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Stronger control of eating 3 months after sleeve gastrectomy predicts successful weight loss outcomes at one year

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ABSTRACT

Background: Weight loss response to sleeve gastrectomy (SG) is variable and predicting the effectiveness of surgery is challenging and elusive. The aim of our study was to assess and quantify the association between eating control and weight loss outcomes and identify the control of eating (CoE) attributes during the early postoperative period that might predict good vs. poor response to SG at one year.

Methods: A prospective longitudinal cohort study using the Control of Eating Questionnaire (CoEQ) was designed as a series before and at 3-, 6-, and 12-months post-SG. Primary outcomes were changes in CoE attributes and percent of total weight loss (%TWL) 12-months post-surgery. Subjects were categorized based on %TWL as good (GR, ≥25 %) or poor responders (PR, <25 %). A receiver operating characteristic and logistic regression analyses were performed.

Results: We included 41 participants (80.5% females, 51.2% Hispanic, mean age 41.7±10.6, median baseline body mass index (BMI) 43.6 kg/m^2 [range 35.2–66.3]) who completed the CoEQ at all four timepoints. The "Difficulty to control eating" score at 3 months revealed the highest area under the curve (AUC) (AUC 0.711; 95%CI 0.524–0.898; p=0.032). In a trade-off between a high Youden index and high sensitivity, the "Difficulty to control eating" score of 7 at 3 months was identified as the optimal cut-off for distinguishing between GRs and PRs. Score ≤7 at 3 months was strongly independently associated with a successful weight loss target of 25%TWL at one-year post-SG (Relative Risk 4.43; 95%CI 1.06–18.54; p=0.042).

Conclusion: "Difficulty to control eating" score at 3 months post-SG is an independent early predictor of optimal response (achieving a successful TWL target of ≥25 % at one-year post-SG). Our results support the utility of this easy-to-administer validated tool for predicting the effectiveness of SG and may assist in identifying individuals with suboptimal response early and helping them with interventions to attain optimal weight loss targets.

1. Introduction

Despite decades of public health efforts aimed at reversing the prevalence of obesity, rates have continued to rise [1–4]. Despite the emergence of increasingly effective medical therapies, metabolic bariatric surgery (MBS) remains the most effective treatment for obesity and adiposity-related complications [5,6]. Sleeve gastrectomy (SG) is the most commonly performed bariatric procedure in the US and worldwide and its frequency is increasing [7,8].

Compared to nonsurgical weight loss, there is a striking change in gut hormones after metabolic bariatric procedures that directly influences satiation, satiety and hedonic eating [9–13]. Moreover, SG is a restrictive bariatric procedure with a longitudinal resection of the gastric fundus, corpus and antrum and preservation of the pylorus, leading to

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the removal of about 80% of the stomach and leaving a remnant with a less than 100 ml capacity [14]. An emerging body of literature also suggests that postoperative weight reduction is associated with a lower inflammatory state. Significant decreases in *C*-reactive protein, ferritin, pro-inflammatory cytokines (tumor necrosis factor α, interleukin-12, interferon-γ) and chemokines (interleukins 1β, 6, 8, 10 and 18, monocyte chemoattractant protein-1) are observed following SG, notable at early stages [15–19].

However, not everyone responds uniformly to SG. Predicting the effectiveness of SG is challenging and elusive [5,20]. Along with neurohormonal and restrictive changes, genetic predisposition and postoperative neural circuit alterations likely account for a large contribution to weight loss, especially in the first 12–18 months [21–25]. There is a plethora of other factors that potentially contribute to the effectiveness of surgical intervention, such as behavioral, lifestyle, psychosocial, and environmental aspects [26–29]. In research settings, there is a correlation between hormonal changes and measures of satiety, with quantifiable correlations with peptides and neurotransmitters [30]. These biological and physiologic alterations, unfortunately, cannot be measured in typical clinical settings.

Early identification and intervention for poor responders has been shown to prevent weight gain and augment weight loss after bariatric surgery [31]. Pre-operative and early postoperative weight loss, however, have not been shown to be good predictors of long-term outcomes [29,32]. Given the variability in long-term weight loss, better strategies are needed to identify the suboptimal responders early in their postoperative course in order to intervene more aggressively and improve the effectiveness of MBS [6,33,34]. Likewise, various psychometric measures have been used to correlate post-surgical weight loss with changes in hedonic eating behaviors [35–39]. Those measures reflect food reward, satiety, and appetite control, and serve as markers of a complex interplay between hormonal and neurological signaling following SG.

Using a prospective bariatric surgery cohort, we have shown divergence of various Control of Eating (CoE) attributes between subjects who responded well to the surgical intervention and those who did not [40]. The aim of this study was to assess and quantify the association between eating control and weight loss outcomes and identify the CoE attributes in a validated psychometric instrument during the early postoperative period that might predict good vs. poor response to SG at one year.

