Original Investigation

Postoperative Behavioral Variables and Weight Change 3 Years After Bariatric Surgery

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IMPORTANCE Severe obesity (body mass index ≥35 [calculated as weight in kilograms divided by height in meters squared]) is associated with significant medical comorbidity and increased mortality. Bariatric surgery induces weight loss, the extent of which can vary. Postoperative predictors of weight loss have not been adequately examined.

OBJECTIVE To describe postoperative eating behaviors and weight control and their effects on 3-year change in weight.

DESIGN, SETTING, AND PARTICIPANTS The Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) study is a multicenter observational cohort study at 10 US hospitals in 6 geographically diverse clinical centers. Adults undergoing first-time bariatric surgical procedures as part of routine clinical care were recruited between 2006 and 2009 and followed up until September 2012. Participants completed detailed surveys regarding eating and weight control behaviors prior to surgery and then annually after surgery for 3 years.

MAIN OUTCOMES AND MEASURES Twenty-five postoperative behaviors related to eating behavior, eating problems, weight control practices, and the problematic use of alcohol, smoking, and illegal drugs. Behaviors examined were divided into those that were never present (preoperatively or postoperatively), those that were always present (preoperatively and postoperatively), and those that underwent a healthy change after surgery (development of a positive behavior or omission of a negative behavior).

RESULTS The sample included a total of 2022 participants (median age, 47 years [interquartile range, 38-55 years]; median BMI, 46 [interquartile range, 42-51]; 78% women): 1513 who had undergone Roux-en-Y gastric bypass and 509 who had undergone laparoscopic adjustable gastric banding. If we consider the cumulative effects of the 3 behaviors that explain most of the variability (16%) in 3-year percent weight change following Roux-en-Y gastric bypass, ie, weekly self-weighing, continuing to eat when feeling full more than once a week, and eating continuously during the day, a participant who postoperatively started to self-weigh, stopped eating when feeling full, and stopped eating continuously during the day after surgery would be predicted to lose a mean (SE) of 38.8% (0.8%) of their baseline weight. This average is about 14% greater weight loss compared with participants who made no positive changes in these variables (mean [SE], −24.6% [1.6%]; mean difference, −14.2%; 95% CI, −18.7% to −9.8%; $P < .001$) and 6% greater weight loss compared with participants who always reported positive on these healthy behaviors (mean [SE], −33.2% [0.6%]; mean difference, −5.7%; 95% CI, −7.8% to −3.5%; $P < .001$).

CONCLUSIONS AND RELEVANCE The results suggest the importance of assessing behaviors related to eating behavior, eating problems, weight control practices, and the problematic use of alcohol, smoking, and illegal drugs in bariatric surgery candidates and patients who have undergone bariatric surgery, and they suggest that the utility of programs to modify problematic eating behaviors and eating patterns should be addressed in research.

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Invited Commentary

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It is important to identify variables that are associated with, or predictive of, successful weight loss outcomes to better evaluate potential risks and benefits to the use of bariatric surgery for treating those with severe obesity. Much research in this area has focused on preoperative factors. In a recent article by Arterburn et al,[1] patients were more likely to lose 30% or more of their baseline weight if they were female and white. Other preoperative factors that have been identified, not always consistently, have included body mass index (BMI; calculated as weight in kilograms divided by height in meters squared), preoperative weight loss, level of physical activity, diabetes, early referral for bariatric surgery, and various psychological and eating behavior variables.[2-4] The topic of psychosocial preoperative predictor variables was recently reviewed by Livhits et al,[5] who reported that mandatory preoperative weight loss and lower BMI were possibly factors predictive of better weight loss after surgery.

