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Preoperative BMI and five-year proportional weight-loss maintenance after Roux-en-Y gastric bypass: a retrospective cohort study

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Research Article

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Abstract

Introduction:

Roux-en-Y gastric bypass (RYGB) produces substantial weight loss, but long-term proportional maintenance varies. We examined whether preoperative body mass index (BMI) category was associated with change in percentage total weight loss (%TWL) between 12 and 60 months after primary RYGB.

Methods

This retrospective cohort study included adults with preoperative BMI ≥ 35 kg/m² who underwent primary RYGB between January 2016 and March 2021 and had weight data at 12 and 60 months. Of 456 eligible patients, 113 (24.8%) lacked 12- or 60-month data and were lost to follow-up (343 analyzed). The primary outcome was $\Delta\%TWL_{12-60}$ (60-month minus 12-month %TWL), analyzed by linear regression before and after adjustment for age, sex, preoperative type 2 diabetes, and 12-month %TWL.

Results

Among 343 patients, mean $\Delta\%TWL_{12-60}$ was − 3.2, − 5.9, and − 5.4 percentage points across ascending BMI categories. Adjusted differences versus BMI 35–<40 kg/m² were − 2.09 points for BMI 40–<45 kg/m² (95% CI, − 4.62 to 0.44) and − 1.57 points for BMI ≥ 45 kg/m² (95% CI, − 4.18 to 1.03; global P=.268). At 60 months, mean %TWL was 28.7%, 28.3%, and 28.9%, whereas mean BMI was 27.2, 30.4, and 33.6 kg/m².

Conclusion

Preoperative BMI category was not clearly associated with %TWL change from 12 to 60 months after RYGB, although the confidence intervals included between-category differences of several percentage points. Similar 5-year %TWL coexisted with substantially different attained BMI values; both measures may therefore provide complementary anthropometric information.

Key Points

- Proportional weight loss decreased modestly from 12 to 60 months after RYGB.
- Preoperative BMI was not clearly associated with %TWL change from 12 to 60 months.
- Similar 5-year %TWL coexisted with markedly different attained BMI values.

Introduction

Roux-en-Y gastric bypass (RYGB) produces substantial and durable weight reduction, although postoperative trajectories vary considerably among individuals. Most weight loss occurs during the first 12–18 months, after which patients may maintain, extend, or partially lose the initial response. A single postoperative measurement therefore does not fully describe long-term durability [1–4].

Interpretation also depends on the outcome metric. Percentage total weight loss (%TWL) quantifies proportional change from baseline and is less intrinsically dependent on preoperative BMI than percentage excess weight loss [5–8]. Attained BMI describes a different dimension: the absolute anthropometric state reached. Patients starting at different BMI levels may consequently achieve similar %TWL while remaining at markedly different postoperative BMI values.

Higher preoperative BMI is consistently associated with higher postoperative BMI, but its relationship with maintenance of proportional weight loss after the first postoperative year is less well defined [2–4,9]. We therefore examined, in a cohort spanning a wide preoperative BMI range, whether BMI category was associated with change in %TWL between 12 and 60 months after primary RYGB, and whether comparable proportional maintenance corresponded to comparable attained BMI.

Materials and Methods

Study Design and Population

A retrospective review of a prospectively maintained database of patients who underwent primary RYGB in our unit between January 2016 and March 2021 was performed. Eligible patients were aged ≥ 18 years, had a preoperative BMI ≥ 35 kg/m², and had valid body-weight measurements at both 12 and 60 months. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [10]. No a priori sample-size calculation was performed; all consecutive eligible patients with the required follow-up data were included.

Exposure and Surgical Technique

The prespecified exposure was preoperative BMI categorized as 35–<40, 40–<45, and ≥ 45 kg/m²; the lowest category served as the reference. These categories reflected institutional clinical stratification during the study period, not standard obesity classes. Procedures were performed using a standardized minimally invasive RYGB technique previously described [11].

