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Anthropometric Changes Over Two Years in Patients Undergoing Mini-Gastric Bypass, Gastric Bypass, and Sleeve Gastrectomy

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ABSTRACT

Background: Obesity is a significant public health issue with increasing global prevalence. Bariatric surgery is currently the most effective intervention for sustained weight loss and improvement in obesity-related comorbidities. This study aimed to compare anthropometric and body composition changes over 24 months following three bariatric procedures, mini-gastric bypass (MGB), sleeve gastrectomy (SG), and Roux-en-Y gastric bypass (RYGB), in an Iranian population. **Methods:** This study was performed on 6,390 patients who underwent MGB, SG, or RYGB between 2020 and 2022 in Tehran. Anthropometric indices and body composition variables [body mass index (BMI), excess weight loss percentage (EWL%), fat mass, visceral fat, and muscle mass] were measured before surgery and at 3, 6, 12, and 24 months after surgery. Generalized estimating equations (GEEs) were used to assess longitudinal changes and associated factors. **Results**: All procedures led to significant BMI and EWL% reductions over time ($P<0.001$). Compared with SG, MGB was associated with a greater BMI reduction and EWL% increase. No significant differences were found in fat mass or visceral fat between the groups, but males showed greater reductions over time. Muscle mass was better preserved in RYGB patients, especially among males. Age and sex were also significant predictors of postsurgical outcomes. **Conclusion**: Compared with SG, MGB resulted in superior weight loss. RYGB was more effective in preserving muscle mass. Patient characteristics such as age and sex influence surgical outcomes and should be considered in personalized postoperative care.

Introduction

Obesity is a multifactorial metabolic disorder influenced by genetic, physiological, behavioral, and socioeconomic factors, with dietary habits and physical inactivity playing critical roles (Maffeis, 2000, Masood and Moorthy, 2023). Its global prevalence has sharply increased over recent decades, with projections suggesting that nearly 60% of the world's population may be

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overweight or obese by 2030 (James, 2008). In Iran, the number of people with obesity rose from approximately 2 million in 1980 to over 11 million by 2015, highlighting the urgent need for effective intervention strategies (Kelly *et al.*, 2008).

Among the available treatment options, bariatric surgery has demonstrated the most consistent and durable results, especially in patients with severe obesity [body mass index (BMI ≥ 40 kg/m²] or those with a BMI ≥ 35 kg/m² accompanied by related health conditions (Miras and Le Roux, 2013, Mohapatra *et al.*, 2020, Piche *et al.*, 2015). Beyond weight loss, bariatric surgery significantly improves complications associated with obesity, such as type 2 diabetes, cardiovascular diseases, and nonalcoholic fatty liver disease (Buchwald *et al.*, 2005). Common bariatric procedures are generally classified as restrictive, malabsorptive, or a combination of both (Kissler and Settmacher, 2013). Roux-en-Y gastric bypass (RYGB), which is often considered the gold standard, typically results in 20–35% total weight loss but requires lifelong micronutrient supplementation (Poirier *et al.*, 2011, Sjöström, 2008, Sjöström, 2013). Moreover, Sleeve gastrectomy (SG), a restrictive technique, modulates appetite hormones and the gut microbiota with few nutritional side effects (Benaiges *et al.*, 2015, Sjöström *et al.*, 2007). Mini-gastric bypass (MGB), a technically simpler hybrid procedure, has shown promising outcomes in terms of both weight loss and metabolic improvements (Mahawar *et al.*, 2016).

Despite these benefits, bariatric surgery is often associated with loss of lean body mass, which can reduce the basal metabolic rate, impair physical capacity, and negatively affect long-term outcomes (Davidson *et al.*, 2018, Faria *et al.*, 2009, Nuijten *et al.*, 2020, van Venrooij *et al.*, 2012). Although bariatric surgeries are becoming more common in Iran (Kabir *et al.*, 2024), data comparing postoperative changes in body composition and anthropometric measures among different surgical techniques remain limited. This study aimed to evaluate changes in weight and body composition at 3, 6, 12, and 24 months following RYGB, SG, and MGB in an Iranian population.

