at M6, and $n = 46$ at M12

Table 2 Anthropometrics, health, and eating behaviors in the year following sleeve gastrectomy, according to baseline diagnosis of food addiction (FA) and binge eating (BE)

Outcome variable†	Group	Baseline	M3	M6	M12	P time	P time* group
Non-FA ($n = 32$) compared with FA ($n = 22$) at baseline							
BMI (kg/m^2)	Non-FA	44.9 (0.8)^a	36.2 (0.8)^b	32.8 (0.8)^c	31.6 (0.8)^d	*< 0.001*	0.405
	FA	44.9 (1.1)^a	35.4 (1.1)^b	31.8 (1.1)^c	30.5 (1.1)^c		
	*P groups	0.974	0.575	0.095	0.436		
EWL (%)	Non-FA	-	− 45.2 (3.2)^a	− 63.2 (3.3)^b	− 69.6 (3.2)^c	*< 0.001*	0.835
	FA	-	− 48.2 (2.9)^a	− 68.2 (3.0)^b	− 74.2 (2.8)^c		
	*P groups	-	0.271	0.279	0.406		
Weekly PA (min)	Non-FA	136.8 (20.7)^a	157.2 (20.7)^a	170.7 (21.4)^a	160.1 (20.7)^a	*< 0.001*	*0.039*
	FA	110.0 (20.5)^a	190.4 (21.5)^b	217.4 (23.3)^b	97.5 (20.5)^a		
	*P groups	0.427	0.227	0.140	*0.041*		
Food tolerance score	Non-FA	24.8 (0.5)^a	21.8 (0.5)^b	22.5 (0.5)^b	22.5 (0.5)^b	*< 0.001*	*0.003*
	FA	25.6 (0.7)^a	19.8 (0.8)^b	21.6 (0.8)^c	19.8 (0.8)^b		
	*P groups	0.088	0.078	0.573	*0.020*		
Calories (kcal/d)	Non-FA	2972.3 (42.1)^a	869.8 (42.7)^b	951.6 (44.2)^b	1129.3 (42.1)^c	*< 0.001*	*0.003*
	FA	3342.6 (100.4)^a	926.9 (104.9)^b	911.3 (113.4)^b	1073.4 (102.6)^b		
	*P groups	0.053	0.319	0.339	0.440		
Protein (gr/d)	Non-FA	121.4 (3.3)^a	50.1 (3.4)^b	52.7 (3.5)^b	57.3 (3.3)^b	*< 0.001*	0.208
	FA	132.5 (5.7)^a	50.3 (6.0)^b	49.5 (6.5)^b	50.6 (6.8)^b		
	*P groups	0.265	0.946	0.511	0.095		
Carbohydrates (gr/d)	Non-FA	382.2 (7.9)^a	93.5 (8.1)^b	99.5 (8.4)^b	121.6 (7.9)^b	*< 0.001*	0.936
	FA	390.9 (14.6)^a	105.2 (15.3)^b	104.6 (16.5)^b	120.5 (14.9)^b		
	*P groups	0.748	0.249	0.508	0.918		
Non-BE ($n = 28$) compared with BE ($n = 26$) at baseline							
BMI (kg/m^2)	Non-BE	45.1 (0.9)^a	36.2 (0.9)^b	32.7 (0.9)^c	31.0 (0.9)^d	*< 0.001*	0.719
	BE	44.8 (0.9)^a	35.5 (0.9)^b	32.1 (0.9)^c	31.2 (0.9)^c		
	*P groups	0.825	0.580	0.135	0.949		
EWL (%)	Non-BE	-	− 45.6 (3.4)^a	− 64.8 (3.4)^b	− 72.8 (3.4)^c	*< 0.001*	0.336
	BE	-	− 47.4 (2.8)^a	− 65.7 (3.1)^b	− 70.0 (2.8)^b		
	*P groups	-	0.511	0.550	0.609		
Weekly PA (min.)	Non-BE	134.9 (21.6)^a	154.8 (21.6)^a	166.6 (21.6)^a	174.8 (21.6)^a	*< 0.001*	*0.007*
	BE	116.2 (19.8)^a	187.7 (20.6)^b	218.3 (23.1)^b	92.1 (19.8)^a		
	*P groups	0.605	0.218	0.078	*0.006*		
Food tolerance score	Non-BE	24.8 (0.6)^a	22.0 (0.6)^b	22.9 (0.6)^b	22.6 (0.6)^b	*< 0.001*	*0.002*
	BE	25.5 (0.7)^a	19.8 (0.7)^b	21.2 (0.7)^b	20.1 (0.7)^b		
	*P groups	0.081	*0.023*	0.129	*0.024*		
Calories (kcal/d)	Non-BE	1986.2 (46.3)^a	906.0 (46.3)^b	938.6 (47.1)^b	1100.9 (46.3)^c	*< 0.001*	*0.047*
	BE	3270.6 (88.1)^a	873.9 (93.4)^b	933.0 (98.2)^{bc}	1114.6 (89.8)^c		
	*P groups	0.081	0.604	0.701	0.873		
Protein (gr/d)	Non-BE	123.7 (3.6)^a	51.6 (3.6)^b	51.1 (3.7)^b	56.2 (3.6)^b	*< 0.001*	0.773
	BE	128.3 (5.1)^a	48.4 (5.4)^b	52.3 (5.9)^b	52.9 (5.2)^b		
	*P groups	0.648	0.422	0.786	0.410		
Carbohydrates (gr/d)	Non-BE	380.0 (8.6)^a	96.2 (8.6)^b	99.8 (8.7)^b	117.7 (8.6)^b	< 0.001	0.976
	BE	391.2 (12.7)^a	100.1 (13.6)^b	103.4 (14.9)^b	125.0 (13.0)^b		
	*P groups	0.621	0.720	0.658	0.605		