Of particular interest for this report are studies that have examined specific eating behaviors, eating problems, and weight control practices as postoperative predictors of weight loss. Postoperative positive changes in eating habits predicted better outcomes in 1236 bariatric patients registered with the French National Medical Insurance Service.[6] Research previously reported that adherence to prescribed food intake guidelines was associated with greater weight loss.[7] Kruseman et al[8] calculated dietary intake from 80 patients' food diaries at 8 years following Roux-en-Y gastric bypass (RYGB) and concluded that less intake was associated with higher rates of achieving greater than 50% excess weight loss. The emergence or reemergence of problems with binge eating (defined as eating an objectively large amount of food accompanied by a sense of loss of control over eating) as well as the emergence or reemergence of loss-of-control eating (defined as eating accompanied by a sense of loss of control, but not necessarily ingesting an objectively large amount of food) have also been demonstrated to be associated with attenuated weight loss or greater weight regain.[9] Other postoperative problematic eating behaviors that have been associated postoperatively with less weight loss have included grazing, snacking, and eating when not hungry.[10-13] Studies have also found that nocturnal eating episodes, stress-induced eating, and a composite measure of aberrant eating behaviors, which included eating when not hungry,[14-16] were all associated with poorer weight loss. Conversely, other studies have not found an association between less weight loss or greater weight regain and postoperative night eating syndrome, rate of eating, and number of daily meals.[17-19] Other postoperative eating-related changes also may result in better weight loss, including decreasing calorie and fat intake, lower postoperative disinhibition, less objective hunger, and fewer cravings for sweets.[20] Regular self-weighing has also been associated with better weight loss maintenance. However, most of the studies have included a small number of participants, and the definitions for various problematic eating behaviors have varied widely or not been well stipulated. Therefore, we studied various eating behaviors, chosen because of prior mention in the literature and/or consensus of their possible utility among the investigators, and their relation to weight loss in a large cohort of bariatric surgery patients followed up prospectively.

Key Points

Question What are the postoperative predictors of the amount of subsequent weight loss following bariatric surgery in severely obese adults?

Findings In a cohort study of 2022 post–bariatric surgery patients from 10 US hospitals in the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) study, those patients who adopted healthier eating and weight control behaviors after surgery experienced significantly greater weight loss than other patients.

Meaning Addressing problematic eating and weight control behaviors, many of which are potentially modifiable, may improve weight loss substantially following bariatric surgery.

Methods

Patients

The Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) study is an observational cohort study of 2458 adults who underwent initial RYGB, laparoscopic adjustable gastric banding (LAGB), or other bariatric procedure at one of 10 centers across the United States.[21] Participants (1738 RYGB, 610 LAGB, 110 other procedure) underwent surgery between March 2006 and April 2009 (eFigure in the Supplement). This report used data collected preoperatively and up to 3 years following surgery, through 2012. Details regarding data collection,[22] cohort baseline characteristics,[23] and weight and medical comorbidity outcomes at 3 years[24] have been previously published. The institutional review board at each center approved the protocol and consent forms. All participants provided written informed consent.

Weight Change

Weight change is reported as the percent change from baseline weight and was measured within 30 days prior to surgery and 3 years following surgery. During in-person follow-up visits, weight was measured using a standard protocol on a study-purchased standard scale (Tanita Body Composition Analyzer, model TBF-310). If an in-person weight was not obtained, weight was measured by research or medical personnel on a nonstudy scale (14.0% of weights). If neither an in-person nor clinical weight was available, a self-reported weight was used (16.2%). Differences between measured and self-reported weights for a sample of participants from the LABS-2 cohort have previously been reported as small.[25]

The 36 participants whose initial bariatric procedure was subsequently reversed or revised before the 3-year weight measurement were excluded, as were 25 women in their second or third trimester of pregnancy or up to 6 months post partum when weighed at year 3.