2. Methods

2.1. Study design

The design of this study has been published previously [40]. Any previously published data presented in this report is only for the purpose of supporting our aims, methods, and conclusions. Briefly, this prospective longitudinal pre-post cohort study was designed as a series of surveys before and after SG using the validated Control of Eating Questionnaire (CoEQ) at the initial pre-surgical visit (baseline), and then at 3, 6, and 12-month timepoints after the surgical procedure [41]. Primary outcomes were changes in selected CoE attributes, and percent of total weight loss (%TWL) 12 months post-surgery, with TWL ≥25 % set as a successful target. Sex, smoking, ethnicity and weight status at baseline were assessed for covariance.

2.2. Study participants

Participants were screened for potential participation in the study from our bariatric surgery program consecutively from June 2016 to August 2019. In accordance with accepted standards and criteria for bariatric surgery, they had a body mass index (BMI) of ≥40 kg/m^2 or 35.0–39.9 kg/m^2 with major weight-related complications. Exclusion criteria included procedures other than SG, previous history of any other bariatric procedure(s), use of anti-obesity medications within the 3 months prior to screening, weight loss ≥5 % prior to initial visit, infection with human immunodeficiency virus, significant intellectual disability, malignancy not in remission (except for non-melanoma skin cancer), age younger than 18 years, and lack of proficiency in English. Using effect sizes for the CoEQ in pharmacological intervention studies, we estimated that 40 subjects would be sufficient to obtain a statistical power of 80 % at an α level of 0.05.

2.3. Survey

The CoEQ is a 21-item questionnaire designed to measure eating control over the previous seven days and has been shown to have good psychometric properties, including internal consistency, reliability, construct, and predictive validity (*Appendix 1*) [41]. It is divided into six sections, measuring satiety, mood, general and specific cravings, and perceived ability to resist certain foods. Except for one question requiring a narrative response, the items are assessed using a 100-mm visual analogue scale (VAS). Nine of the CoEQ items were selected for analysis as they were thought to be more direct measures of CoE attributes. Although this survey has not been validated in bariatric surgery populations before, we have previously shown correlations between various attributes of this instrument and the magnitude of post-surgical weight loss response [40].

2.4. Statistical analysis

Descriptive statistics were calculated to determine patients' characteristics. A Shapiro-Wilk test of normality and a visual inspection of the parameters' histograms, Q-Q plots, and box plots showed that the vast majority of values, except for weight, were not normally distributed [42, 43]. Therefore, nonparametric statistical methods were applied to analyze baseline characteristics and perform over time comparison for all continuous variables, except for weight where parametric statistical techniques were utilized. Data were presented as the mean±standard deviation (SD), median [min-max], and count and percentage.

The dynamics of CoEQ measures was assessed by comparing the VAS at each postoperative timepoint to the baseline. Percent TWL was defined as total weight loss at each defined timepoint (using initial weight as a reference) divided by initial weight, and TWL of 25% (25% TWL) at 12 months was used as the successful weight loss target consistent with the significant body of evidence reported previously in the literature [44–49]. Percent excess weight loss (%EWL) was defined as total weight loss at each time point divided by excess weight at the initial visit (initial weight – ideal weight [corresponding to BMI of 25 kg/m^2]), and EWL of 50% (50%EWL) at 12 months was used as the cut-off value for adequate weight loss [50–53]. Stratification into good responders (GR) and poor responders (PR) was performed based on % TWL at 12 months, with those who lost ≥25%TWL considered GRs.

Diagnosis of adiposity-related complications was established according to the most up-to-date guidelines. Specifically, dyslipidemia was defined as the presence of any of the following: hypercholesterolemia, elevated low-density lipoprotein cholesterol (LDL-C), decreased high-density lipoprotein cholesterol (HDL-C), hypertriglyceridemia, or treatment with an *anti*-dyslipidemia medication(s) [54]. Obstructive sleep apnea (OSA) diagnosis was established using overnight polysomnography and was defined as an apnea-hypopnea index (AHI) ≥15 or an AHI ≥5 associated with symptoms, such as excessive daytime sleepiness, fatigue, impaired cognition, mood disorders, insomnia, hypertension, ischemic heart disease, or history of stroke [55]. Hypertension was defined as a systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥80 mm Hg, based on an average of ≥2 careful readings obtained on ≥2 occasions, or treatment with an anti-hypertensive medication(s) [56].