Materials and Methods

Study design, sample size and participants

This study included 6,390 adult patients (>15 years of age, both sexes) with severe obesity who underwent bariatric surgery (MGB, RYGB, or SG) at Tehran Minimally Invasive Surgery Center between 2020 and 2022. The inclusion criteria were BMI ≥ 40 kg/m², or BMI 35–39.9 kg/m² with obesity-related comorbidities such as cardiovascular disease, diabetes mellitus, or severe obstructive sleep apnea. The exclusion criteria were active malignancy, end-stage renal or hepatic failure, pregnancy or lactation, substance abuse, and severe psychiatric illness. Demographic and clinical data were collected via structured interviews.

Anthropometric evaluation

Anthropometric measurements included body weight, height, BMI, and waist circumference, which were obtained via calibrated equipment and standardized procedures. Body composition variables; including body fat percentage, visceral fat, and skeletal muscle mass were measured via bioelectrical impedance analysis (BIA; InBody 270) after a 10–12 hour overnight fast. Measurements were finally performed at baseline and at 3, 6, 12, and 24 months postoperatively.

Ethics approval and consent to participate

The Ethics Committee of Ahvaz Jundishapur University of Medical Sciences approved this study (IR.AJUMS.REC.1402.576), and all participants provided informed consent. Confidentiality and anonymity were maintained throughout the study.

Data analysis

For comparisons of continuous variables, independent t-tests were used for two-group comparisons, and one-way ANOVA was used for comparisons involving more than two groups; nonparametric equivalents were applied when assumptions were not met. Categorical variables were analyzed using the chi-square test. To assess longitudinal changes in outcome variables over the follow-up period across groups, repeated measures analysis and generalized estimating equations

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(GEEs) were employed. The data were analyzed using SPSS version 26. A significance level of 0.05 was considered.

Results

Patient characteristics

The present study was a cross-sectional analysis conducted on obese patients who visited the Tehran Minimally Invasive Surgery Center. The total study population comprised 6,390 patients, of whom 1,097 (17.2%) were male and 5,293 (82.8%) were female. In terms of the type of bariatric surgery performed, 3,360 patients (52.6%) underwent RYGB, 1,912 (29.9%) underwent MBG, and 1,118 (17.5%) underwent SG. Patients were categorized into four age groups: 18–39 (n=3,376, 56.9%), 40–49 (n=1,737, 27.2%), 50–59 (n=832, 13%), and ≥60 years (n=184, 2.9%) (**Table 1**).

Table 2 presents the values of BMI, fat mass, visceral fat, muscle mass, and EWL% for the three surgical procedures at baseline and at 3, 6, 12, and 24 months postoperatively. Considerable changes were observed at each follow-up interval. However, due to sample attrition over time and the unequal number of participants across the different time points, direct statistical comparisons were not feasible. Therefore, regression analysis was applied to evaluate the association between the type of surgery and changes in body composition.

Analyses were conducted to examine differences based on age group and sex. Gender-related data are presented in the tables, whereas comparisons by age group did not reach statistical significance in most analyses and were not included in the Tables.

BMI changes

The results of GEE analysis indicated that BMI significantly changed over time across different surgical groups. Specifically, patients in the MBG presented a greater reduction in BMI over time than did those in the SG ($p < 0.001$).

Additionally, sex was found to significantly influence BMI changes over time. Male patients had a higher BMI than female patients did (B = 1.27) (Table 3).

Excess weight loss percentage (EWL%) changes

According to GEE analysis, the EWL% significantly differed over time among the surgical groups. Patients in the MB group experienced a significantly greater increase in EWL% over time than did those in the SG group (*P*=0.037). In addition, sex was significantly associated with EWL% changes. Compared to female patients, male patients had a lower EWL% (B=–2.903). (**Table 3**).

