# Factors associated with different patterns of weight change after bariatric surgery: A longitudinal study

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## Abstract

# Background

Bariatric surgery is the most effective treatment for obesity. During long-term follow-up, weight loss (WL) is variable between subjects. The aim of this study is to assess the change in percentage of total weight loss (%TWL) and excess weight loss (%EWL) and to describe the factors associated with greater or lesser WL over time.

# Methods

Longitudinal study including patients treated with laparoscopic Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (LSG) and followed at Hospital Universitario San Ignacio, Bogotá (Colombia). Baseline data was recorded before surgery. Follow-up was performed at 3 (n=192), 6 (n=190), 9 (n=188), 12 (n=186), 24 (n=99) and 36 (n=30) months. Generalized Estimating Equation (GEE) analysis was used to assess the change in %TWL and %EWL over time.

# Results

196 patients were included (82.4% female, BMI 41.3±5.2 kg/m$^2$). The tendency to increase on %TWL (31.6±6.6) and %EWL (80.2 RIQ 70.7-97.3) was evident in the first year, stabilizing after that. Nutritionist follow-up, baseline BMI>40 kg/m$^2$ and WL≥10kg before surgery were associated with an average higher increase of %TWL (2.39% p=0.014, 0.41% p<0.001 and 0.37% p=0.003, respectively). Subjects who performed physical activity >30 minutes/day after surgery reduced %TWL in 0.74% (p=0.009). Similar findings were described on %EWL.

# Conclusion

Follow-up during the first year after bariatric surgery is critical to achieving %TWL and %EWL goals. This study suggests that modifiable factors such as nutritional follow-up, WL before surgery and time of physical activity are associated with a significant change in %TWL and %EWL during follow-up by a multidisciplinary team.


## Highlights

- Weight loss (WL) patterns after bariatric surgery are variable.
- There is a tendency to increase on the percentage of total weight loss (%TWL) and percentage of excess weight loss (%EWL) in the first year and stabilize after that time.

- Nutritional follow-up, pre-surgical WL and physical activity were associated with greater change in %TWL and %EWL.
- This study suggests that there are non-modifiable factors such as baseline BMI can affect %EWL

# Introduction

Obesity is a chronic, prevalent and multifactorial disease (1). It is related to an increased risk of type 2 diabetes (T2D), dyslipidemia, sleep apnea, coronary heart disease, deterioration in quality of life and increased mortality (1–3). Due to the exponential increase, its incidence has reached epidemic levels in different parts of the world and in Colombia, it is the cause of 6.7% of all deaths (4).

Compared with traditional nonsurgical weight loss methods, bariatric surgery achieves rapid, significant, and sustained weight loss, as well as remission of obesity-related comorbidities, so despite its invasiveness, it is the most efficacious approach for the treatment of obesity and obesity-related comorbidities (5).

During the long-term follow-up of patients treated with bariatric surgery, weight loss is variable between subjects. Between 15–35% of the patients that undergo bariatric surgery do not reach their goal for weight loss during the first 2 years after the procedure (5). Several factors of poor weight loss have been described including neural predictors (6), psychological predictors such as problematic eating behaviors and psychological distress, and clinical predictors like age, A1C and BMI before surgery (7). On the other hand, adherence to diet and exercise after surgery has been described as good prognostic factors (5) for weight loss in observational studies.

However, information on the patterns of weight loss, measured as percentage of total weight loss (%TWL) and percentage of excess weight loss (%EWL), over time is limited. Furthermore, there are few data on predictors related to greater or lesser weight loss during follow-up. This information would be useful to facilitate early detection and intervention of patients treated with bariatric surgery with inadequate weight loss during follow-up.

The aim of this study is to assess the change in %TWL and %EWL over time and to describe the factors associated with greater or lesser weight loss in a cohort of patients underwent to bariatric surgery in an obesity clinic.