Data Collection and Outcomes

Demographic, anthropometric, clinical, operative, and follow-up variables were entered prospectively and extracted retrospectively. Body weight was recorded preoperatively and at protocolized 12- and 60-

month visits. Baseline variables included age, sex, weight, BMI, and preoperative hypertension, type 2 diabetes, obstructive sleep apnea, and dyslipidemia.

%TWL was calculated as:

$$\%TWL = [(\text{preoperative weight} - \text{postoperative weight}) / \text{preoperative weight}] \times 100$$

The primary outcome was:

$$\Delta\%TWL = \%TWL \text{ at 60 months} - \%TWL \text{ at 12 months}$$

Negative values indicated lower proportional weight loss at 60 months, values near zero indicated approximate maintenance, and positive values indicated additional proportional weight loss after 12 months.

Secondary weight outcomes were weight, BMI, and %TWL at 12 and 60 months; changes in weight and BMI; recurrent weight gain; weight-based suboptimal clinical response; and BMI > 30, >35, and > 40 kg/m² at 60 months. Recurrent weight gain was defined as recovery, by 60 months, of at least 25% of the weight lost between the preoperative assessment and the protocolized 12-month assessment, using the 25% threshold proposed in the most recent international Delphi consensus [12], applied here to the 12-month reference point consistent with the study's focus on the maintenance phase between 12 and 60 months:

$$\text{Recurrent weight gain (\%)} = [(\text{weight}_{60} - \text{weight}_{12}) / (\text{preoperative weight} - \text{weight}_{12})] \times 100$$

Weight-based suboptimal clinical response was defined as %TWL < 20%, a threshold used in prior reporting standards typically applied at 12 months [13–14] and extended here, on an exploratory basis, to the 60-month assessment, and represented only the weight component of the broader clinical construct. Postoperative BMI thresholds were descriptive and were not interpreted as indicating an inadequate procedure.

Hypertension, type 2 diabetes, obstructive sleep apnea, and dyslipidemia were assessed preoperatively and at 60 months. Remission was evaluated only among patients with the corresponding condition at baseline and was defined as documented clinical remission at the 60-month assessment. These outcomes were considered exploratory.

Statistical Analysis

Continuous variables were summarized as mean ± standard deviation or median and interquartile range, and categorical variables as frequencies and percentages. Comparisons across BMI categories used one-way analysis of variance (ANOVA), Welch ANOVA when variance homogeneity was not satisfied, the Kruskal–Wallis test for non-normally distributed variables, and Pearson's chi-square or Fisher's exact test for categorical variables.

The association between BMI category and Δ%TWL12–60 was evaluated using linear regression. The unadjusted model included BMI category alone. The prespecified adjusted model included BMI category, age per 10-year increment, sex, 12-month %TWL, and preoperative type 2 diabetes. Covariates were selected a priori on clinical grounds. Adjustment for 12-month %TWL was intended to compare subsequent 12-to-60-month change among patients who had achieved a similar proportional weight-loss response at 12 months. Coefficients are reported as mean differences in Δ%TWL12–60, in percentage points, with 95% confidence intervals. The overall association of BMI category was assessed using a global two-degree-of-freedom test before interpretation of individual contrasts.

Model assumptions were assessed through residual diagnostics, linearity and heteroscedasticity assessment, collinearity diagnostics, leverage, and Cook's distance. Observations with Cook's distance > 4/n were examined in sensitivity analyses but were not automatically excluded. Prespecified sensitivity analyses used HC3 heteroscedasticity-consistent standard errors, nonparametric bootstrap confidence intervals, exclusion of influential observations, and continuous modeling of preoperative BMI. The primary analysis was restricted to patients with valid weight measurements at both 12 and 60 months. Complete cases were analyzed; no imputation was performed. Baseline characteristics of included and excluded patients were compared using Welch’s t test for continuous variables and Pearson’s chi-square test for categorical variables, restricted to variables available for excluded patients (Supplementary Table S1). Secondary analyses were exploratory and were not adjusted for multiple comparisons. Tests were two-sided with P<.05. Effect estimates and 95% confidence intervals were prioritized over isolated P values. Analyses were performed using IBM SPSS Statistics, version 29.0.1.1 for macOS.