Table 1. General characteristics of the study participants.

Variable	N	%
Type of surgery		
RYGB	3360	52.6
MBG	1912	29.9
SG	1118	17.5
Total	6390	100
Sex		
Male	1097	17.2
Female	5293	82.8
Total	6390	100
Age category		
18-39	3637	56.9
40-49	1737	27.2
50-59	832	13.0
60≤	184	2.9
Total	6390	100

***RYGB**: Roux-en-Y gastric bypass; **MBG:** Mini gastric bypass; **SG:** Sleeve gastrectomy*.

Fat mass and visceral fat

No significant differences in fat mass or visceral fat were observed between the surgical groups. However, over time, fat mass decreased more in males than in females (*P*=0.015), and a similar trend was observed for visceral fat (*P*=0.035) (**Table 3**).

Muscle mass

The findings from GEE analysis revealed a significant difference in muscle mass index over time across the surgical groups. Muscle mass was better preserved in the classic RYGB group than in the SG group (*P*=0.043).

In addition, age and sex were significantly associated with changes in muscle mass over time. Muscle mass was better maintained in male

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patients than in female patients (*P*<0.0001) (**Table 3**), whereas age, especially over 50 years was associated with more muscle wasting over time (*P*<0.0001) (data not shown).

Discussion

The current study is one of the largest comparative analyses of bariatric surgery outcomes in the Middle Eastern population, offering valuable insights into the effectiveness of three major surgical procedures over a 24-month follow-up period. The findings demonstrate significant and sustained improvements in anthropometric parameters and body composition across all three procedures, with notable differences in their respective trajectories and magnitudes of change. Although several surgical techniques exist-with different mechanisms and efficacy profiles-no standardized protocol governs their selection; decisions are primarily based on clinician judgment and patient preference (Cunningham, 1991, Davidson *et al.*, 2018).

The findings corroborate the study by McTigue *et al.*, which reported greater excess weight loss with RYGB compared with SG at the 5-year follow-up (McTigue *et al.*, 2020). Moreover, in the present study, BMI or EWL% reduction was greater in the MBG than in the SG, which aligns with findings from Hatami and Kansou (Hatami *et al.*, 2022, Kansou *et al.*, 2016). However, the performance of MGB in this study was particularly noteworthy, achieving weight loss outcomes comparable to those of RYGB while maintaining the technical simplicity of a single anastomosis. This finding supports the growing body of evidence suggesting that MGB is a viable alternative to more complex procedures, as demonstrated in multicenter European studies by Carbajo (Carbajo *et al.*, 2017).

Table 2. Body composition, BMI and EWL% before and after bariatric surgery (up to 24 months).

Variable	Baseline	Months after surgery 3	6	12	24
BMI (kg/m^2)					
SG	432(45.1±6.9)[a]	380(36.3±5.8)	345(33.3±6.1)	255(31.2±6.2)	137(32.2±6.8)
MGB	601(46.2±6.1)	574(37.1±5)	545(33.2±4.8)	475(29.6± 4.4)	318(28.4±4.3)
RYGB	1132(44.1±5.4)	995(36±4.7)	9412(32.9±4.6)	809(30.1±4.5)	616(29.9±4.6)
Fat mass					
SG	176(54.6±13)	93(39.7±9.9)	88(33.4±10.3)	54(27.5±10.3)	7(31.9±11.9)
MGB	598(58.7±12.6)	312(39.9±10.1)	236(32±9.7)	173(23.5± 8.6)	58(21.4±8.8)
RYGB	207(56.2±12.8)	138(40±11.2)	132(32.5±10.4)	84(25.8±9.6)	18(25.6±7)
Visceral fat (%)					
SG	176(16.3±6)	93(10.9±3.5)	88(9.1±3.5)	54(7.7±3.6)	7(9±3.6)
MGB	596(16.5±5)	312(11.3±3.7)	236(8.8±3.1)	173(6.3± 2.6)	58(5.5±2.8)
RYGB	206(15.4±4.4)	138(10.7±4)	132(8.3±3.2)	84(6.4±2.9)	18(6.5±2.5)
Muscle mass (%)					
SG	176(62.9±13.9)	93(55.9±10.5)	88(53.8±10.8)	54(53.3±10.1)	7(52.6±13)
MGB	599(62.7±13.2	312(56.8±12)	236(54.1±10.8)	173(52.4± 10.3)	58(50.3±8.9)
RYGB	207(59.2±10.5)	138(54.2±9)	132(51.9±7)	84(51±7.5)	18(47.7±4.3)
EWL% (%)					
SG		380(45.3±14.7)	345(62.3±19.1)	255(73.1±21.9)	137(70.4±25.6)
MGB		574(43.9±13.3)	574(63.2±15.7)	475(80.3±17.9)	318(85.1± 19.1)
RYGB		995(44.8±14.3)	941(61.7±17.1)	809(76±19.5)	616(77.1±20.3)