†Data are presented as estimated mean (SE) according to the mixed model analysis [P time—time effect = analyze the changes over time in the two groups; P time*group—group time effect = analyze the interaction between the trend of change over time and the group effect]. Rates with different superscripts ($^{a, b}$) differ significantly from each other in that row for within group differences at $P \leq 0.05$

* P groups—between group differences at each time point

BE binge eating, *BES* Binge Eating Scale, *BMI* body mass index, *EWL* excess weight loss, *FA* food addiction, *PA* physical activity, *WC* waist circumference. 3-, 6-, and 12-month postoperative (M3, M6, M12)

food addiction at M12 reported spending fewer weekly hours in PA and consuming greater daily amounts of carbohydrates than did those who did not meet this criterion at M12 ($P < 0.001$ and $P = 0.013$, respectively). Women without food addiction achieved significantly higher %EWL and %TBWL, and lower mean BMI at M12 than did women who met the criterion for food addiction at M12 ($P = 0.005$, $P = 0.005$, and $P = 0.003$, respectively, Table 3). Food addiction score at M12 was negatively correlated with weekly PA ($r = -0.559$, $P < 0.001$), food tolerance scores ($r = -0.428$, $P = 0.005$), and weight loss from M6 to M12 ($r = -0.342$, $P = 0.041$). Additionally, women who met the criterion of binge eating at M12 reported significantly higher rates of vomiting at M12 (50.0 vs. 13.2%, $P = 0.017$).