Results

Cohort Characteristics

Of the 456 eligible patients, 113 were excluded because either the 12- or 60-month weight measurement was unavailable, leaving 343 participants for the primary analysis (Fig. 1). Mean age was 47.6 ± 8.2 years, 247 patients (72.0%) were female, and mean preoperative BMI was 43.6 ± 3.7 kg/m². Fifty-seven patients (16.6%) had BMI 35–<40 kg/m², 155 (45.2%) had BMI 40–<45 kg/m², and 131 (38.2%) had BMI ≥ 45 kg/m². Baseline characteristics are shown in Table 1. Compared with excluded patients, included patients had a higher mean preoperative BMI (43.6 ± 3.7 vs 42.5 ± 4.7 kg/m²; P=.020; Supplementary Table S1).

Table 1
Baseline characteristics according to preoperative BMI category.

Characteristic	BMI 35–<40 kg/m² (n = 57)	BMI 40–<45 kg/m² (n = 155)	BMI ≥ 45 kg/m² (n = 131)	P value
Age, years	49.4 ± 7.6	47.5 ± 8.2	46.9 ± 8.3	.138
Female sex, n (%)	42 (73.7)	110 (71.0)	95 (72.5)	.914
Preoperative weight, kg	104.7 ± 12.4	114.5 ± 14.4	128.3 ± 14.0	< .001
Preoperative BMI, kg/m²	38.2 ± 1.3	42.5 ± 1.5	47.3 ± 1.9	< .001
Hypertension, n (%)	29 (50.9)	71 (45.8)	57 (43.5)	.648
Type 2 diabetes, n (%)	30 (52.6)	64 (41.3)	44 (33.6)	.047
Obstructive sleep apnea, n (%)	16 (28.1)	61 (39.4)	52 (39.7)	.265
Dyslipidemia, n (%)	21 (36.8)	59 (38.1)	33 (25.2)	.055

Data are presented as mean ± standard deviation or n (%). BMI, body mass index.

Primary Outcome

At 12 months, mean %TWL was 31.9 ± 7.6%, 34.2 ± 7.9%, and 34.3 ± 8.1% across ascending BMI categories. At 60 months, mean %TWL was 28.7 ± 8.3%, 28.3 ± 10.5%, and 28.9 ± 11.2%, respectively. Mean BMI increased across categories at both assessments: 26.0, 27.9, and 31.1 kg/m² at 12 months and 27.2, 30.4, and 33.6 kg/m² at 60 months (Table 2). Thus, nearly identical mean %TWL across categories at 60 months coexisted with a progressive gradient in attained BMI, from 27.2 to 33.6 kg/m².

Table 2
%TWL and BMI at 12 and 60 months.

Outcome	BMI 35–<40 kg/m² (n = 57)	BMI 40–<45 kg/m² (n = 155)	BMI ≥ 45 kg/m² (n = 131)	P value
%TWL at 12 months, %	31.9 ± 7.6	34.2 ± 7.9	34.3 ± 8.1	.122
%TWL at 60 months, %	28.7 ± 8.3	28.3 ± 10.5	28.9 ± 11.2	.890
Δ%TWL12–60, percentage points	−3.2 ± 6.2	−5.9 ± 8.4	−5.4 ± 9.2	.044
BMI at 12 months, kg/m²	26.0 ± 2.9	27.9 ± 3.3	31.1 ± 3.9	< .001
BMI at 60 months, kg/m²	27.2 ± 3.3	30.4 ± 4.3	33.6 ± 5.3	< .001

Data are presented as mean ± standard deviation. The P value for Δ%TWL12–60 was obtained using the Kruskal–Wallis test and therefore differs from the global test from the linear regression model in Table 3. *The 60-month %TWL comparison used Welch analysis of variance. Negative values indicate a reduction in proportional weight loss. BMI, body mass index; %TWL, percentage total weight loss.*