One-way repeated measures analysis of variance (ANOVA) (for normally distributed values) and Friedman's two-way analysis of variance by ranks (for non-parametric values) were run to determine the dynamics of weight, BMI and CoEQ attributes over time. Means were compared using two-tailed paired and independent t-tests. Wilcoxon matched-pair signed-rank and Mann-Whitney were used to compare medians. Proportions were compared using Fisher's Exact Test due to its advantage of producing an exact distribution rather than an approximate one for relatively small sample sizes. Univariate and multivariate logistic regression was used to determine the association of CoE attributes and potential confounding factors with weight loss outcomes and Relative Risk (RR) was calculated.

The receiver operating characteristic (ROC) curve was constructed under the nonparametric assumption and the ROC curve analysis was performed to identify the cut-off score that would assist in distinguishing between GRs and PRs. The area under the ROC curve (AUC) was calculated using the trapezoidal rule (approximating the region under the curve as a trapezoid with further calculation of the area) to determine the diagnostic value of a specific CoE attribute in the context of others and to identify the optimal cut-off score; it also served as an indicator of the specific score performance [57–59]. Sensitivity, specificity, positive and negative predictive values (PPV and NPV, respectively) along with the test accuracy were calculated utilizing a 2 × 2 table. A Youden index (Y = Sensitivity + Specificity – 1) was calculated with a maximum index being indicative of the optimal cut-off score [60].

All statistical analyses and data visualization were performed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) 23.0 with a p-value ≤0.05 indicating statistical significance.

3. Results

3.1. Characteristics of study participants

Supplement 1 shows the study flow for subject participation. Out of 767 screened, 461 completed the baseline CoEQ. The first 41 patients who completed surveys at all four timepoints were included in the analysis. The full description of baseline clinical characteristics has been previously reported and is also demonstrated in Supplement 2 [40] The mean age of the participants was 41.7 ± 10.6 years, 80.5 % (n = 33) were female, and 51.2 % (n = 21) were Hispanic. There were 31.7 % (n = 13) current or former smokers at baseline, but no one was smoking at the time of surgery. The baseline BMI was 43.6 [35.2–66.3] kg/m^2. The most common adiposity-related complications were dyslipidemia (78.0 %, n = 32), OSA (56.1 %, n = 23) and hypertension (41.5 %, n = 17).

3.2. Dynamics of weight status over one year post-SG

Changes in weight status (weight, BMI, TWL, and EWL) and selected CoE attributes over the course of the study have been previously reported and are also presented in Table 1, Supplements 3–8 [40]. Briefly, using %TWL as the target outcome, both GR and PR groups had comparable weight (122.4 ± 15.6 kg vs. 129.6 ± 21.2 kg; p > 0.05) and BMI (42.8 [37.4–66.3] kg/m^2 vs. 44.9 [35.2–64.2] kg/m^2; p > 0.05) at baseline. The time interval between baseline and surgery did not differ between the two groups (5.6 [1.4–17.7] months vs. 6.6 [1.0–15.9] months; p > 0.05). GRs and PRs also had comparable BMI at the time of surgery (42.8 [37.4–66.3] kg/m^2 vs. 44.9 [35.2–64.2] kg/m^2, respectively; p > 0.05). Both GRs and PRs demonstrated substantial TWL and EWL over 12 months post-SG observation period (p < 0.001 over-time comparison in both groups). Overall, all participants had a substantial total and excess weight loss over the first 3 months post-SG (19.3 % [9.3–41.3] and 45.2 % [18.9–92.4], respectively) and by 12 months post-SG achieved %TWL of 22.9 % [4.7–46.5] (p < 0.001 over-time comparison) and EWL of 50.5 % [12.4–117.3] (p < 0.001 over-time comparison) (Supplement 3). Nevertheless, significant differences in TWL between GRs and PRs started to be observed early in the postoperative course, and by the 12-month timepoint, TWL among GRs was almost twice as high as among PRs (30.0 % [25.0–46.5] vs. 18.1 % [4.7–24.8]; p < 0.001). A similar trend was observed with respect to

Table 1
Change in weight status over the course of the study, depending on %TWL at one year post-sleeve gastrectomy.