Discussion

This prospective study of women who underwent SG found different trends between binge eating and food addiction over the postoperative year, and different associations of these classifications with weight loss outcomes and eating and lifestyle behaviors. About half the women met the criteria of binge eating prior to surgery according to the BES questionnaire; this decreased to less than one-fifth at 1-year postoperative. In contrast, food addiction prevalence, as measured by the YFAS, decreased from 41% at baseline to 7% at 6 months postoperative, but rose to 29% during the subsequent 6 months. Women who met the criteria for food addiction or binge eating at baseline reported spending less time in physical activity and their food tolerance scores were significantly lower at 1-year postoperative, compared with women without food addiction or binge eating at baseline. Women with food addition at 1-year postoperative had lower weight loss outcomes, including lower %EWL and %TBWL, and higher mean BMI. Although BS is generally effective in reducing body weight, a substantial proportion of individuals achieves suboptimal weight loss. Thus, identifying modifiable prognostic indicators for postoperative weight outcomes is important [6]. The existing literature on potential predictors of success following BS is far from conclusive [10]. The diverse factors that have been investigated for their effect on postoperative outcomes include various problematic eating behaviors such as binge eating [6]. Our results corroborate previous reports that described a high prevalence of binge eating among candidates for BS, up to 50% [1]. Our findings also concur with studies that showed reductions during the first postoperative year in binge eating after different types of BS, including SG [1, 2, 5, 22]. This is not surprising since BS procedures anatomically restrict the capacity to binge eat or overeat. However, at longer-term follow-up, binge eating symptoms may revert and even return to pre-surgery levels [1]. In the current study, women who were categorized with binge eating at 1-year postoperative also had a higher prevalence of vomiting than did women without this categorization. Vomiting may result from overeating or attempts to binge eat [1]. Vomiting commonly occurs postoperatively, both acutely and involuntarily, or in response to dysphagia [23]. Self-induced vomiting related to concerns of body weight and shape are considered to appear more rarely following BS, though these might reflect compensatory behaviors and reflect the development of new eating disorders post-surgery [23]. In the current study, the categorization of binge eating, either at pre-surgery or post-surgery, was not related to BMI or %EWL outcomes at 1-year postoperative. However, focusing on binge

Table 3 Anthropometrics, health, and eating behaviors in the year following sleeve gastrectomy, according to food addiction (FA) and binge eating (BE) at 12-month postoperative (M12)

Outcome variable†	Non-FA $n = 29$	FA $n = 12$	P value	Non-BE $n = 38$	BE $n = 8$	*P* value
Weight (kg)	77.7 ± 11.7	92.7 ± 16.7	*0.002*	81.3 ± 15.3	82.1 ± 10.7	0.885
BMI (kg/m^2)	29.9 ± 4.3	35.2 ± 6.3	*0.003*	31.4 ± 5.6	31.5 ± 4.6	0.964
EWL (%)	−76.0 ± 19.6	−57.2 ± 15.3	*0.005*	−70.8 ± 21.2	−68.3 ± 17.7	0.753
TBWL (%)	−32.5 ± 8.1	−25.9 ± 5.5	*0.005*	−30.9 ± 8.5	−28.8 ± 6.1	0.501
WC (cm)	94.3 ± 11.5	102.0 ± 13.8	0.084	96.7 ± 12.9	93.0 ± 123	0.443
Weekly PA (min.)	189.3 ± 113.7	45.8 ± 60.0	*< 0.001*	149.5 ± 110.1	101.3 ± 144.0	0.292
Calories (kcal/d)	1077.2 ± 215.6	1203.0 ± 339.3	0.161	1121.1 ± 248.7	1093.8 ± 359.1	0.796
Protein (g/d)	54.9 ± 15.8	52.3 ± 15.0	0.618	54.7 ± 15.8	53.1 ± 9.6	0.794
Carbohydrates (g/d)	110.2 ± 38.3	148.2 ± 51.3	*0.013*	122.0 ± 47.4	120.9 ± 52.4	0.951
Fat (g/d)	44.9 ± 15.1	46.6 ± 19.3	0.771	45.6 ± 15.4	44.9 ± 19.0	0.918

†Data are presented as mean ± SD or median (IQR) according to the variable at M12

P between groups at M12 were obtained from the independent t test or Mann-Whitney