Mean Δ%TWL12–60 was − 3.2 ± 6.2 percentage points in the BMI 35–<40 kg/m² group, − 5.9 ± 8.4 in the BMI 40–<45 kg/m² group, and − 5.4 ± 9.2 in the BMI ≥ 45 kg/m² group. In the unadjusted model, differences versus the reference group were − 2.69 points (95% CI, − 5.24 to − 0.14; P=.039) and − 2.19 points (95% CI, − 4.80 to 0.42; P=.100), with global P=.115. After adjustment, corresponding differences were − 2.09 points (95% CI, − 4.62 to 0.44; P=.105) and − 1.57 points (95% CI, − 4.18 to 1.03; P=.236), with global P=.268. The adjusted R^2 was 0.040 (Table 3). Because inference was prespecified to rest on the global two-degree-of-freedom test, the individually significant unadjusted contrast for the BMI 40–<45 kg/m² group (P=.039) was not interpreted as evidence of an association. The descriptive Kruskal–Wallis comparison of Δ%TWL12–60 across categories in Table 2 (P=.044) is reported for completeness and likewise does not constitute the prespecified inferential test.

Table 3
Unadjusted and adjusted linear regression models for Δ%TWL12–60.

Predictor	Unadj. B	95% CI	P value	Adj. B	95% CI	P value
BMI 35–<40 kg/m²	Reference	—	—	Reference	—	—
BMI 40–<45 kg/m²	−2.69	−5.24 to − 0.14	.039	−2.09	−4.62 to 0.44	.105
BMI ≥ 45 kg/m²	−2.19	−4.80 to 0.42	.100	−1.57	−4.18 to 1.03	.236
Age, per 10-year increment	—	—	—	0.69	−0.41 to 1.80	.219
Male sex	—	—	—	−1.73	−3.69 to 0.24	.085
%TWL at 12 months, per point	—	—	—	−0.19	−0.30 to − 0.08	.001
Preoperative type 2 diabetes	—	—	—	−0.24	−2.11 to 1.63	.803

Dependent variable: Δ%TWL12–60. B values are unstandardized coefficients expressed in percentage points (Unadj., unadjusted; Adj., adjusted); n = 343. Reference categories were BMI 35–<40 kg/m², female sex, and absence of preoperative type 2 diabetes. Global test for BMI category: unadjusted P=.115; adjusted P=.268. Model R^2=0.057; adjusted R^2=0.040; overall model P=.003. BMI, body mass index; CI, confidence interval; %TWL, percentage total weight loss.

Secondary Outcomes

Recurrent weight gain occurred in 11 of 57 patients (19.3%), 46 of 155 (29.7%), and 47 of 131 (35.9%) across ascending BMI categories (P=.073). Weight-based suboptimal clinical response occurred in 9 (15.8%), 33 (21.3%), and 29 (22.1%) patients, respectively (P=.596). At 60 months, BMI > 30 kg/m² was present in 22.8%, 51.6%, and 74.8%; BMI > 35 kg/m² in 1.8%, 16.8%, and 36.6%; and BMI > 40 kg/m² in 0%, 2.6%, and 11.5% (all P≤.001).

Remission of hypertension, obstructive sleep apnea, and dyslipidemia did not differ clearly across BMI categories. Documented type 2 diabetes remission was observed in 60.0%, 81.3%, and 86.4% of patients with diabetes at baseline across ascending BMI categories (P=.019) (Table 4).

Table 4
Secondary weight-related outcomes and obesity-associated medical problems.