Parameter	Groups	n	Baseline	3 months	6 months	12 months	p-value (over time comparison)
Weight, kg	GR	18	122.4 ± 15.6	92.6 ± 12.6### **	86.3 ± 13.3### ***	83.9 ± 12.1### ***	<0.001
	PR	23	129.6 ± 21.2	107.2 ± 18.3###	106.2 ± 18.8###	108.1 ± 18.0###	<0.001
BMI, kg/m^2	GR	18	42.8 (37.4–66.3)	32.9 (26.8–48.7)### **	30.4 (24.0–47.0)### **	29.8 (22.4–45.2)### ***	<0.001
	PR	23	44.9 (35.2–64.2)	36.6 (27.6–54.2)###	36.9 (27.8–52.7)###	38.1 (29.2–52.8)###	<0.001
Total weight loss (TWL), %	GR	18	–	22.8 (17.3–41.3)### ***	28.3 (19.8–46.7)### ***	30.0 (25.0–46.5)### ***	<0.001
	PR	23	–	17.0 (9.3–26.6)###	17.4 (6.2–26.2)###	18.1 (4.7–24.8)###	<0.001
Excess weight loss (EWL), %	GR	18	–	58.6 (30.6–92.4)### ***	69.1 (35.2–107.1)### ***	70.4 (47.5–117.3)### ***	<0.001
	PR	23	–	38.6 (18.9–81.0)###	39.8 (16.8–80.1)###	38.1 (12.4–64.8)###	<0.001

GR, Good Responders (participants who achieved TWL ≥25 % at one year post-sleeve gastrectomy); PR, Poor Responders (participants who achieved TWL <25 % at one year post-sleeve gastrectomy).
Values are expressed as μ ± SD for normally distributed and median (min-max) for non-parametric continuous variables. Analyses for changes over time are based on one-way repeated measures ANOVA (for normally distributed continuous variables) and Friedman's two-way analysis of variance by ranks (for non-parametric continuous variables).
Differences in weight status and scores between each of the subsequent timepoints (3, 6 or 12 months) in comparison to the baseline were analyzed using paired two-sided *t*-test (for normally distributed continuous variables) and Wilcoxon matched-pair signed-rank test (for non-parametric continuous variables), with statistical significance denoted as.
– p ≤ 0.05.
– p ≤ 0.01.
– p ≤ 0.001.
Differences in weight status and scores between groups with TWL ≥25 % vs. TWL <25 % at each of the timepoints (baseline, 3, 6 or 12 months) were analyzed using an independent two-sided *t*-test (for normally distributed continuous variables) and two-tailed Mann-Whitney test (for non-parametric continuous variables). Asterisks denote statistically significant differences.
*– p ≤ 0.05.
**– p ≤ 0.01.
***– p ≤ 0.001.

excess weight loss, with GRs showing approximately twice the weight loss in comparison to PRs at 12 months post-SG (70.4 % [47.5–117.3] vs. 38.1 % [12.4–64.8]; $p < 0.001$) (Table 1).

3.3. Dynamics of control of eating attributes over one year post-SG

A composite summary of changes in CoE attributes as a function of time and weight loss response was reported elsewhere and is shown in Fig. 1a and b, Supplements 3–8 [40]. At baseline, there were no substantial differences between GRs and PRs in all CoE attributes, except for "Desire for sweet foods", which was significantly lower among GRs (44 [0–90] vs. 75 [9–100], p = 0.026).

At 3 months, the "Difficulty to control eating" was the first and only CoE attribute to reveal a significant difference between GR and PR groups (7 [0–50] vs. 17 [5–63]; p = 0.006). Interestingly, an identical observation was made when comparing participants based on their 1-year post-SG EWL achievement. The "Difficulty to control eating" was also the first and only CoE attribute to exhibit a considerable difference