BE binge eating, *BES* Binge Eating Scale, *BMI* body mass index, *EWL* excess weight loss, *FA* food addiction, *PA* physical activity, *TBWL* total body weight loss, *WC* waist circumference

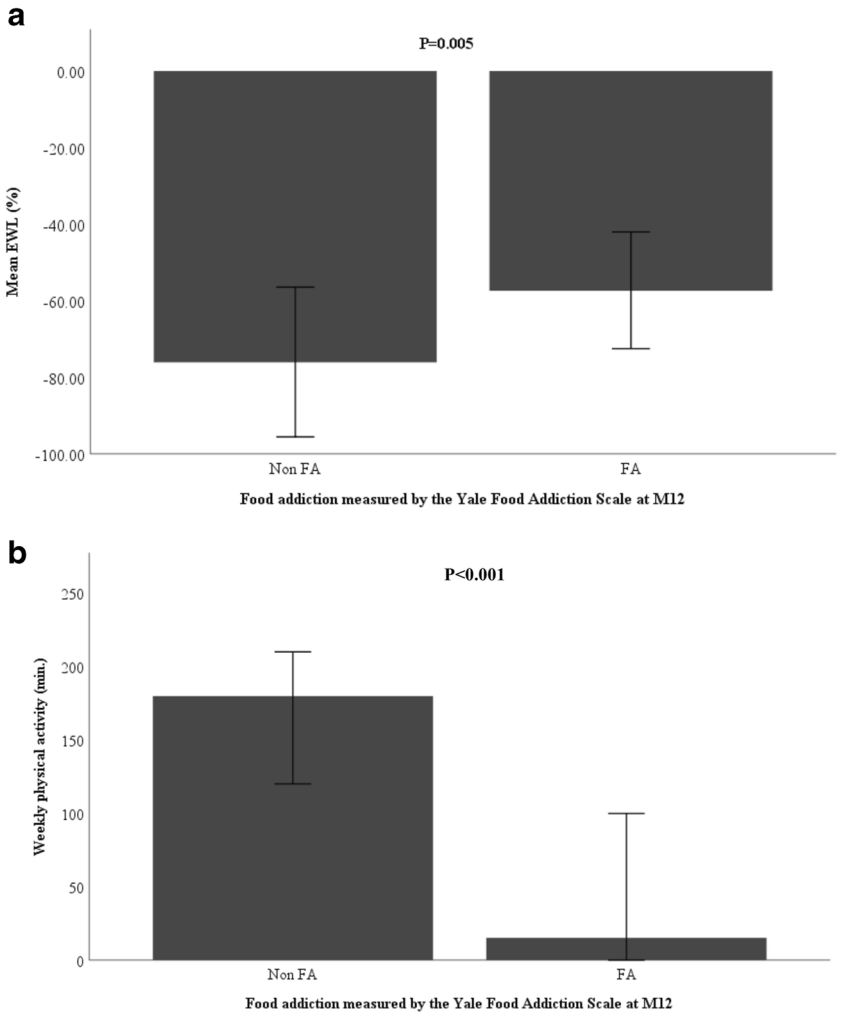

Fig. 2 Excess weight loss (EWL) and reported physical activity 12 months following sleeve gastrectomy, according to food addiction and binge eating categorization at 12 months post-surgery. Excess weight loss (**a**) and weekly physical activity (**b**). EWL, excess weight loss; FA, food addiction. Food addiction was measured by the Yale Food Addiction Scale (YFAS) and was available for $n = 41$ at M12