# Methods

A longitudinal study was conducted, including adult patients treated with bariatric surgery (laparoscopic Roux-en-Y gastric bypass (RYGB) or Laparoscopic sleeve gastrectomy (LSG) between January 2011 and December 2019, and followed at the Obesity Clinic of Hospital Universitario San Ignacio in Bogotá, Colombia. Patients with history of surgical complications such as peritonitis, anastomotic fistula formation, thrombotic complications (superior mesenteric vein thrombosis, pulmonary embolism, deep vein thrombosis) or infection in the immediate postoperative period were excluded. Glomerular filtration

rate (GFR) ≤30 ml/min/1.73m2, CHILD C liver cirrhosis or liver failure, alcoholism or drug dependence, pregnancy or active neoplasms were also exclusion criteria. All patients signed an informed consent. The Ethics Committee of Hospital Universitario

San Ignacio approved the protocol and all methods were carried out in accordance with relevant guidelines and regulations.

Data on baseline demographic, type of surgery, comorbidities, and clinical characteristics, such as preoperative weight and BMI, were obtained from the systematically collected medical records. The follow-up during the first year was carried out at 3, 6, 9 and 12 months by a multidisciplinary team that includes a bariatric surgeon, nutritionist and endocrinologist. Subsequently, waist circumference and weight measurements were performed annually up to the third year. All patients were prescribed with protein, micronutrients and vitamin D supplement during the first year. After that, vitamin D and micronutrient supplementation was continued indefinitely.

A detailed analysis of lifestyle habits was evaluated using questionnaire-based interviews performed 12 months after surgery. Adequate physical activity was defined as physical activity of moderate intensity ≥ 5 days a week or of vigorous intensity ≥ 3 days a week or a combination of moderate and vigorous intensity between 3 to 5 days a week, with a minimum total time of 200 minutes per week. Patients who attended at least two nutrition consultations per year were classified as adherent to nutrition follow-up. Adherence to diet was defined as consumption ≤1200 calories per day and was evaluated using 24-hour recall questionnaires in each visit. The calculation of grams of alcohol was carried out with the formula designed by the WHO (8). Percentage of Total weight loss (%TWL; initial weight minus actual weight, divided by initial weight × 100)(9) and Percentage of excess weight loss (%EWL; initial weight minus actual weight, divided by initial weight minus ideal weight × 100)(9,10) was calculated at 3, 6, 9 and 12 months and every year after surgery.

For continuous variables, mean and standard deviation or median and interquartile range were reported according with the variable distribution. For categorical variables, frequency and percentages are reported. In order to estimate the trend of weight over time we performed a longitudinal analysis using Generalized Estimating Equation (GEE). The advantage of GEE is that it takes into account the fact that the serial observations of the same patient are autocorrelated, and let us to evaluate how the average of the response variables change with covariates. In the present study, an exchangeable correlation structure was used. As a sensitivity analysis, we fitted GEE models also assuming either an unstructured or an “independent” correlation structure, without significant changes in the results. Multivariable GEE was used to identify the coefficients of each covariate. The time model with a significant contribution (p-value<0.05) and the lowest quasi-likelihood information criterion (QIC) represents the best model for the data (11). A statistical STATA 16.0 package was used for the analyses.

# Results

The demographic and clinical data of patients are shown in Table 1. 196 patients, were included in the analysis. 82.4% was female with a mean age of 52 ± 12 years old. Severe sleep apnea (64%), dyslipidemia (56.2%), non-alcoholic steatohepatitis (NASH) (56.3%) and hypertension (50.5%) were the most frequent comorbidities. Type 2 diabetes was presented in one third of the subjects with a mean A1c of 6.16±1.19%. Almost two thirds of patients were treated with RYGB.

Table 1
Baseline characteristics.