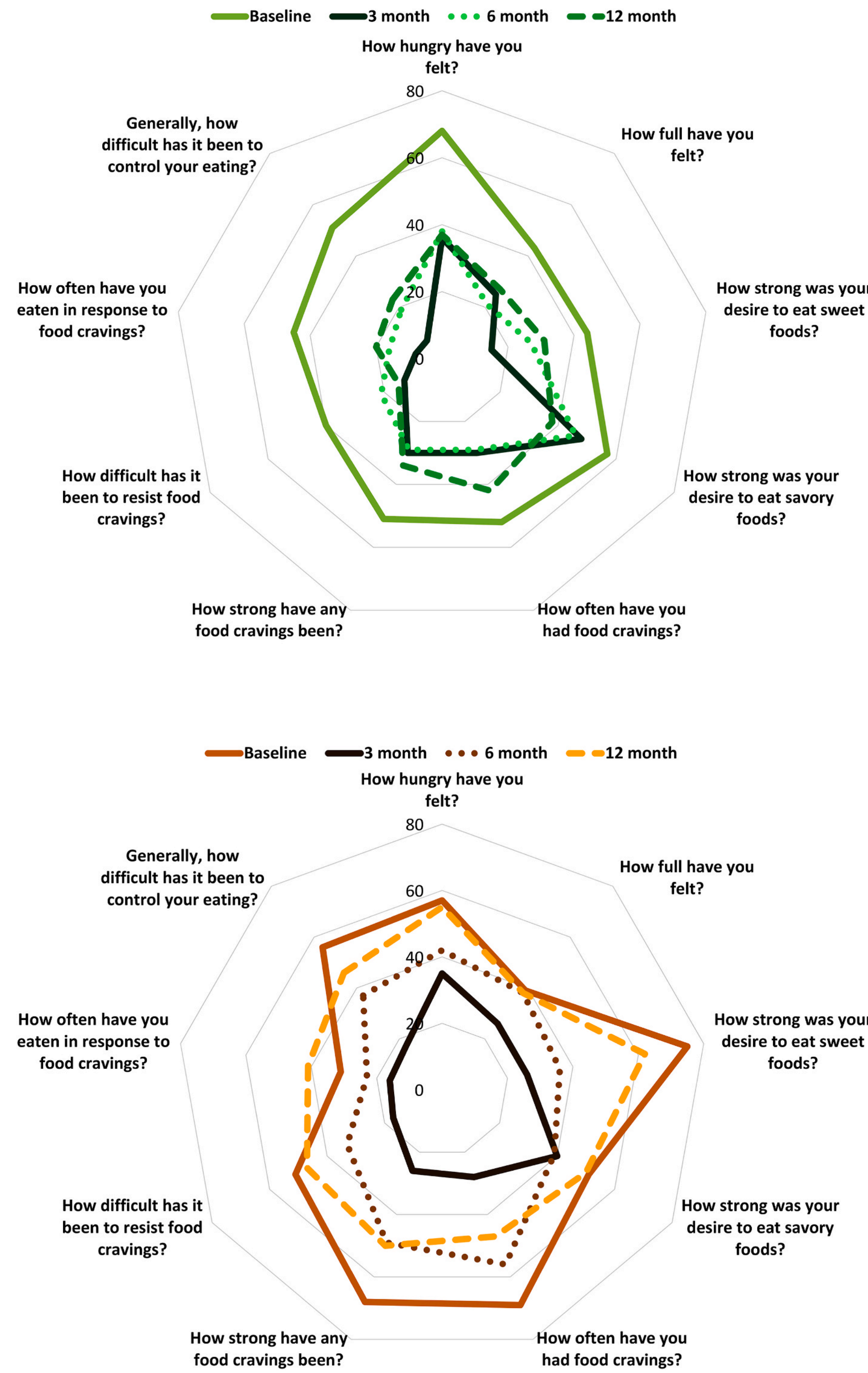

Fig. 1. Changes in Control of Eating attributes over one year post-sleeve gastrectomy. Data is shown in a radar chart with values representing scores (VAS measured in mm). The responses for the "How full have you felt" are expressed as (100 – mean response value). Fig. 1a. Changes in Control of Eating attributes among Good Responders (TWL≥25 %). Fig. 1b. Changes in Control of Eating attributes among Poor Responders (TWL<25 %).

and reach the same score of 7 at 3 months among those who eventually attained 50%EWL at one year post-SG compared to those who did not (7 [0–50] vs. 21 [5–63]; p = 0.005).

3.4. Receiver operating characteristic (ROC) analysis and score performance

The results of ROC analysis for the CoE attributes at 3 months post-SG with a target outcome of achieving ≥25%TWL at one year are presented in Fig. 2 and Supplement 9. The "Difficulty to control eating" attribute was the only one that in the ROC analysis revealed the highest AUC and demonstrated statistical significance (AUC 0.711; 95%CI 0.524–0.898; p = 0.032). The AUC of 0.711 is considered acceptable as it falls in the interval between 0.7 and 0.8 [61]. In a trade-off between a high Youden index and high sensitivity, the score of 7 had the Youden index of 0.34 (as one of five indexes exceeding 0.3), but at the same time had the highest sensitivity among all of those (0.556), which was identified as the optimal cut-off for distinguishing between GRs and PRs.

The "Difficulty to control eating" cut-off score performance is shown in Supplement 10. The sensitivity and specificity of the cut-off score of 7 were 55.6 % and 78.3 %, respectively. Such high specificity signified that over 75 % of PRs would have a "Difficulty to control eating" score >7 at 3 months. The positive predictive value (PPV) was 66.7 %, meaning that two-thirds of the patients with a score ≤7 at 3 months were able to achieve 25%TWL at one year. The negative predictive value (NPV) was 69.2 %, meaning that this proportion of the individuals with a score >7 at 3 months were PRs. Moreover, the accuracy of the "Difficulty to control eating" question was 68.3 %, suggesting sufficient performance of the parameter in identifying both GRs and PRs.