eating findings alone may be misleading as other maladaptive eating patterns can emerge post BS, such as grazing, loss-of-control eating, and vomiting [1, 3]. The current study did not investigate these. Notably, binge eating may evolve over time, as the stomach can enlarge in the long-term following BS [1]. The prevalence of food addiction prior to SG reported in the current study is within the range reported by others, 14–58% [6]. Moreover, our finding of a decrease in food addiction concurs with reports of lower rates of food addiction postoperatively, ranging from 2 to 14 [10, 12]. However, our postoperative rate at 12 months was closer to the rate of one-third demonstrated in a cohort of 44 individuals following BS [12]. We report that baseline food addiction was not related to %EWL or BMI post-surgery. Similarly, a few prospective studies reported that food addiction prior to BS was not associated with weight loss outcomes up to 12 months post-surgery [10, 12, 24]. However, BMI was stabilized at 6-month postoperative among the women of our cohort who were categorized with food addiction at baseline, while continuing to decrease up to 12-month postoperative among women without food addiction at baseline. Moreover, food addiction categorization at 1-year postoperative was related to poorer weight loss outcomes. We report that meeting the criteria of food addiction classification pre- and post-surgery was related to less hours reported for PA and with lower food tolerance scores at 1-year postoperative. This corroborates associations that have been demonstrated of food addiction prior to BS with various post-surgical psychopathologies and specific eating/lifestyle behaviors [6]. However, the current study did not examine changes in other related psychopathologies and behaviors that were previously associated with food addiction, such as night eating syndrome [25], emotional eating [20], depression, and quality of life [24]. It is important to note that food addiction is still considered a controversial concept, thus not formally integrated into the DSM-5 [8]. Generally, there appears to be an excessive conceptual heterogeneity within behavioral addictions, and lack of agreement as to how various repetitive and problematic behaviors should be conceptualized [26]. Moreover, addiction to eating or food is different from other behavioral addictions, and perhaps more akin to substance addictions because of the ingested 'substance', i.e., food [26]. Nevertheless, emerging evidence links food addiction to different subthreshold psychopathological

domains (e.g., depressive symptoms and eating subthreshold symptoms), suggesting that it might be a dimension underlying different conditions or symptom clusters [6, 27]. Overall, more rigorous research methods with larger and more diverse patients are needed to better understand the clinical utility and validity of food addiction following BS [6]. Importantly, addictive eating type and food addiction in the context of BS have been investigated in greater depth in recent years, though clinical implications, such as the integration of pre-BS psychological evaluations, have not become routine practice [6]. Strengths of the present report include its being one of the few documented studies to prospectively examine food addiction by YFAS at pre- and post-SG. However, our study has several limitations. First, the sample size included only women; thus, generalizability of results may be limited. Nevertheless, women comprise more than 70% of the persons who undergo BS worldwide [28]. Moreover, previous reports have shown associations of female sex with eating disorders and addictive behaviors in various populations, including persons who undergo BS [29]. Furthermore, the relatively small sample size made it difficult to perform further subgroups analysis, such as whether outcomes differed between women whose initial diagnosis of food addiction or binge eating was to those who initial diagnosis was not resolve at M12. The second limitation stems from the study design, which did not assess associations of food addiction and binge eating on weight outcomes beyond 12 month, when weight regain might occur [10]. Third, some of the measures in this study were based on patients' self-reports (e.g., PA and eating patterns); nevertheless, this study included mostly validated assessment tools (e.g., the YFAS, BES, and food tolerance questioners). Finally, examining changes in other related psychopathologies and behaviors that were previously associated with food addiction, (e.g., depression and decreased quality of life) could contribute to bridge the gaps in existing knowledge on the clinical implications of food addiction in the context of BS.

In conclusion, this study suggests that women may experience sustained reductions in food addiction in the short-term of up to 6 months following BS. However, this reduction was not maintained at M12, and was accompanied by poorer weight and behavior-related outcomes. Additional follow-up studies are required to evaluate longer-term effects of pre- and postoperative food addiction and binge eating following BS. Furthermore, clinical practice should be focused on the psychological aspects associated with obesity, as these may affect postoperative outcomes.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in this study were approved by the institutional review board and in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The RCT study was pre-registered in the NIH registration website (TRIAL no. NCT02483026).