| | n=196 | |
|---|---|---|
| Age in years, mean (DS) | 52.8 | (12.0) |
| Female, n (%) | 160 | (82.4) |
| Anthropometric measures before surgery | | |
| Baseline weight in Kg, mean (SD) | 104.6 | (16.1) |
| Body mass index kg/m$^2$, mean (SD) | 41.3 | (5.2) |
| Waist perimeter in centimeters, mean (SD) | 124.1 | (13.2) |
| Medical history | | |
| Dyslipidemia, n (%) | 109 | (56.2) |
| NASH, n (%) | 107 | (56.3) |
| Hypertension, n (%) | 98 | (50.5) |
| Obstructive sleep apnea, n (%) | | |
| Mild (AHI 5 – 14.9 events per hour) | 42 | (22.2) |
| Moderate (AHI 15 – 29.9 events per hour) | 37 | (19.5) |
| Severe (AHI ≥30 events per hour) | 70 | (37) |
| Type 2 Diabetes, n (%) | 64 | (33) |
| Coronary heart disease, n (%) | 2 | (1.05) |
| Laboratory studies before surgery | | |
| A1c, % (SD) | 6.16 | (1.19) |
| Glycemia, mg/dl (SD) | 103.1 | (18.3) |
| Total Cholesterol, mg/dl (SD) | 189.5 | (38.2) |
| 25 OH vitamin D3, ng/dl (SD) | 27.2 | (13.1) |
| Type of surgery | | |
| RYGB, n (%) | 125 | (64.4) |
| Sleeve, n (%) | 69 | (35.6) |

A1c: glycosylated hemoglobin; AHI: apnea-hypopnea index; SD: standard deviation; %TWL: Percentage of total weight loss; %EWL: Percentage of excess weight loss; Kg: kilograms; kg/m2: kilograms/meters2; NASH: non-alcoholic steatohepatitis; RYGB: laparoscopic Roux-en-Y gastric bypass

| | n=196 | |
|---|---|---|
| Physical Activity after surgery | | |
| >30 minutes/day, n (%) | 129 | (67.5) |
| >5 days/week, n (%) | 73 | (38.6) |
| Mild intensity, n (%) | 37 | (19.7) |
| Moderate and intense, n (%) | 151 | (80.3) |
| Alcohol consumption ≥25 grams after surgery, n (%) | 27 | (14.3) |
| Anthropometric measures after surgery | | |
| %TWL end of follow-up, mean (SD) | 32.4 | (6.6) |
| %EWL end of follow-up, mean (SD) | 77.7 | (22.3) |
| IMC end of follow-up in Kg/m2, mean (SD) | 28.8 | (4.1) |
| A1c: glycosylated hemoglobin; AHI: apnea-hypopnea index; SD: standard deviation; %TWL: Percentage of total weight loss; %EWL: Percentage of excess weight loss; Kg: kilograms; kg/m2: kilograms/meters2; NASH: non-alcoholic steatohepatitis; RYGB: laparoscopic Roux-en-Y gastric bypass | | |

Baseline BMI was 41.3 ± 5.2 kg/m$^2$ and after 1-year post-bariatric surgery reduced to 27.9 ± 3.3 Kg/m$^2$ (Mean difference 13.21, p <0.001). A similar finding was evident when the basal BMI was compared with BMI after 2 years (Mean difference 13.19 p<0.001) and 3 years (Mean difference 14.09, p < 0.001). Waist perimeter reduced from 124.0 ± 13.2 cm at baseline to 98.1±10.9 cm at 1 year (p<0.001).

There was a tendency to lose weight in the first 18 months, then the weight tends to stabilize. The %TWL increased after 6 (27.5±5.6%), 9 (30.9±5.9%) and 12 months (31.7±6.1%), after that at 24 (31.4±6.1%) and 36 months (32.8±6.1%) tends to stabilize (Figure 1a). Only 3.7% of the subjects had a %TWL <20% after 12 months of follow-up. The %EWL increase in the first year, and tends to stabilize after that time (Figure 1b). The median %EWL at the end of the first year was 80.2 (RIQ 70.7-97.3). 96.4% of patients achieved more than 50% of %EWL in the first year after bariatric surgery.

Using the GEE to analyze weight change through %TWL, the longitudinal analysis showed an average increase of 0.27% per month of follow-up (p <0.001). On average, patients with basal BMI ≥40 kg/m$^2$ had a higher increase in %TWL compared those with lower BMI, (0.41%, p<0.001). Similarly, subjects who lost ≥10 kg before surgery had a higher increase of %TWL (0.37%, p=0.003). Patients with continued follow-up by a nutritionist, on average increased the %TWL by 2.39% (p=0.014) compared to patients without follow-up (Table 2).