3.5. Association of control of eating attributes and weight loss outcomes

As the next step, a univariate logistic regression model was constructed. The "Difficulty to control eating" score ≤7 at 3 months was strongly associated with reaching a successful weight loss target of ≥25%TWL at one year post-SG (RR 4.50; 95%CI 1.16–17.51; p = 0.030), while sex, ethnicity, smoking status and BMI at baseline showed no significant association (Table 2). After adjusting for sex, ethnic background, smoking and baseline BMI in a multivariate model, the association remained strong (RR 4.43; 1.06–18.54; p = 0.042), providing a rationale that the "Difficulty to control eating" score ≤7 at 3 months is an independent predictor of good response to SG.

In parallel with the above-mentioned findings, the score also demonstrated significant association with losing ≥50%EWL at 12 months (RR 6.40; 95%CI 1.44–28.4; p = 0.015) (Table 2). However, BMI at baseline was inversely associated with achieving this target (RR 0.87; 95%CI 0.77–0.97; p = 0.016). In a multivariate model, considering sex, ethnicity, smoking and a baseline BMI, a similar pattern was observed. Participants with the "Difficulty to control eating" score ≤7 at 3 months were almost 17 times more likely to achieve ≥50%EWL at one year (RR 16.7; 95%CI 1.91–145.8; p = 0.011), but BMI at baseline continued being inversely associated with attaining this target.

4. Discussion

The aim of our study was to identify CoE attributes that may predict longer-term weight loss outcomes post-SG. Focusing on the measures capturing eating behaviors, compared to PRs, subjects who lost ≥25% TWL reported greater differences compared to baseline scores. At 3 months, question 19 – "Generally, how difficult has it been to control your eating?" corresponding to the "Difficulty to control eating" CoE attribute – seemed to best predict weight loss at one year after surgery and distinguish between GRs and PRs.

Although optimization of lifestyle behaviors with any weight loss intervention is desirable and important, biological changes after MBS may be more relevant. In fact, genetic contributors may be more predictive of weight loss outcomes approximately one year after Roux-en-Y Gastric Bypass (RYGB) when compared to environmental influence [62]. The superior effectiveness of metabolic bariatric procedures may be a result of pleiotropic entero-neuroendocrine changes, including bile acid signaling, enhanced gut hormone secretion, reduction or resolution of systemic inflammation, central suppression of energy consumption, altered responsiveness in key brain areas, blunting of adaptive thermogenesis, and shifts in gut microbiome composition [19,63–69].

From the ingestive behavior perspective, manifestations include changes in eating habits and routines, altered appetite and sensory perceptions, increased satiation (sensation of "fullness" and earlier meal termination), changes in hedonic preferences, and implementation of newly-developed strategies to cope with cravings and urges [70–74]. Up to two-thirds of patients after MBS report a reduction in interest in foods high in sugar, fat and complex carbohydrates, in addition to alcohol, which results in up to 70 % reduction in caloric intake [75,76]. Interestingly, changes in hedonic eating behavior after SG have been noticed across most types of foods, while individuals who underwent RYGB were more selective in their food preferences [73,77]. Overall, eating behavior traits post-SG are a result of a complex interplay between the restrictive nature of this procedure, neurohormonal changes affecting the gut-brain axis, and neurobehavioral factors, such as pre-prandial

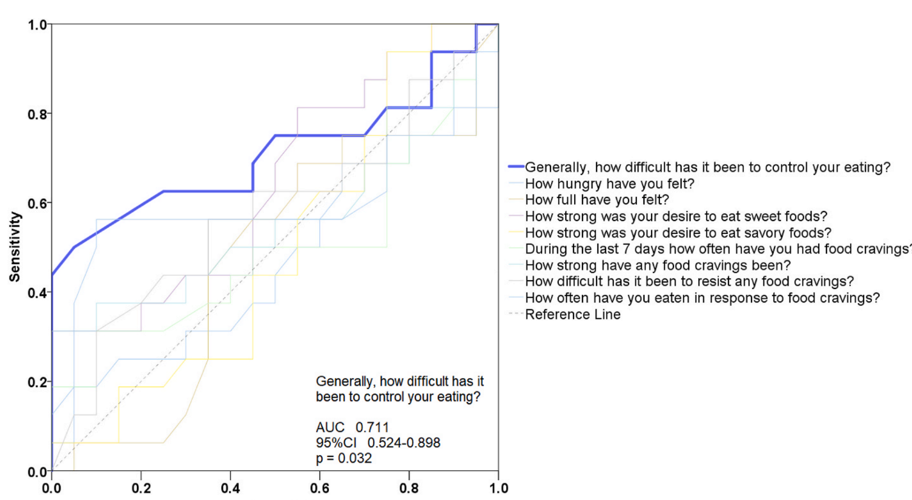

Fig. 2. Receiver operating characteristic (ROC) curve and area under the curve (AUC) analysis for comparison of various Control of Eating attributes at 3 months in determining response to sleeve gastrectomy at one year. Data are presented in Supplement 9.

