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Original Article

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Comparative Analysis of Various Weight Loss Success Criteria Models After Bariatric Metabolic Surgery in Korean Morbid Obese Patients

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ABSTRACT

Purpose: To identify weight loss prediction models by validating previous models using weight loss success criteria.
Materials and Methods: Patients with morbid obesity from 4 hospitals were retrospectively analyzed between Jan 2019 and 2022. Preoperative demographics, postoperative data, and 1-year follow-up weight loss outcomes were compared between 2 groups who underwent laparoscopic sleeve gastrectomy (LSG) and laparoscopic Roux-en-Y gastric bypass (LRYGB). Additionally, the predictive factors for the success of excess weight loss (EWL) (>50%) and total weight loss (TWL) (>25%) were analyzed.
Results: Of the 162 patients, 137 were enrolled during the study period, 75 underwent LSG, and 62 underwent LRYGB. The >50% EWL and >25% TWL 1 year after surgery were 61.3% and 43.1%, respectively. Diabetes mellitus medication use was reduced in 94.8% of patients with type 2 diabetes mellitus. Male sex and body mass index (BMI) were independent risk factors for successful weight loss (SWL) or >50% EWL (odds ratio [OR] for BMI 0.830, 95% confidence interval [CI] 0.764–0.902), whereas achieving >25% TWL was not affected by sex or BMI (OR for BMI 1.010, 95% CI 0.957–1.065). External validation of the prediction models showed an acceptable range of accuracy (adjusted R^2 66.5–71.3%).
Conclusion: LSG and LRYGB are feasible and effective bariatric procedures for SWL in Korean patients with morbid obesity. The TWL model was a more appropriate criterion than EWL, and weight loss prediction models may help assess the 1-year outcomes of bariatric surgery.

Keywords: Bariatric surgery; Prediction; Weight loss

INTRODUCTION

Morbid obesity is related to several kinds of metabolic diseases, such as hypertension, type 2 diabetes mellitus (T2DM), dyslipidemia, obstructive sleep apnea, and non-alcoholic fatty liver disease [1]. The effect of bariatric surgeries on weight loss and improvement of comorbid diseases has been well established in previously published large-scale randomized controlled

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Conflict of Interest
None of the authors have any conflict of interest.

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studies [2,3]. Since national insurance coverage began for bariatric surgery in Korea in 2019, bariatric surgery cases have rapidly increased. Laparoscopic sleeve gastrectomy (LSG) and laparoscopic Roux-en-Y gastric bypass (LRYGB) are the most commonly performed bariatric surgeries in Korea [4].

The effect of bariatric surgery is assessed using various indicators, such as percent excess weight loss (% EWL), percent total weight loss (% TWL), and percent excess body mass index loss (% EBMIL) [5]. According to the Korean Society for Metabolic and Bariatric Surgery (KSMBS) guidelines, ≥50% EWL should be achieved for successful weight loss (SWL) [6]. However, evidence that % TWL is more sensitive and specific than other indicators is accumulating [5,7]. As predicting the effect of bariatric surgery for patients with morbid obesity is necessary, many weight loss prediction models have been introduced [8-16]. However, these models have been developed and validated using Caucasian populations. Consequently, there has been a lack of accurate prediction models for Korean patients with obesity, primarily because of the absence of external validation [17].

The purpose of this study was to assess which SWL indicator criteria were better, between % EWL and % TWL, and to determine which previous weight loss prediction model yielded better results in predicting weight loss 1 year after bariatric surgery. This assessment was conducted using 1-year follow-up data from Korean patients with morbid obesity after bariatric surgery.

MATERIALS AND METHODS

1. Patient selection

We retrospectively analyzed the medical records of patients with morbid obesity who underwent bariatric surgery between January 2019 and June 2022 from 4 hospitals (Korea University Anam Hospital, Korea University Guro Hospital, Korea University Ansan Hospital, and Kyung Hee University Hospital at Gangdong). Patients with a body mass index (BMI) >35 kg/m^2 or BMI >30 kg/m^2 with one or more comorbidities, such as hypertension, T2DM, and dyslipidemia, who were indicated for bariatric surgery in Korea, were included in this study [6]. All patients who had undergone LSG or LRYGB were included in this study. Each patient was assessed for the most suitable type of operation according to the KSMBS guidelines [6]. We collected data on sex, age, height, weight, BMI, comorbidities, operation time, intraoperative events, and length of hospitalization. After surgery, the patients were followed up regularly in outpatient clinics, and their weight, BMI, and laboratory changes were recorded. Postoperative complications were recorded according to the Clavien–Dindo grade [18].