Table 2
Analysis using Generalized Estimating Equation (GEE) showing the factors affecting the evolution of percentage of total weight loss (%TWL) and percentage of excess weight loss (%EWL) after bariatric surgery.

| Factors | Percentage of Total weight loss (%TWL) | | | Percentage of excess weight loss (%EWL) | | |
|---|---|---|---|---|---|---|
| | Coefficient | 95% CI | p | Coefficient | 95% CI | p |
| Time (months) | 0.27 | 0.22, 0.32 | <0.001 | 2.39 | 2.17, 2.63 | <0.001 |
| Baseline BMI [a] | 0.41 | 0.27, 0.56 | <0.001 | -1.42 | -1.79, -1.05 | <0.001 |
| Weight loss before surgery [b] | 0.37 | 0.19, 0.56 | 0.003 | 0.61 | 0.13,1,08 | 0.013 |
| Physical activity >30 minutes/day [c] | -0.74 | -1.24, -0.24 | 0.009 | -1.44 | -2.73, -0.15 | 0.029 |
| Nutritionist follow-up [d] | 2.39 | 0.62, 4.17 | 0.014 | 5.05 | 0.25,9.86 | 0.039 |

[a] Compared to subjects with BMI <40; [b] Compared with subjects with weight loss before surgery <10 kg; Compared to patients with physical activity <30 minutes/day [d] Compared to patients who attend to nutritionist consultation <2 times for year.

An average increase of 2.39% per month was detected in the %EWL. Compared with patients with lower BMI, those with basal BMI ≥40 kg/m$^2$, had a lower %EWL (1.42%, p<0.001) (Table 2). In contrast, subjects who lost ≥10 kg before surgery had a higher increase of %EWL (0.61%, p=0.013). On average, the patients with follow-up by a nutritionist in the obesity clinic increased the %EWL by 5.05% (p=0.039) compared to patients who did not continue the follow-up (Table 2).

The subjects who performed more than 30 minutes of physical activity had a lower %TWL and %EWL by 0.74% (p=0.009) and 1.44% (p=0.029), respectively (Table 2). Subjects ≥65 years had less weight loss compared to younger patients, without achieving a statistically significant difference (p=0.06). No association was found between significant weight changes with other clinical variables such as a history of T2D and A1C. Regarding the waist circumference change, we did not find an association with any of the recorded variables.

# Discussion

Obesity is a chronic, prevalent and multifactorial disease (1). Latin American countries such as Argentina, Brazil, Chile and Colombia have insurance coverage for bariatric surgery, the most effective option for long-term weight loss and control of obesity-related comorbidities (12). However, at least one third of patients treated with bariatric surgery do not reach their goal for weight loss after the procedure (5).

Multiple guidelines have described several predictors of successful post-operative weight loss such as behavioral changes, pre-operative weight loss and nutrition therapy (12). Similar to other cohorts we described the tendency to increase on %TWL and %EWL in the first year and a plateau after that time(13,14). In this study we found that baseline BMI, weight loss before surgery, nutritional follow-up and time of physical activity during the 12 months after surgery were associated with a significant change in %TWL and %EWL and we quantified the size of the impact.

*Baseline BMI.*

Although the age and proportion of female patients in our study is similar to that reported in similar cohorts, our baseline BMI is significantly lower (15). In Latin American countries such as Brazil (16) and Mexico (5), the basal BMI was 49.3 ± 8.3 kg / m2 and 48 kg / m2, respectively. This finding highlights the importance of analyzing and reporting data from different regions.

Pre-operative BMI has an important effect on weight loss outcomes among patients who had bariatric surgery (13,14). Seo et al. described the increase in %TWL was higher among patients treated with RYGB whose pre-operative BMI was ≥40 and it kept increasing even up to 5 years after surgery (13). Contrarily, we found that in the subgroup of patients with greater weight and BMI before surgery, the weight loss was lower at the end of follow-up, a finding that has been described in other publications (12,17). Halliday et al. described that the degree of weight loss 1 year after bariatric surgery was associated with GLP-1, oxyntomodulin and glicentin three months after LSG or RYGB(18,19). However, early enhancement of the incretin effect after bariatric surgery could be attenuated after long-term follow-up limiting weight loss.