Behaviors

This analysis focused on postoperative behaviors, many of which were deemed modifiable, that related to eating behav-

Table 1. Modifiable Practices and Behaviors

Category	Practice or Behavior
Weight loss practices	Self-weigh at least weekly
	See nutritionist or dietitian
	See personal trainer or exercise specialist
	Keep a food diary
	Count fat grams
	Decrease fat intake
	Reduce number of calories eaten
	Use a very low-calorie diet
	Cut out between-meal snacking
	Eat fewer high-carbohydrate foods
	Eat special low-calorie diet foods
	Eat or drink meal replacements
	Increase fruits and vegetables
	Cut out sugar-sweetened beverages
Alcohol, smoking, and illegal drugs	Alcohol use disorder
	Current smoker
	Illegal drug use
Eating behaviors and problems	Eat breakfast regularly
	Eat breakfast, lunch, and dinner regularly
	Eat when feeling full, more than once a week
	Eat when not hungry, more than once a week
	Eat continuously during the day or part of the day
	Binge-eating disorder
	Loss-of-control eating
	Night eating syndrome
	Evening hyperphagia
	Night eating

ior and eating problems, weight control practices, and the problematic use of alcohol, smoking, and illegal drugs. These were grouped into positive behaviors and negative behaviors. The behaviors listed in **Table 1** were all assessed via self-administered questionnaires described previously,[23] at baseline and at follow-up years 1, 2, and 3. Participants were considered to have regularly seen a nutritionist/dietitian or trainer/exercise specialist if they self-reported seeing such an individual at least 6 times in the last 6 months. Participants were identified as engaging in a given weight control practice (eg, counting fat grams) if they reported doing so regularly during the previous 6 months. Participants were identified as having eaten a meal regularly if they reported regularly eating the meal 6 to 7 times per week. The form also asked, "During the past 6 months, have you had times when you ate continuously during the day or parts of the day without planning what and how much you would eat?"; this question was designed to assess the behavior labeled as *grazing*. Detailed definitions of binge-eating disorder, loss-of-control eating, night eating syndrome, and alcohol use disorder have been reported previously.[26,27]

Statistical Analysis

Descriptive statistics summarize baseline characteristics for each procedure, with frequencies and percentages used for categorical data and medians and interquartile ranges (IQRs) for continuous data. The baseline characteristics of participants with behavioral questionnaires at every time (preoperatively and after 1, 2, and 3 years of follow-up) were compared with participants missing at least 1 behavioral questionnaire. Statistical significance was tested using the Wilcoxon rank sum test for continuous data and Pearson χ^2 test for categorical data.

Linear regression models were constructed by procedure for each behavior. The response variable was year 3 percent weight change, and the variables of interest were the modifiable behaviors represented by 4 binary variables indicating whether the behavior was reported as being practiced at each assessment time (baseline and years 1, 2, and 3). Three types of behavioral patterns were estimated from the binary variables: (1) never, indicating the participant reported not engaging in the behavior at baseline or at any follow-up time; (2) always, indicating the participant reported engaging in the behavior at baseline and at every follow-up time; and (3) start/stop, indicating the participant started a positive behavior (eg, self-weighing; ie, first reported not engaging in the behavior at baseline but then engaging in the behavior at every follow-up time) or stopped a negative behavior (eg, binge eating; ie, first reported engaging in the behavior at baseline but then not engaging in the behavior at every follow-up time). Each model controlled for age at time of surgery, baseline BMI, and sex. In addition, RYGB models controlled for preoperative diabetes status and LAGB models controlled for band size (large vs small) because these baseline factors were found to be significantly associated with 3-year weight change.[28] Participants with missing 3-year weight data were excluded from the analysis (eFigure in the Supplement). The models were fit using full information maximum likelihood, which allowed us to use all available information. Participants with a 3-year weight who have behavior data for at least 1 time (baseline, 1 year, 2 years, or 3 years) were included.

For each behavior, pairwise comparisons were made between each combination of the 3 patterns. These *P* values and confidence limits were adjusted for multiple comparisons using the Bonferroni correction. Model-based estimates were not reported if a behavioral pattern was uncommon (<5 participants with complete data reported the pattern).

Analyses were conducted using SAS version 9.4 statistical software (SAS Institute, Inc). All reported *P* values are 2-sided. The *P* values that were not corrected were considered statistically significant if less than .05.