We set the primary outcome of bariatric surgery as weight loss 1 year after surgery. The weight loss was subdivided into % EWL and % TWL [6]. The 1-year postoperative % EWL was calculated as (initial body weight - body weight 1 year after operation)/(initial body weight - ideal body weight)×100, where ideal body weight was calculated using Devine's formula [19]. The % TWL was calculated as (initial body weight−body weight 1 year after operation)/(initial body weight)×100. SWL was defined as either >50% or TWL >25%.

2. Predicting models selection

As no published weight loss prediction models are available for the Korean population, we used previously published externally validated prediction models [17]. Most models in the study were made using BMI-based calculations, whereas a few other models were created using body weight-based calculations [7-16]. Among the models, we chose the 2 most predictive and accurate in previous externally validated studies, using BMI and weight loss, respectively [8,15]. Baltasar's models used preoperative BMI to predict the BMI 1 year after operation: predicted BMI=initial BMI×0.4+11.75 [8]. Conversely, Seyssel's model used preoperative weight to predict weight loss 1 year after surgery: predicted TWL=0.4×preoperative weight−0.21×age [15].

3. Statistical analysis

All statistical analyses were performed using SPSS ver. 26 (IBM SPSS Statistics, IBM, Armonk, NY, USA). The baseline characteristics were compared using the Student's t-test. The Mann–Whitney U test was performed if the variables were confirmed to be nonparametrically distributed based on the Kolmogorov–Smirnov test. The chi-square and Fisher's exact tests were used to analyze categorical variables. Linear regression was used to assess the relationship between predicted and observed BMI. Correlation parameters included the regression coefficient (B) with a 95% confidence interval (95% CI).

The adjusted squared Pearson correlation coefficient (R^2) was used to determine the diagnostic accuracy of each model. Calibration was assessed by the standard error of the estimate (SE), root mean square error, and paired sample t-test between the mean predicted and mean observed BMI. In addition, the difference between the mean predicted and observed BMI was calculated.

All statistical tests were 2-sided, and P values <0.05 were considered significant.

This study was approved by the Institutional Review Boards of the Korea University Hospital (K2023-1912-001) and Kyung Hee University Hospital at Gangdong (2023-08-013).

RESULTS

1. Clinicopathologic characteristics

Among 162 patients who underwent bariatric surgery at the 4 hospitals, 25 were excluded because they were lost to follow-up, and a total of 137 patients were included. Overall, 76 patients underwent LSG, and 61 underwent LRYGB. The mean age was significantly higher in patients who underwent LRYGB than LSG (47.3±10.9 vs. 40.7±12.0 years, *P*<0.001). Preoperative BMI was significantly higher in patients who underwent LSG than LRYGB (39.8±6.9 vs. 36.4±5.1 kg/m^2, *P*<0.001). Weight and BMI decreased significantly 1-year postoperatively. The length of hospital stay was significantly longer in the LSG group than in the LRYGB group. The operative times were similar between the 2 groups. Two patients experienced severe postoperative complications: one had acute kidney insufficiency, and the other had omental bleeding, which required bleeding control (**Table 1**).

2. 1-year weight loss outcome

All patients were followed up for 1 year after the operation. Overall, 61.3% of the patients achieved >50% EWL. For each group, 59.2% of the patients who underwent LSG and 63.9%

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Table 1. Demographic findings of the patients after bariatric surgery

Baseline characteristics	Total (n=137)	LSG group (n=76)	LRYGB group (n=61)	P value
Age (years)	43.6±12.0	40.7±12.0	47.3±10.9	0.001
Sex				0.526
Male	42 (30.7)	25 (32.9)	17 (27.9)	
Female	95 (69.3)	51 (67.1)	44 (72.1)	
Preoperative weight (kg)	104.6±23.0	109.4±24.9	98.6±17.7	0.004
Preoperative BMI (kg/m^2)	38.3±6.4	39.8±6.9	36.4±5.1	0.001
DM	102 (74.5)	46 (60.5)	56 (91.8%)	<0.001
DM medication at operation	77 (56.2)	36 (47.4)	41 (67.2%)	0.02
ASA score				0.811
2	111 (81.0)	60 (78.9)	51 (83.6%)	
3	25 (18.2)	15 (19.7)	10 (16.4%)	
4	1 (0.7)	1 (1.3)	0	
Hospitalization (days)	4.0 (2–28)	5.0 (2–28)	4.0 (3–8)	<0.001
Operation time (min)	137.2±43.4	141.2±46.0	132.2±39.8	0.221
Postopertive complication	2 (1.5)	2 (2.6)	0	0.502

Values are mentioned as mean±standard deviation or median (interquartile range) or number (%).
LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, BMI = body mass index, DM = diabetes mellitus, type 2, ASA = American Society of Anesthesiologists.