It was interesting the differential relation between baseline BMI and %TWL or %EWL. Cadena-Obando et al. described the factors associated to failure in achieve ≥50% of EWL in 130 patients with severe obesity (>40% of the patients had a BMI ≥50 kg/m$^2$). They found a significant inverse correlation between baseline BMI and %EWL at 12 months (5). They described that subjects with BMI>50 kg/m$^2$ tend to lose less weight compared to subjects with BMI <40 kg/m$^2$ during the first year, because heavier population requires losing more weight in a short period of time (5).

# Weight loss before surgery

The benefit of preoperative weight loss on long-term postoperative weight loss remains unclear(20). Cadena-Obando et al (5) showed that %EWL before surgery, was not associated with greater weight loss after surgery. However, in most of the obesity clinics, patients are required to lose weight before surgery to reduce surgical complications. In our study a weight loss ≥ 10 kg was associated with better %TWL and %EWL at the end of follow up. Recently, Sun et al analyzed the association of weight loss and mortality at 30 days after bariatric surgery in 480075 patients(21). They found that a small preoperative weight loss was associated with a statistically significant reduction in postoperative mortality(21). Suggesting that the preoperatory weight loss should be “goal-oriented” without delay the surgical intervention(20).

# Nutrition follow-up

We describe follow-up by a specialized nutritionist as main predictor of %TWL and %EWL. Other papers have described that the adherence to the postoperative diet, when participants have returned to eating regular foods, also was associated with larger postoperative weight losses (22,23). Other studies found that regular nutritional follow-up and compliance with postoperative dietary counseling improve weight maintenance (24) and greater %EWL (25). In addition patients whit continued follow-up had better adherence to multivitamin supplementation reducing the risk of nutritional deficiencies following bariatric procedures(24). According to McGrice et al. this will minimize nutritional deficiencies that cause fatigue, and minimize food cravings to improve long-term weight loss, as well as providing increased quality of life (26). The consumption of 30 grams/day of alcohol, regardless of the type of liquor, is related to weight gain and obesity (23). However, in our population, alcohol consumption was lower than 30 grams and we did not find association.

# Exercise

Exercise improves health, with well-characterized physiological and weight loss benefits, including weight loss maintenance (27). Forbush et al. described in patients treated with bariatric surgery, and followed for 5 years, that an increased time of physical activity helped to maintain the %EWL (28). Gallé described greater weight loss and reduction in waist circumference among participants with an exercise program consistent in 60-minute training sessions carried out two times per week and supervised by specialists, with expertise in adapted physical activity (29). Similar studies suggests that moderate to vigorous intensity physical activity ≥ 150 min/week is critical for maintaining weight loss or even increase %EWL (27,30,31).

Bond et al. shown that %EWL were greater in patients who changed their physical activity status from inactive to active compared to patients who remain inactive after RYBG, adjusting for differences in age, sex, ethnicity, preoperative weight and BMI (32). However, in those who began to exercise after surgery, the weight loss was similar to those who exercised before surgery (32). Nevertheless, in our study the subjects who exercise ≥30 minutes had less %TWL and %EWL, this could be associated to the increase in percentage of muscle mass related to physical activity, but the body composition data was not available for this study.

As a strength, our data show factors related to a significant change in %TWL and %EWL using GEE models in patients treated with bariatric surgery who receive usual care during long-term follow-up in an obesity clinic with a multidisciplinary team. Likewise, biochemical and clinical factors such as diet, exercise (time, intensity and frequency) and alcohol consumption were recorded and analyzed. Among the limitations, body composition data was not available for this study. Additionally, eating behavior such as binge eating or uncontrolled eating was not evaluated during follow-up, however, all patients had a preoperative nutritional and psychiatric evaluation that ruled out this type of behavior before surgery.

# Conclusion

Even though, there is a tendency to lose weight in the first 18 months, the %TWL and %EWL increase only in the first year, and tends to stabilize after that time. This study suggests that there are non-modifiable factors such as baseline BMI and modifiable factors such as nutrition follow-up, weight loss before surgery ≥10 kg and time of physical activity after surgery associated with significant %TWL and %EWL change during the follow-up. Our findings suggest that these modifiable factors should be evaluated during the early stage after bariatric surgery. However, additional studies are required to clarify other factors associated with greater weight loss during long term follow up in this population.