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Spirou D, Raman J, Smith E. Psychological outcomes following surgical and endoscopic bariatric procedures: a systematic review. Obes Rev. 2020;21(6):e12998. https://doi.org/10.1111/obr.12998.
2. Mack I, Ölschläger S, Sauer H, et al. Does laparoscopic sleeve gastrectomy improve depression, stress and eating behaviour? A 4-year follow-up study. Obes Surg. 2016;26(12):2967–73. https://doi.org/10.1007/s11695-016-2219-8.
3. Ivezaj V, Wiedemann AA, Lawson JL, et al. Food addiction in sleeve gastrectomy patients with loss-of-control eating. Obes Surg. 2019;29(7):2071–7. https://doi.org/10.1007/s11695-019-03805-8.
4. Meany G, Conceição E, Mitchell JE. Binge eating, binge eating disorder and loss of control eating: effects on weight outcomes after bariatric surgery. Eur Eat Disord Rev. 2014;22(2):87–91. https://doi.org/10.1002/erv.2273.
5. Wadden TA, Faulconbridge LF, Jones-Corneille LR, et al. Binge eating disorder and the outcome of bariatric surgery at one year: a prospective, observational study. Obesity (Silver Spring). 2011;19(6):1220–8. https://doi.org/10.1038/oby.2010.336. Erratum in: Obesity (Silver Spring). 2016 Jan;24(1):267
6. Ivezaj V, Wiedemann AA, Grilo CM. Food addiction and bariatric surgery: a systematic review of the literature. Obes Rev. 2017;18(12):1386–97. https://doi.org/10.1111/obr.12600.
7. Wiss DA, Brewerton TD. Incorporating food addiction into disordered eating: the disordered eating food addiction nutrition guide (DEFANG). Eat Weight Disord. 2017;22(1):49–59. https://doi.org/10.1007/s40519-016-0344-y.
8. Ivezaj V, White MA, Grilo CM. Examining binge-eating disorder and food addiction in adults with overweight and obesity. Obesity (Silver Spring). 2016;24(10):2064–9. https://doi.org/10.1002/oby.21607.
9. Gearhardt AN, Corbin WR, Brownell KD. Preliminary validation of the Yale Food Addiction Scale. Appetite. 2009;52(2):430–6. https://doi.org/10.1016/j.appet.2008.12.003.
10. Sevinçer GM, Konuk N, Bozkurt S, et al. Food addiction and the outcome of bariatric surgery at 1-year: prospective observational study. Psychiatry Res. 2016;244:159–64. https://doi.org/10.1016/j.psychres.2016.07.022.
11. Murray SM, Tweardy S, Geliebter A, et al. A longitudinal preliminary study of addiction-like responses to food and alcohol consumption among individuals undergoing weight loss surgery.