Table 2. 1-year outcomes after bariatric surgery of the patients

Variables	Total (n=137)	LSG group (n=76)	LRYGB group (n=61)	P value
Preoperative BMI (kg/m^2)	38.3±6.4	39.8±6.9	36.4±5.1	0.001
Weight loss (kg)	25.3±9.9	27.0±10.4	23.2±9.0	0.024
Percent excess weight loss (%)	56.6±20.2	55.9±22.4	57.5±17.2	0.646
Percent TWL (%)	24.0±7.3	24.6±7.7	23.3±6.8	0.295
Weight loss success				
≥50% excess weight loss	84 (61.3)	45 (59.2)	39 (63.9)	0.573
≥25% TWL	59 (43.1)	36 (47.4)	23 (37.7)	0.256

Values are mentioned as mean±standard deviation or number (%).
LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, BMI = body mass index, TWL = total weight loss.

Table 3. Changes of diabetic medication 1-year after bariatric surgery of the patients with preoperative diabetic medication

Associated factors	Total (n=77)	LSG group (n=36)	LRYGB group (n=41)	P value
DM medication (n=77)				0.669
Stopped	54 (70.1)	26 (72.2)	28 (68.3)	
Reduced dose	19 (24.7)	9 (25.0)	10 (24.4)	
Same dose	4 (5.2)	1 (2.8)	3 (7.3)	

Values are mentioned as number (%).
LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, DM = diabetes mellitus, type 2.

of those who underwent LRYGB, respectively (P=0.573), achieved >50% EWL. Furthermore, 43.1% of the patients achieved >25% TWL, 47.4% in the LSG group, and 37.7% in the LRYGB group, respectively (P=0.256) (**Table 2**). Notably, 77 patients had T2DM preoperatively, among whom 73 (94.8%) stopped taking medication 1 year after surgery (**Table 3**).

In the multivariate analysis, male sex (odds ratio [OR] 2.580, 95% CI 1.013–6.574) and BMI (OR 0.830, 95% CI 0.764–0.902) were independent risk factors for achieving >50% EWL (**Table 4**). However, none of these factors significantly affected achieving >25% TWL (OR for BMI 1.010, 95% CI 0.957–1.065) (**Table 5**).

3. Validating predicting models

External validation using Baltasar's model showed that the model explained 71.3% of the variation of weight loss of the overall patients (adjusted R^2 0.713) and presented goodness

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Table 4. Risk factors for hindering successful weight loss or more than 50% of excess weight loss at 1 year after operation

Associated factors	Univariate			Multivariate		
	OR	95% CI	P value	OR	95% CI	P value
Age (by 60 or more)			0.963			
<30	0.813	0.183–3.600	0.785			
30–39	0.688	0.176–2.684	0.590			
40–49	0.733	0.187–2.880	0.657			
50–59	0.950	0.229–3.945	0.944			
Male sex	1.200	0.565–2.548	0.635	2.580	1.013–6.574	**0.047**
BMI[a]	0.872	0.814–0.935	**<0.001**	0.830	0.764–0.902	**<0.001**
ASA score (by 2)			0.300			
3	0.500	0.208–1.021	0.121			
4	0.000	0–∞	1.000			
DM	0.916	0.415–2.023	0.828			
Type of operation (by LSG)						
LRYGB	1.221	0.610–2.446	0.573			
Preop HbA1c[a]	1.079	0.849–1.372	0.532			
Preop total cholesterol[a]	0.998	0.991–1.006	0.689			

P values in bold means statistically significant.
OR = odd ratio, CI = confidence interval, BMI = body mass index, ASA = American Society of Anesthesiologists, DM = diabetes mellitus, type 2, LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, Preop = preopertive, HbA1c = hemoglobin A1C.
[a]Continuous variable.