Results

Cohort Description

As shown in the eFigure in the Supplement, 3 years after surgery, weight was obtained for 1513 of 1670 participants (91%) who had undergone RYGB and 509 of 548 participants (93%) who had undergone LAGB. For the total of 2022 participants included in this analysis, the median age was 47 years (IQR, 38-55 years); the median BMI was 46 (IQR, 42-51); and 78% were women. Among these participants, the observed median percent weight loss 3 years after surgery was 31.5% (IQR, 24.6%-38.4%; range, 59.2% loss to 0.9% gain) for RYGB and

16.0% (IQR, 8.1%-23.1%; range, 56.1% loss to 12.5% gain) for LAGB. The median 3-year weight loss was 40 kg (IQR, 31-52 kg; range, 110-kg loss to 1-kg gain) for RYGB and 20 kg (IQR, 10-29 kg; range, 75-kg loss to 20-kg gain) for LAGB.

Eating Patterns and Behaviors

Most participants who underwent RYGB and LAGB completed behavioral questionnaires at baseline and all 3 follow-up times; 89% of those who underwent RYGB and 90% of those who underwent LAGB completed at least 2 behavioral questionnaires. For both procedures, there were no statistically significant differences in preoperative BMI or sex between participants with a behavioral questionnaire at every time and those missing at least 1 questionnaire. Participants missing at least 1 behavioral questionnaire were significantly younger (RYGB: median age, 43 years [IQR, 35-51 years]; LAGB: median age, 46 years [IQR, 35-55 years]) compared with participants with complete behavioral data (RYGB: median age, 49 years [IQR, 39-56 years]; $P < .001$; LAGB: median age, 50 years [IQR, 40-57 years]; $P = .01$).

eTable 1 in the Supplement shows the unadjusted relationships between the changes in each behavior and year 3 weight change. The mean weight changes are divided into the never, always, and healthy change categories. The mean (SE) weight loss was greater among those in the self-weighing weekly category who started this positive behavior postoperatively (−33.9% [0.5%]) compared with those who never engaged in this behavior (−31.0% [0.6%]; mean difference, −3.0%; 95% CI, −4.9% to −1.1%; $P < .001$) or those who had always engaged in this behavior (−31.7% [0.4%]; mean difference, −2.3%; 95% CI, −3.6% to −0.9%; $P < .001$). Those who had started to count fat grams also lost significantly more weight (mean [SE], −35.8% [1.7%]) than those who had never done so (mean [SE], −31.3% [0.3%]; mean difference, −4.5%; 95% CI, −7.9% to −1.1%; $P = .01$). The mean (SE) weight loss was greater in those who began using a very low-calorie diet (−35.6% [1.4%]) than those who had never done so (−31.1% [0.3%]; mean difference, −4.6%; 95% CI, −7.4% to −1.7%; $P = .002$); it was also greater in those who ceased between-meal snacking (−35.6% [1.4%]) than those who had never done so (−31.1% [0.3%]; mean difference, −4.5%; 95% CI, −7.5% to −1.5%; $P = .003$). Those who no longer had problems with loss-of-control eating had greater mean (SE) weight loss (−34.6% [0.6%]) than those who had never reported loss-of-control eating (−32.6% [0.3%]; mean difference, −2.0%; 95% CI, −3.5% to −0.6%; $P = .003$) and greater weight loss than those who had always had problems with loss-of-control eating (−28.1% [0.6%]; mean difference, −6.5%; 95% CI, −8.5% to −4.5%; $P < .001$). The mean (SE) weight loss was greater in those who changed and began eating breakfast regularly (−32.8% [0.6%]) than those who had always eaten breakfast regularly (−31.2% [0.4%]; mean difference, −1.6%; 95% CI, −3.1% to −0.1%; $P = .03$); it was also greater in those who changed and began eating breakfast, lunch, and dinner regularly (−32.9% [0.6%]) than those who had always engaged in this behavior (−31.3% [0.4%]; mean difference, −1.6%; 95% CI, −3.1% to −0.2%; $P = .02$).