Table 2
Logistic regression analysis of associations between difficulty to control eating, sex, ethnicity, smoking status, BMI at baseline, and weight loss at one year post-sleeve gastrectomy (%TWL and %EWL).

Variables	Good Responders (%TWL ≥25 % at one year)						%EWL ≥50 % at one year					
	Univariate			Multivariate			Univariate			Multivariate		
	RR	95 % CI	p-value	RR	95 % CI	p-value	RR	95 % CI	p-value	RR	95 % CI	p-value
Generally, how difficult has it been to control your eating? Score ≤7 at 3 months post-sleeve gastrectomy	**4.50**	**1.16–17.51**	**0.030**	**4.43**	**1.06–18.54**	**0.042**	**6.40**	**1.44–28.4**	**0.015**	**16.7**	**1.91–145.8**	**0.011**
Sex												
Female	1.39	0.28–6.79	0.685	2.68	0.34–21.21	0.350	0.64	0.13–3.11	0.578	1.62	0.15–18.25	0.688
Ethnicity												
Hispanic	0.62	0.18–2.13	0.444	0.59	0.12–2.85	0.509	0.61	0.18–2.09	0.428	1.07	0.15–7.63	0.946
Smoking												
Current or former	1.80	0.48–6.81	0.384	1.45	0.34–6.28	0.616	1.60	0.42–6.11	0.492	1.41	0.24–8.41	0.709
BMI at baseline, *kg/m²*	0.97	0.89–1.06	0.506	0.95	0.86–1.05	0.339	**0.87**	**0.77–0.97**	**0.016**	**0.80**	**0.68–0.95**	**0.012**

TWL, Total Weight Loss; EWL, Excess Weight Loss.

hedonic motivation, disinhibition, cognitive preoccupation, and coping mechanisms. The challenge, however, is that analyses of these physiologic effects are not practical, available, or useful in routine clinical settings. Obstacles in utilizing hormone levels diagnostically and/or prognostically include a lack of standardization protocols, complicated processing and handling requirements, and individual variability resulting from factors such as diet, physical activity, stress, and anxiety [78].

Identifying surrogate measures for biological predictors of postoperative weight loss is therefore an area of investigation that could potentially translate into improved long-term outcomes for bariatric surgery patients. Our data show that control of eating is quantifiable and changes after sleeve gastrectomy [40]. There is also a drift towards baseline in the first year after surgery, with suboptimal responders exhibiting less suppression of these measures during the first year after their procedure. Other tools measuring eating behavior, such as the Dutch Eating Behavior Questionnaire (DEBQ), Questionnaire on Weight and Eating Patterns, Three-Factor Eating Scale (TFEQ), Yale Food Addiction Scale, and the Adult Eating Behavior Questionnaire (AEBQ), exhibit comparable performance demonstrating association between reduction in hunger, feelings of satiety and satiation, overall eating control, eating in response to cravings or environmental cues, etc., and weight loss [79–83].

We did not correlate our data with measured gut hormones, but studies examining the association between hormonal alterations and control of eating elements, such as satiety and hedonic responses, in both surgical and non-surgical subjects, suggest that changes in eating behaviors are likely useful as surrogate measures [65,84]. There is one report of an extreme case of exaggerated gut hormone response after sleeve gastrectomy that correlated with severe anorexia and reversed with octreotide [85]. One study showed that reduced ghrelin levels measured at 6 months after SG significantly correlated with decreased hunger scores [86]. Using healthy volunteers without obesity, others have shown that the kinetics of hunger scores using VAS correlated strongly with the pattern of secretion of gut hormones after different sequences of meal consumption [87].

Experimental manipulation of gut hormones provides another element of evidence that VAS instruments can serve as surrogate markers for both changes in energy consumption and control of eating via satiety and hedonic responses. Both oxyntomodulin and PYY, for example, when given as an intravenous infusion, result in reduced caloric intake and hunger scores [88,89]. Likewise, infusion of a GLP-1 agonist in subjects who were both lean and had obesity demonstrated a dose-dependent effect on similar measures of hunger and fullness [90]. Subcutaneous GLP-1, with and without activation of receptors for glucose-dependent insulinotropic polypeptide, are currently available clinically for the treatment of obesity [91–93].