Table 5. Risk factors for hindering successful weight loss or more than 25% of total body weight loss at 1 year after operation

Associated factors	Univariate		
	OR	95% CI	P value
Age (by 60 or more)			0.946
<30	1.050	0.250–4.417	0.947
30–39	1.260	0.339–4.681	0.730
40–49	0.852	0.226–3.209	0.813
50–59	1.137	0.292–4.437	0.853
Male sex	0.858	0.411–1.794	0.684
BMI	1.010	0.957–1.065	0.727
ASA score (by 2)			0.836
3	1.304	0.546–3.116	0.550
4	2,282,736,190.9853	0–∞	1.000
DM	0.464	0.213–1.012	0.054
Op type (by LSG)			
LRYGB	0.673	0.339–1.336	0.257
preop HbA1c	0.861	0.676–1.097	0.225
preop total cholesterol	0.996	0.989–1.004	0.382

OR = odd ratio, CI = confidence interval, BMI = body mass index, ASA = American Society of Anesthesiologists, DM = diabetes mellitus, type 2, LSG = laparoscopic sleeve gastrectomy, Op = operative, LRYGB = laparoscopic Roux-en-Y gastric bypass.
[a]Continuous variable.

of fit with an SE of 2.86 kg/m^2. In contrast, Seyssels' model showed a 66.5% variation in the overall patients (adjusted R^2 0.665) and presented goodness of fit with an SE of 3.08 kg/m^2 (**Table 6**). The mean BMI difference between the predicted and observed BMI at 1 year after operation was lesser in Baltasar's model than Seyssel's, in the overall group, and in each type of operation subgroups (−1.98±3.46 vs. −2.60±3.17). Additionally, the mean BMI difference was lesser in LRYGB than in LSG using Baltasar's model (−1.54±2.94 vs. −2.36±3.83) and Seyssel's model (−2.26±2.89 vs. −2.90±3.39) (**Table 7**).

Table 6. Results of linear regression analysis between predicted and observed BMI 1 year after surgery for prediction models in all, LSG, and LRYGB group

Group	Model	B	95% CI	P value	R	R^2	adjusted R^2	SE	RMSE
All	Baltasar	1.776	1.586–1.967	<0.001	0.846	0.715	0.713	2.86	2.85
	Seyssel	1.221	1.074–1.367	<0.001	0.817	0.668	0.665	3.08	3.08
LSG	Baltasar	1.830	1.572–2.088	<0.001	0.854	0.730	0.726	3.07	3.07
	Seyssel	1.244	1.053–1.435	<0.001	0.833	0.694	0.690	3.27	3.27
LRYGB	Baltasar	1.695	1.367–2.024	<0.001	0.802	0.643	0.637	2.61	2.61
	Seyssel	1.127	0.870–1.383	<0.001	0.753	0.566	0.559	2.87	2.88

BMI = body mass index, LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass, B = regression coefficient, CI = confidence interval, R = Pearson's correlation coefficient, SE = standard error of the estimate, RMSE = root mean square error.

Table 7. Comparison of predicted and observed postoperative BMI at 1 year after surgery for prediction models in all, LSG, and LRYGB group

Models	All		LSG		LRYGB	
	Predicted BMI	BMI difference	Predicted BMI	BMI difference	Predicted BMI	BMI difference
Baltasar	27.06±2.54	−1.98±3.46	27.71±2.74	−2.36±3.83	26.28±2.04	−1.54±2.94
Seyssel	26.44±3.57	−2.60±3.17	27.17±3.91	−2.90±3.39	25.56±2.90	−2.26±2.89

Values are shown as mean±standard deviation.
BMI = body mass index, LSG = laparoscopic sleeve gastrectomy, LRYGB = laparoscopic Roux-en-Y gastric bypass.

DISCUSSION

Consistent with previous studies, bariatric surgery was found to be an effective and safe treatment for obesity. Our findings indicate that the mean % EWL and % TWL were 56.6±20.2% and 24.0±7.3%, respectively. A total of 61.3% and 43.1% of patients were successfully treated with 50% EWL and 25% TWL, respectively. A large-scale retrospective study on the effect of LRYGB and gastric banding using the American population showed 60.9±21.2% of % EWL and 31.4±9.4% of % TWL 1 year after surgery [20]. Another large-scale study using a Dutch population showed that a median % TWL of 38.5% and % EWL of 84.2% were achieved in 8,945 patients 603 days after bariatric surgery, with a mean preoperative BMI of 47.7 kg/m² [5]. Moreover, 26.9±8.9% of % TWL 48 weeks after bariatric surgery was reported in a Korean multicenter prospective study, which was lower than the previous 2 studies [21]. Considering the interracial differences and lower mean preoperative BMI in our study, the differences in % TWL might have arisen from these factors. In our data, a 1-year % TWL of 24.0±7.3% was comparable to those of the previous study with a Korean population [21]. Furthermore, it is worth noting that the Dutch study observed that most patients reached their maximum weight loss approximately 600 days after surgery. Given that our study only collected data up to the 1-year mark, patients might have experienced further weight loss beyond this timeframe [5].