RYGB*: Roux-en-Y gastric bypass;* ***MBG:*** *Mini gastric bypass;* ***SG:*** *Sleeve gastrectomy*; ***BMI****: Body mass index*; **EWL%**: *Excess weight loss percentage;* [a]: n(mean±SD).

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Table 3. Impact of bariatric surgery type and sex on body composition parameters: Regression analysis results.

Variable	B	95% Wald Confidence Interval		P-value[a]
		Upper	Lower	
BMI				
SG	0	0	0	0
MGB	-0.103	-0.055	-0.150	<0.0001
RYGB	-0.010	0.035	-0.055	0.657
Male	1.278	1.938	0.618	<0.0001
EWL%				
SG	0	0	0	0
MGB	0.238	0.462	0.014	0.037
RYGB	0.096	0.308	-0.117	0.377
Male	-2.903	0.720	-5.087	0.009
Fat mass				
SG	0	0	0	0
MGB	0.232	0.462	0.002	0.048
RYGB	0.025	0.210	0.159	0.788
Male	-3.887	-0.763	-7.012	0.015
Visceral fat				
SG	0	0	0	0
MGB	0.104	0.223	-0.016	0.089
RYGB	-0.017	0.067	-0.101	0.692
Male	-1.656	-0.118	-3.193	0.035
Muscle mass				
SG	0	0	0	0
MGB	0.104	0.224	-0.016	0.091
RYGB	-0.137	0.269	-0.005	0.043
Male	25.179	26.620	23.737	<0.0001

***RYGB**: Roux-en-Y gastric bypass; **MBG:** Mini gastric bypass; **SG:** Sleeve gastrectomy; **BMI**: Body mass index; **EWL%**: Excess weight loss percentage; [a]: Sleeve Surgery was used as a reference and statistical analysis was performed via the Generalized Estimating Equation (GEE)..*

The trajectory of weight loss across all procedures followed the expected pattern, with rapid initial loss in the first six months, followed by a more gradual decline that was stabilized by 18-24 months. This pattern mirrors findings from the Swedish Obese Subjects study and other long-term bariatric research, suggesting that the Iranian population responds similarly to surgical intervention despite potential genetic and cultural differences.

Perhaps more significant than weight loss alone was the profound change in body composition observed across all procedures. The substantial reduction in visceral fat-averaging 45-55% across procedures-represents a clinically meaningful improvement in the metabolic risk profile. No significant differences in fat or visceral fat loss were observed between the surgical groups, which is consistent with the findings of Sivakumar *et al*. (Sivakumar *et al.*, 2024). However, males experience greater fat reduction than females (Nguyen *et al.*, 2022, Sun *et al.*, 2021). Additional research indicated a more significant decrease in visceral fat with bypass surgery, emphasizing its metabolic advantages (Favre *et al.*, 2018, Henry *et al.*, 2024).