Despite the superior efficacy of MBS for weight loss, long-term maintenance, and improvement of obesity-related complications, there is a great degree of variability in response [6,94]. For individuals who are considered poor responders to surgical weight loss or regain significant weight, options include intense lifestyle interventions, anti-obesity pharmacotherapy, and endoscopic or surgical revision procedures. Reoperation can be beneficial for some patients but may carry increased perioperative risk compared to primary surgery [95,96]. Anti-obesity medications (AOMs) may also be effective therapeutically for weight recurrence and suboptimal postsurgical weight loss [31,97–99]. Moreover, adjunctive use of AOMs may halt the trajectory of post-bariatric weight recurrence [100], with potential implications for the prevention of this particular complication. One study showed liraglutide can be as effective as a revisional restrictive procedure and more effective than an endoscopic procedure [101]. Additionally, newer generation AOMs are much more effective than older options [92,93] and although there is not yet published data for weight recurrence, they may prove to be superior to revision procedures. Hence, early identification of suboptimal responders to bariatric surgery may be useful for expedited intervention before significant weight recurrence occurs.

Our ROC analysis demonstrated acceptable and statistically significant AUC for the “Difficulty to control eating” CoE attribute in identifying GRs. As the aim of our study was to identify the CoE attribute(s) that would serve the purpose of screening and predicting good response to SG at one year, we targeted the score demonstrating a combination of high Youden index balanced with high sensitivity. Using a logistic regression model, changes in “Difficulty to control eating” provide the best accuracy for predicting optimal weight loss at one year after SG, with an absolute score of 7 or less at 3 months demonstrating the strongest quantifiable measure. Therefore, a score of 7 at 3 months was identified as the optimal cut-off for distinguishing between GRs and PRs. Identifying individuals with optimal vs. suboptimal responses early in the post-SG course is critical. In large studies of subjects who underwent MBS, self-reported lower levels of disinhibition and hunger along with a reduction in overall energy, carbohydrates, fat and protein intake shortly after the procedures were associated with overall greater weight loss at 10 years post-surgery, suggesting that early control of eating attributes is essential in securing long-term weight loss success [102–104].

If this finding can be reproduced and validated, it would potentially serve as a valuable tool in the clinical setting given its simplicity without excessive burden on patient acceptance and comprehension, time constraints, and ease of interpretation. We believe these preliminary findings are hypothesis-generating since they need to be validated among larger populations, after RYGB, across a wide spectrum of baseline BMI levels, and at multiple different sites.

5. Strengths

To our knowledge, this study is the first to determine a cut-off score to help predict the achievement of a successful weight loss target at one year post-SG. We utilized the CoEQ, a validated tool that can be easily introduced in routine clinical settings to assess individuals who underwent SG early in the post-operative period and predict their weight loss outcomes. Another strength was the use of %TWL for setting up a successful weight loss target, as our analysis along with previously published literature demonstrated that %EWL is influenced by baseline BMI [105,106]. In addition, we did not have any missing data by design, which improves the reliability of our study results. Moreover, the prospective longitudinal study design increases the strengths of evidence, minimizes the risk of biases, and supports the transferability and generalizability of our study findings.

6. Limitations

First, our sample size was relatively small. Out of 767 patients who were initially screened, 461 (60.1 %) provided informed consent and a baseline questionnaire, and of those, we included the first 41 patients (8.9 %) who had CoEQ completed at all consecutive time points. It is possible that a larger number of subjects would lead to the identification of other items with significant predictive value. Our particular instrument was applied only to patients undergoing SG, and it is unknown if similar findings would be noted after other metabolic procedures. Also, we did not assess other potential confounding factors in our model, such as the use of obesogenic medications, socioeconomic status, duration of obesity, or adherence to physical activity recommendations. In the future, it would also be beneficial to measure the association of our CoE attributes with weight loss outcomes beyond one year after surgery.

7. Conclusion

Our study demonstrates that the "Difficulty to control eating" score measured at 3 months post-SG serves as an independent early predictor of optimal response (achieving a successful total weight loss target of $\geq$25 % at one year). The results of our study provide strong evidence and open avenues for using a convenient, validated tool to help with predicting the effectiveness of sleeve gastrectomy. More research is needed to confirm the validity, generalizability, and potential for implementation as a clinical tool.

- The Control of Eating Questionnaire can be used as an easy-to-administer, validated tool for predicting the effectiveness of SG early in the postoperative course.
- Improved overall control of eating at 3 months post-SG is an independent early predictor of achieving a successful total weight loss target of $\geq$25 % at one year.
- Implementation of the Control of Eating Questionnaire in the routine clinical practice of healthcare professionals providing care for people with obesity after SG may help to identify individuals with a poor response early in the postoperative course and select patients that may benefit from early tailored behavioral, biofeedback-based techniques, in addition to dietary and pharmaceutical interventions to assist in attaining optimal weight loss targets.

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Author contribution

All authors made substantial contributions to the conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

Ethical review

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. The study was approved by the Institutional Review Board.

Declaration of AI and AI-assisted technologies in the writing process

No use of AI and AI-assisted technologies in this study.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.obpill.2024.100111.

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