Outcome	BMI 35–<40 kg/m²	BMI 40–<45 kg/m²	BMI ≥ 45 kg/m²	P value
Secondary weight-related outcomes				
Recurrent weight gain ≥ 25%, n (%)	11 (19.3)	46 (29.7)	47 (35.9)	.073
Weight-based suboptimal response at 60 mo, n (%)	9 (15.8)	33 (21.3)	29 (22.1)	.596
BMI > 30 kg/m² at 60 months, n (%)	13 (22.8)	80 (51.6)	98 (74.8)	< .001
BMI > 35 kg/m² at 60 months, n (%)	1 (1.8)	26 (16.8)	48 (36.6)	< .001
BMI > 40 kg/m² at 60 months, n (%)	0 (0.0)	4 (2.6)	15 (11.5)	.001
Documented remission of obesity-associated medical problems				
Hypertension remission, n/N (%)	21/29 (72.4)	42/71 (59.2)	35/57 (61.4)	.453
Type 2 diabetes remission, n/N (%)	18/30 (60.0)	52/64 (81.3)	38/44 (86.4)	.019
Obstructive sleep apnea remission, n/N (%)	13/16 (81.3)	51/61 (83.6)	43/52 (82.7)	.973
Dyslipidemia remission, n/N (%)	14/21 (66.7)	44/59 (74.6)	23/33 (69.7)	.753

Recurrent weight gain was operationally defined as recovery at 60 months of at least 25% of the weight lost between the preoperative and protocolized 12-month assessments. Weight-based suboptimal clinical response was defined as %TWL < 20% at 60 months. Remission refers to documented clinical remission at 60 months; denominators include only patients with the corresponding condition before surgery. Comparisons were exploratory and unadjusted. BMI, body mass index; %TWL, percentage total weight loss.

Sensitivity Analyses

The interpretation of the primary model was unchanged with HC3 standard errors, bootstrap confidence intervals, exclusion of 14 potentially influential observations, or continuous modeling of BMI. In the continuous-BMI model, the coefficient was 0.07 percentage points per 1-kg/m² increment (95% CI, − 0.18 to 0.32; P=.571).

Discussion

This retrospective cohort examined whether preoperative BMI category was associated with proportional weight-loss change between 12 and 60 months after RYGB. Mean %TWL decreased in every BMI stratum, and after prespecified adjustment the data did not provide clear evidence of an association between BMI category and Δ%TWL12–60. The confidence intervals included between-category differences of several percentage points and do not establish equivalence. At 60 months, descriptively similar mean %TWL across categories coexisted with a progressive gradient in attained BMI. These findings concern different dimensions of postoperative weight status: proportional change during follow-up and absolute BMI attained at 5 years.

Long-term RYGB cohorts show substantial mean weight loss with marked variation in individual trajectories [2–4,15–17]. Evidence on preoperative BMI is less consistent and depends on the outcome metric and interval [9]. Ochner et al. reported lower initial proportional loss and different subsequent trajectories at higher preoperative BMI [18], whereas recent trajectory analyses identified heterogeneous profiles rather than a uniform gradient of poorer 5-year proportional loss with increasing baseline BMI [4,19]. Direct comparison is limited by differences in procedure mix, outcome definition, starting point, and follow-up completeness. The present analysis addresses a narrower question: the association between BMI category and proportional change after the protocolized 12-month assessment. This distinction may account for differences from studies modeling weight loss from the preoperative baseline.

The contrast between %TWL and attained BMI follows from what each measure quantifies. %TWL expresses change relative to preoperative weight and is less dependent on baseline BMI than percentage excess weight loss [5–8]. Attained BMI describes the absolute anthropometric state reached. When height is unchanged, attained BMI is mathematically determined by baseline BMI and proportional weight loss; a BMI gradient is therefore expected when patients with different starting BMI values achieve similar %TWL. The contribution of the present data is to document the persistence of this gradient at 5 years and to show how it can be obscured when %TWL is reported alone. Conversely, attained BMI cannot isolate the response to surgery because it incorporates the preoperative starting point. Because BMI does not directly measure body composition, organ dysfunction, or individual health risk [20], postoperative BMI thresholds should be interpreted as anthropometric descriptors rather than as evidence of procedural inadequacy or clinical disease burden. Reporting %TWL and attained BMI together provides complementary information, but neither measure is a standalone clinical outcome.