Relative to eating when full, eating when not hungry, and eating continuously throughout the day, those who made healthy changes in these behaviors lost significantly greater amounts of weight (mean [SE], −33.9% [0.5%], −33.6% [0.5%], and −34.8% [0.6%], respectively) than those who had never engaged in these behaviors (mean [SE], −31.3% [0.3%], −31.5% [0.3%], and −33.2% [0.4%], respectively) and those who had always engaged in these behaviors (mean [SE], −24.7% [1.5%], −25.8% [1.1%], and −29.2% [0.4%]) ($P = .01$ for stopping vs never eating continuously throughout the day; $P < .001$ for all other behaviors; eTable 1 in the Supplement). Overall, this suggests that having never engaged in certain negative behaviors was associated with greater weight loss, but overall the greatest weight loss was achieved by those who made healthy changes.

In eTable 2 in the Supplement, the unadjusted relationship between the change in each modifiable behavior and year 3 percent weight change is given for the LAGB group. The results were similar to those for the RYGB group.

Multiple Behavior Changes

Multiple behavior changes were associated with greater weight loss. If we consider the cumulative effects of the 3 behaviors that explain most of the variability (16%) in 3-year percent weight change following RYGB, ie, weekly self-weighing, continuing to eat when feeling full more than once a week, and eating continuously during the day, a participant who postoperatively started to self-weigh, stopped eating when feeling full, and stopped eating continuously during the day would be predicted to lose a mean (SE) of 38.8% (0.8%) of their baseline weight (**Table 2**). This average is about 14% greater weight loss compared with participants who made no positive changes in these variables (mean [SE], −24.6% [1.6%]; mean difference, −14.2%; 95% CI, −18.7% to −9.8%; $P < .001$) and 6% greater weight loss compared with participants who always reported positive on these healthy behaviors (mean [SE], −33.2% [0.6%]; mean difference, −5.7%; 95% CI, −7.8% to −3.5%; $P < .001$). Similar results were obtained for LAGB (eTable 2 in the Supplement).

The unadjusted relationships between the changes in each predictor and 3-year percent weight change are shown in eTable 3 and eTable 4 in the Supplement. Model fits were assessed using standardized root mean square residual; these data are shown in eTable 5 and eTable 6 in the Supplement. Fit summary examples are shown in eTable 7 and eTable 8 in the Supplement. The exact number of participants representing each variable in Table 1 are shown in eTable 9 in the Supplement.

Discussion

The results of this study suggest that certain behaviors, many of which are modifiable, are associated with weight loss differences of significant impact in patients undergoing RYGB or LAGB. The magnitude of this difference is large and clinically meaningful. In particular, the data suggest that developing positive changes in behavior, including ceasing negative behaviors or increasing positive behaviors, can affect the amount of weight loss. However, the cumulative effect of changing sev-

Table 2. Predicted Year 3% Weight Change for 3 Modifiable Behaviors Together[a]

	Predicted Year 3% Weight Change (SE)			Predicted Difference (95% CI) of Year 3 % Weight Change			*P* Value		
Procedure	Pattern 1	Pattern 2	Pattern 3	Pattern 2 Minus Pattern 1	Pattern 3 Minus Pattern 1	Pattern 3 Minus Pattern 2	Pattern 2 vs Pattern 1	Pattern 3 vs Pattern 1	Pattern 3 vs Pattern 2
RYGB (n = 1513)	−24.6 (1.6)	−33.2 (0.6)	−38.8 (0.8)	−8.6 (−12.8 to −4.3)	−14.2 (−18.7 to −9.8)	−5.7 (−7.8 to −3.5)	<.001	<.001	<.001
LAGB (n = 509)	−7.1 (2.0)	−18.6 (1.2)	−26.4 (1.6)	−11.5 (−17.8 to −5.2)	−19.3 (−25.6 to −13.0)	−7.8 (−11.9 to −3.7)	<.001	<.001	<.001

Abbreviations: LAGB, laparoscopic adjustable gastric banding; RYGB, Roux-en-Y gastric bypass.