The success rate for EWL of >50% was higher than that for TWL of >25%. However, in a large-scale observational study, the authors proposed that 20–25% TWL was sufficient for weight loss and remission of T2DM compared to 25% or higher TWL [22]. Applying this threshold to our data, 101 of 137 patients (73.7%) had SWL with >20% TWL. Considering that lowering the threshold of TWL may have a risk of lower specificity, care must be taken to apply >20% TWL [7]. The type of operation was not associated with the achievement of SWL in our study; similar results were found in multicenter randomized controlled trials (RCTs). In the SLEEVEPASS trial, the % EWL at 5 years was higher in the LRYGB group than in the LSG group (49% vs. 57%). However, the authors failed to demonstrate a clinically significant difference between the 2 groups, as the minimal clinically important difference set initially was not achieved [2]. In another RCT, the SM-BOSS trial, the % EBMIL at 5 years after bariatric surgery was comparable between LSG and LRYGB (61.1% vs. 68.3%, P=0.22).

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With respect to the metabolic effect of bariatric surgery, especially in improving T2DM, 70.1% of patients stopped T2DM medication, and 24.7% of patients reduced their medication dosage. This effect was similar between the LSG and LRYGB groups (68.3% vs. 72.2%, P=0.669) and has already been demonstrated in RCTs [2,3].

Regarding safety issues, only 2 patients (1.5%) experienced short-term complications that required re-admission and supportive care for acute kidney insufficiency (Clavien–Dindo Grade II) and reoperation for omental bleeding (Clavien–Dindo Grade IIIb). Otherwise, no severe complications were observed, such as bleeding or fistula on the staple lines, anastomosis site leakage, internal herniation, or pulmonary thromboembolism. A Korean multicenter trial reported an overall early complication rate of 6.3% (4/64) [21]. Abundant experience in gastrointestinal surgery, including gastric cancer surgery, might have contributed to the extremely low complication rate in our study. Therefore, the surgeons in our study had already overcome the learning curve of bariatric surgeries.

Moreover, the % EWL might be affected by preoperative BMI because patients with high BMI should reduce more weight to achieve the same % EWL than patients with lower BMI values with similar ideal body weight [23]. Therefore, % EWL might over- or underestimate the effect of bariatric surgery according to the BMI of the patients. A higher BMI was a negative independent risk factor for achieving >50% EWL (OR 0.83, 95% CI 0.764–0.902), whereas BMI did not affect achieving >25% TWL (**Tables 3** and **4**). Considering the current trend for indicators of SWL, evidence regarding indicators independent of BMI, such as >25% TWL, is accumulating [5,7]. Therefore, % TWL was more appropriate for assessing the effects of bariatric surgery in our study group.

Baltasar's and Seyssel's models were validated to predict the 1-year outcome of the patients who underwent bariatric surgery, which could explain 71.3% and 66.5% of the patients with an acceptable mean difference between the predicted and observed BMIs of −1.98±3.46 vs. −2.60±3.17, respectively. The mean BMI difference between predicted and observed BMI was smaller in LRYGB than in LSG (−1.54±2.94 vs. −2.36±3.83). This phenomenon may be mainly because of the inevitable heterogeneity caused by the surgeon performing LSG, whereas LRYGB is a more standardized procedure. In addition, 44.5% of the patients underwent LRYGB in this study, which was higher than the average rate of 9.1% for RYGB conducted in the Asian-Pacific region [4].

To the best of our knowledge, this study is the first to validate weight loss prediction models externally to predict the effect of bariatric surgery in Korean patients with obesity [17] and to evaluate which criteria were appropriate between >50% EWL and >25% TWL. This study is expected to be the cornerstone for future studies concerning more precise models on a larger scale.

This study had some limitations. First, owing to the retrospective study design, there might have been selection bias in the collected data. However, this was a multicenter study, and bias might have been reduced owing to the variety of patient pools in each hospital. Second, this study included a relatively small number of patients. Third, prediction models based on Caucasian populations were used. However, our data showed better accuracy than the previous external validations [17]. Further studies are required to develop a prediction model for East Asian populations.

Fourth, the follow-up period was relatively short, and the risk of weight regain was not evaluated. Future studies with longer follow-up data are expected, including assessing weight regain risk.

CONCLUSION

LSG and LRYGB are safe, feasible, and effective bariatric procedures for Korean patients with morbid obesity. Weight loss should be evaluated using % TWL, which is unaffected by preoperative BMI. For Korean patients with obesity, Baltasar's and Seyssel's models may predict the 1-year outcomes of bariatric surgery.

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