The adjustment strategy warrants explicit comment. Conditioning Δ%TWL12–60 on 12-month %TWL estimates subsequent change among patients with a similar measured proportional response at 12 months. Because 12-month %TWL is a postoperative variable and a component of the change score, the model does not estimate the total causal effect of preoperative BMI on long-term weight loss. Adjustment reduced the between-category differences, but the confidence intervals remained compatible with between-category differences ranging from negligible to several percentage points. Measurement error and regression to the mean remain possible. The result should therefore be interpreted as a lack of clear evidence of association, not as evidence of equivalent maintenance.

The exploratory secondary findings do not alter the primary interpretation. Recurrent weight gain was numerically more frequent across ascending BMI categories, but the comparison did not provide clear evidence of association (P=.073). Estimates vary with the denominator, reference weight, and threshold [12–14,21–22]. Documented type 2 diabetes remission differed across categories, but the comparison was unadjusted and restricted to patients with diabetes at baseline. Unmeasured differences in diabetes duration, severity, or treatment could account for this pattern. These analyses were not adjusted for multiple comparisons.

The 5-year results have implications for how weight outcomes are described in follow-up. Although mean %TWL was similar across strata, BMI > 35 kg/m² was present in 1.8% of patients in the lowest preoperative BMI category and 36.6% in the highest. This difference identifies variation in attained anthropometric status; it does not establish a corresponding difference in individual health risk. Long-term outcome frameworks after metabolic and bariatric surgery include weight, obesity-associated medical problems, nutritional status, quality of life, behavior, and complications rather than a single weight metric [23]. Postoperative attendance is often incomplete [24], although continued follow-up is recommended [5,25]; evidence linking attendance to long-term %TWL remains inconclusive [26]. These findings support interpreting %TWL, attained BMI, obesity-associated medical problems, and nutritional outcomes together during individualized follow-up.

Strengths include a homogeneous cohort of primary RYGB procedures, standardized measurements at protocolized 12- and 60-month visits, a continuous primary outcome, prespecified adjustment, and several sensitivity analyses. The main limitation was incomplete follow-up: 113 of 456 eligible patients (24.8%) lacked one or both primary outcome measurements. Included patients had a modestly higher preoperative BMI than excluded patients, so attrition bias cannot be excluded. The retrospective, single-center design leaves the possibility of residual confounding and may limit generalizability. The smallest BMI stratum included 57 patients, and the adjusted confidence intervals did not exclude between-category differences of several percentage points. Secondary analyses were exploratory and unadjusted. These limitations constrain causal inference and the precision of between-category estimates.

Conclusion

In this retrospective cohort, preoperative BMI category was not clearly associated with proportional weight-loss change between 12 and 60 months after RYGB, although the estimates were not sufficiently precise to establish equivalence. Similar mean %TWL at 5 years coexisted with progressively higher attained BMI as preoperative BMI increased. Interpreting %TWL together with attained BMI and clinical outcomes may provide a more complete basis for individualized long-term assessment than either anthropometric measure alone.

Declarations

Ethical Approval

The study was conducted in accordance with the ethical standards of the institutional research committee and with the Declaration of Helsinki and its subsequent amendments. The study protocol was approved by the appropriate institutional research ethics committee. The committee waived the requirement for individual informed consent because of the retrospective nature of the study.

Informed Consent

Given the retrospective design, individual informed consent was waived by the institutional ethics committee.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Author Contribution

CP, CN, and SS conducted the database review. CP performed the statistical analysis. All authors contributed to the drafting and final editing of the article.

Data Availability

All data supporting the findings of this study are available within the paper and its Supplementary Information. Deidentified data may be made available by the corresponding author upon reasonable request, subject to institutional authorization, ethics approval, and applicable data-protection regulations.