[a] The following are the behavior patterns: behavior pattern 1, never self-weighed, always kept eating when full, and always ate continuously; behavior pattern 2, always self-weighed, never kept eating when full, and never ate continuously; and behavior pattern 3, started self-weighing, stopped eating when full, and stopped eating continuously. Never indicates participant reported not doing the behavior at baseline or at any follow-up time; always, participant reported doing the behavior at baseline and at every follow-up time; started, participant reported not doing the behavior at baseline and doing the behavior at every follow-up time; and stopped, participant reported doing the behavior at baseline and not doing the behavior at every follow-up time.

eral of these behaviors, eg, initiating self-weighing and ceasing both eating when full and eating continuously during the day, is additive. Relative to the prior literature in this area, it has previously been shown that after RYGB, decreased intake of calories[8] and fat,[9] better dietary adherence,[6] denying a snack-eating pattern,[10] decreased food urges, and a lower prevalence of grazing[10] have all been associated with greater weight loss. After LAGB, it has been shown that decreased hunger and disinhibition,[20] better dietary compliance,[7] improved eating behavior and changes to healthier eating patterns,[21,29] less "nonhunger" eating,[30] and less "uncontrolled eating"[30] are associated with better weight loss outcomes.[31] Also, a recent report from the Swedish Obese Subjects study found that participants who had lower levels of disinhibition and hunger at 6 months and 1 year lost more weight at 2-, 6-, and 10-year follow-up.[32] While most of these studies have been of modest sample size, usually 200 participants or fewer, there have been exceptions with larger sample sizes.[6,10,28,29] Also of note, research on obesity treatment in general suggests positive benefits for self-weighing,[33] regular breakfast eating,[34] and increased consumption of fruits and vegetables.[35] In general, these results are quite compatible with reports from the National Weight Control Registry, which tracks more than 10 000 individuals who have successfully lost weight and maintained the weight loss.[36] However, most of the research on bariatric surgery has focused on only 1 or a few eating-related or weight control variables. Thus, while such positive changes in eating behavior have been implicated before in improving weight loss outcomes, this is the first large-scale, multicenter study using a prospective design with commonly used definitions and a variety of such behaviors to document the importance and to quantify the magnitude of these changes (eAppendix in the Supplement).

The finding that those who adopted healthier eating behaviors lost more weight than those who had always engaged in them is of interest. One possible explanation is that those in the latter group had already experienced the benefits of those behaviors before surgery in terms of weight regulation.

The strengths of this study include the sample size and the careful assessment of eating problems, eating behaviors, and weight loss practices by self-assessment using the multicenter design. These speak to the generalizability of the findings. The study does have limitations. All behavior change data are based on self-report, and it is certainly possible that some or many of these variables are proxy variables for some unmeasured variable. However, changes in these variables were associated with weight loss changes of considerable magnitude, suggesting that these are relevant issues. This was an observational cohort study, and the data cannot be interpreted to demonstrate a causal relationship between weight loss and eating and weight behaviors. The direction of influence cannot be ascertained. For example, successful weight loss may encourage patients to engage in more healthy behaviors, and weight regain may drive the decision to cease healthy behaviors. Fifth, one cannot say whether the patients in the second group had not tried or actually engaged in healthier behaviors at some point.

Conclusions

The results indicate that certain weight control practices and eating behaviors that can be assessed after bariatric surgery can significantly influence the amount of weight loss after bariatric surgery. This suggests that structured programs to modify problematic eating behaviors and eating patterns following bariatric surgery should be evaluated as a method to improve weight outcomes among patients undergoing bariatric surgery. The results also underscore the need for health care professionals to target these behaviors in the postoperative period.

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Study concept and design: Mitchell, Flum, Pories, Wolfe.
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