This research indicates that muscle mass is more effectively preserved following RYGB than following SG, which aligns with the findings of Barzin *et al.* (Barzin *et al.*, 2021). This highlights the potential advantages of Roux-en-Y in maintaining strength during significant weight loss. The preservation of lean muscle mass, particularly in the RYGB group, challenges excessive muscle loss following bariatric surgery earlier. The results suggest that with appropriate nutritional support

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and follow-up, patients can maintain functional muscle mass while achieving substantial fat loss. This finding has important implications for long-term metabolic health and functional capacity, as muscle mass preservation is crucial for maintaining the metabolic rate and preventing weight regain. Males retain more muscle than females, likely due to higher baseline muscle mass and testosterone levels (Emara *et al.*, 2022). Age was a significant predictor of muscle loss, supporting Molero *et al*. (Molero *et al.*, 2022), who linked increased age to greater postoperative muscle wasting. These findings highlight the need for targeted strategies to maintain muscle mass, especially in older and female patients.

Moreover, in the present study, patient-specific factors such as age and sex were associated with weight and muscle loss over time, as also reported in studies by Hider *et al*. (Hider *et al.*, 2024) and Hamed *et al*. (Hamed *et al.*, 2017). These results reinforce the importance of age- and sex-specific strategies in postoperative care to optimize long-term outcomes.

The success of bariatric surgery in the Iranian population demonstrates the universal applicability of these procedures across diverse ethnic and cultural backgrounds. However, several factors unique to the study's population deserve consideration. The relatively younger age of this study (mean age 38.5) compared with many Western studies may have contributed to the excellent outcomes observed, as younger patients typically demonstrate better surgical tolerance and adherence to postoperative guidelines.

The high female predominance (78.3%) in this study reflects global trends in bariatric surgery utilization. However, these findings may also indicate cultural factors specific to Iranian society, where body image concerns and health-seeking behaviors may differ between genders. This demographic pattern has implications for healthcare resource allocation and the development of gender-specific postoperative support programs.

The improvements observed at 24 months offer promising evidence of the long-lasting benefits of bariatric surgery for the study's population. The lack of significant weight regain during the second year after surgery indicates that patients have successfully adjusted to their new anatomical and physiological conditions. This finding is important, especially considering the concerns about maintaining weight loss in the long term after bariatric procedures

The application of advanced statistical models, including GEE, allows greater reliability and clinical utility of the results, especially when a longitudinal study design is used. However, there are some limitations that need to be added during the interpretation of the results. The observational nature of this study, while informative as to real-world effectiveness, limits the study's capacity to make causal inferences about the relative efficacy of procedures. Furthermore, few data are available for patients' dietary adherence, supplement use, and physical activity in conjunction with a relatively short follow-up, which may not fully account for long-term complications, or patterns of weight regain that may emerge beyond 2 years.

Future studies should aim for a longer follow-up period with 5-year and 10-year outcome evaluations as well as the incorporation of quality-of-life endpoints and the resolution of comorbidities. Investigations into the genetic, psychological, and socioeconomic determinants of the respond to bariatric surgery are warranted to elucidate individual variability. The development of predictive models incorporating these factors could enhance patient selection and personalized treatment planning.

Conclusion

This study presents strong evidence for the effectiveness of bariatric surgery among the Iranian population, with all three procedures showing significant and sustained improvements in anthropometric and body composition parameters. The differential outcomes between procedures also provide valuable guidance for surgical selection. While RYGB has demonstrated superior overall results, the excellent performance of MGB, combined with its reduced operative complexity and shorter learning curve, makes it an attractive option

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for centers developing bariatric programs. The good outcomes with SG, despite being the least effective of the three procedures, support its continued use as a first-line option for appropriate candidates.

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Conflict of interest

The authors declared no competing interests.

Authors' contributions

Banpouri S, Mansoori A, Ansar H and Veissi M designed and conducted the research; Seyedtabib M analyzed the data; and Banpouri S, Mansoori A and Veissi M wrote the paper. Veissi M had primary responsibility for final content. All the authors read and approved the final manuscript.

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