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Figures

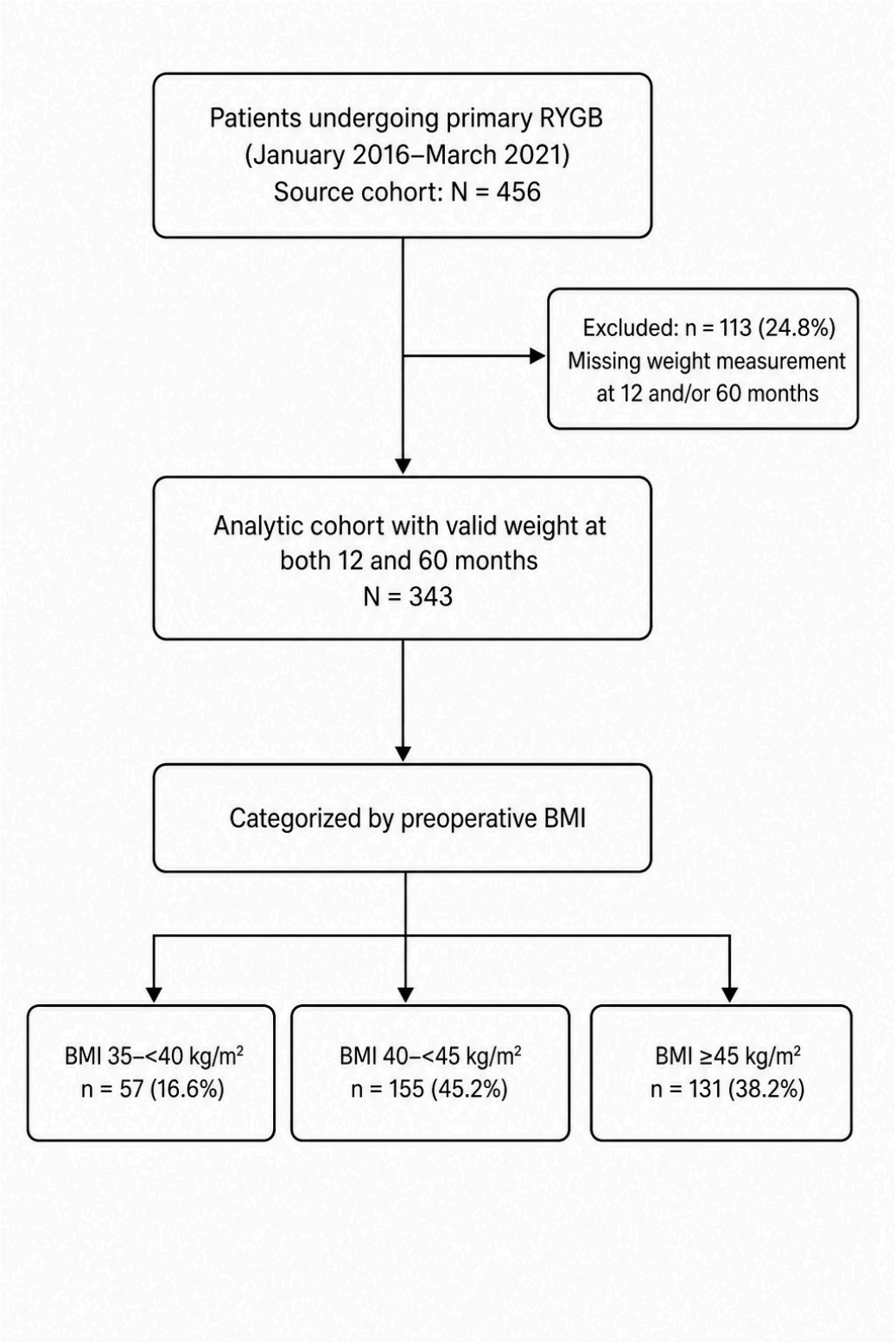


Figure 1

Study participant flow and distribution across preoperative BMI categories. BMI, body mass index.

Supplementary Files

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