Obes Surg. 2019;29(8):2700–3. https://doi.org/10.1007/s11695-019-03915-3.
12. Pepino MY, Stein RI, Eagon JC, et al. Bariatric surgery-induced weight loss causes remission of food addiction in extreme obesity. Obesity (Silver Spring). 2014;22(8):1792–8. https://doi.org/10.1002/oby.20797.
13. Josbeno DA, Jakicic JM, Hergenroeder A, et al. Physical activity and physical function changes in obese individuals after gastric bypass surgery. Surg Obes Relat Dis. 2010;6(4):361–6. https://doi.org/10.1016/j.soard.2008.08.003.
14. Suter M, Calmes JM, Paroz A, et al. A new questionnaire for quick assessment of food tolerance after bariatric surgery. Obes Surg. 2007;17(1):2–8. https://doi.org/10.1007/s11695-007-9016-3.
15. Sherf Dagan S, Tovim TB, Keidar A, et al. Inadequate protein intake after laparoscopic sleeve gastrectomy surgery is associated with a greater fat free mass loss. Surg Obes Relat Dis. 2017;13(1):101–9. https://doi.org/10.1016/j.soard.2016.05.026.
16. Gormally J, Black S, Daston S, et al. The assessment of binge eating severity among obese persons. Addict Behav. 1982;7(1):47–55. https://doi.org/10.1016/0306-4603(82)90024-7.
17. Grupski AE, Hood MM, Hall BJ, et al. Examining the Binge Eating Scale in screening for binge eating disorder in bariatric surgery candidates. Obes Surg. 2013;23(1):1–6. https://doi.org/10.1007/s11695-011-0537-4.
18. Marek RJ, Tarescavage AM, Ben-Porath YS, et al. Replication and evaluation of a proposed two-factor Binge Eating Scale (BES) structure in a sample of bariatric surgery candidates. Surg Obes Relat Dis. 2015;11(3):659–65. https://doi.org/10.1016/j.soard.2014.09.015.
19. Marek RJ, Ben-Porath YS, Ashton K, et al. Minnesota multiphasic personality inventory-2 restructured form (MMPI-2-RF) scale score differences in bariatric surgery candidates diagnosed with binge eating disorder versus BMI-matched controls. Int J Eat Disord. 2014;47(3):315–9. https://doi.org/10.1002/eat.22194.
20. Clark SM, Saules KK. Validation of the Yale Food Addiction Scale among a weight loss surgery population. Eat Behav. 2013;14(2):216–9. https://doi.org/10.1016/j.eatbeh.2013.01.002. Erratum in: Eat Behav. 2014 Aug;15(3):513
21. Beaton DE, Bombardier C, Guillemin F, et al. Guidelines for the process of cross-cultural adaptation of self-report measures. Spine (Phila Pa 1976). 2000;25(24):3186–91. https://doi.org/10.1097/00007632-200012150-00014.
22. Luiz LB, Brito CL, Debon LM, et al. Variation of binge eating one year after Roux-en-Y gastric bypass and its relationship with excess weight loss. PLoS One. 2016;11(12):e0167577. https://doi.org/10.1371/journal.pone.0167577.
23. Williams-Kerver GA, Steffen KJ, Mitchell JE. Eating pathology after bariatric surgery: an updated review of the recent literature. Curr Psychiatry Rep. 2019;21(9):86. https://doi.org/10.1007/s11920-019-1071-7.
24. Koball AM, Clark MM, Collazo-Clavell M, et al. The relationship among food addiction, negative mood, and eating-disordered behaviors in patients seeking to have bariatric surgery. Surg Obes Relat Dis. 2016;12(1):165–70. https://doi.org/10.1016/j.soard.2015.04.009.
25. Baldofski S, Tigges W, Herbig B, et al. Nonnormative eating behavior and psychopathology in prebariatric patients with binge-eating disorder and night eating syndrome. Surg Obes Relat Dis. 2015;11(3):621–6. https://doi.org/10.1016/j.soard.2014.09.018.
26. Starcevic V. Behavioural addictions: a challenge for psychopathology and psychiatric nosology. Aust N Z J Psychiatry. 2016;50(8):721–5. https://doi.org/10.1177/0004867416654009.
27. Piccinni A, Marazziti D, Cargioli C, Mauri M, Stallone T. Food addiction: is it a nosological category or a psychopathological dimension? Preliminary results of an Italian study. Horm Mol Biol Clin Invest. 2018;36(1):/j/hmbci.2018.36.issue-1/hmbci-2018-0021/hmbci-2018-0021.xml. doi: https://doi.org/10.1515/hmbci-2018-0021.
28. Welbourn R, Hollyman M, Kinsman R, et al. Bariatric surgery worldwide: baseline demographic description and one-year outcomes from the fourth IFSO global registry report 2018. Obes Surg. 2019;29(3):782–95. https://doi.org/10.1007/s11695-018-3593-1.
29. Li L, Wu LT. Substance use after bariatric surgery: A review. J Psychiatr Res. 2016;76:16–29. https://doi.org/10.1016/j.jpsychires.2016.01.009.