# Abbreviations

A1c
glycosylated hemoglobin
AHI
apnea-hypopnea index
SD
standard deviation
%EWL
Percentage of excess weight loss
Kg
kilograms
kg/m2
kilograms/meters2
NASH
non-alcoholic steatohepatitis
RYGB
laparoscopic Roux-en-Y gastric bypass
GEE
Generalized Estimating Equation, T2D:type 2 diabetes.

# Declarations

**Conflict-of-Interest Disclosure.**

Author 1 reports speaker fees from Novo Nordisk and research grants from Novo Nordisk. Author 2 reports speaker fees from NovoNordisk, Elli Lilly, Boeringher, Novartis and Medtronic and research grants from Medtronic, Novartis and Abbott. Author 3 reports research grants from NovoNordisk. No other potential conflicts of interest are reported.

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# Figures

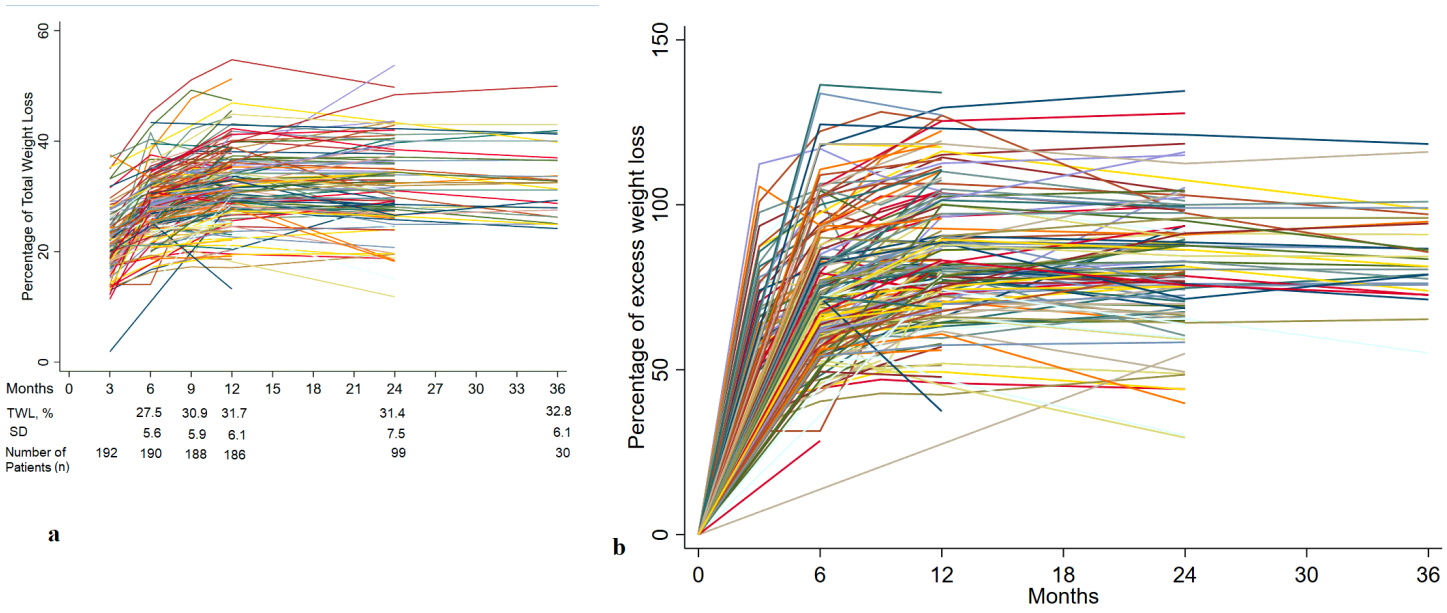


**Figure 1**

The %TWL increased after 6 (27.5±5.6%), 9 (30.9±5.9%) and 12 months (31.7±6.1%), after that at 24 (31.4±6.1%) and 36 months (32.8±6.1%) tends to stabilize (Figure 1a). Only 3.7% of the subjects had a

%TWL <20% after 12 months of follow-up. The %EWL increase in the first year, and tends to stabilize after that time (Figure 1b).