

Original Article

Bariatric Surgery Favorably Modulates Global Longitudinal Strain and Homeostatic Model Assessment for Insulin Resistance in Patients With Obesity Without Comorbidities

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ABSTRACT

Background: The present study assessed the effect of bariatric surgery (BS) on left ventricular global longitudinal strain (LV-GLS) and homeostatic model assessment for insulin resistance (HOMA-IR) and investigated whether a correlation exists between LV-GLS and HOMA-IR in obese patients without comorbidities.

Methods: Patients with a body mass index (BMI) above 35 were included and underwent varying BS procedures. Patients' data, comprising BMI calculation, HOMA-IR with fasting glucose and fasting insulin measurements, and evaluation of GLS with tissue Doppler echocardiography, were collected before BS and at 12-month follow-up after BS.

Results: A total of 142 patients who underwent BS were included in the study. BS significantly reduced HOMA-IR (mean difference, 3.79; $P < .001$), and mean GLS improved substantially postoperatively (mean difference, -3.25 ; $P < .001$). Among 18 patients with either borderline or abnormal GLS, all experienced improvement of GLS to the normal range in post-surgery follow-up (mean difference, -6.3 ; $P < .01$). Changes in GLS and HOMA-IR did not show a significant correlation with one another. Improvement in GLS and HOMA-IR scores did not differ significantly between BS subtypes ($P = .78$ and $.83$, respectively).

Conclusions: GLS could be measured before and after BS to determine LV function improvement in obese patients, given that obesity may have a direct hemodynamic effect on LV function independent of other consequences, such as hypertension and diabetes. Furthermore, regardless of the BS technique used, BS has a positive impact on HOMA-IR and GLS. (*Iranian Heart Journal 2026; 27(4): 50-59*)

KEYWORDS: overweight; metabolic surgery; insulin sensitivity; LV-GLS; cardiac function tests

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Obesity, defined as a body mass index (BMI) of 30 or higher, is a chronic disease affecting millions of people.^{1,2} The World Obesity Federation predicted in the 2022 World Obesity Atlas that 1 billion people worldwide, comprising 1 in 5 women and 1 in 7 men, will be living with obesity by 2030.³ This chronic disease is associated with diverse, increasing disease burdens, including 21 nonoverlapping cardiometabolic, digestive, respiratory, neurological, musculoskeletal, and infectious diseases. Accordingly, obesity may represent a critical target for multimorbidity prevention that avoids the complexities of multitarget preventive regimens.⁴

Because high morbidity and mortality rates are associated with class III obesity (BMI ≥ 40) and with a BMI of 35 to 39 in the presence of a coexisting condition, surgical weight-loss procedures, known as bariatric surgeries (BS), are increasingly utilized.¹ In 2022, the American Society for Metabolic and Bariatric Surgery (ASMBS) and the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) provided major updates to the 1991 National Institutes of Health (NIH) guidelines for BS. They recommended metabolic and bariatric surgery (MBS) for individuals with a BMI of 35 kg/m² or greater-regardless of the presence, absence, or severity of comorbidities-and also for individuals with metabolic disease and a BMI of 30 to 34.9 kg/m².⁵ This recent amendment in BS indications shows that lower BMI thresholds are required to become a candidate for this type of surgery.

As a growing number of BS is anticipated, concerns regarding the safety, efficacy, and durability of these procedures emerge. Long-term data consistently indicate the safety, efficacy, and durability of MBS in the treatment of clinically severe obesity and its comorbidities.^{6,7} Considering the efficacy of BS on cardiac function, several studies have suggested beneficial cardiac effects of this

surgery on diastolic function, systolic function, and myocardial structure in patients with obesity.^{8,9} Moreover, a systematic review and network meta-analysis concluded that single-anastomosis gastric bypass and sleeve gastrectomy (SG) may be efficacious options for patients with high insulin resistance.¹⁰ Despite the presence of multiple studies focusing on the effect of BS on cardiac function and insulin resistance, few studies have used left ventricular global longitudinal strain (LV-GLS) and Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) as tools for assessment, respectively.¹¹⁻¹⁵

In the current prospective study, we aimed to examine the effect of BS and its different subtypes on LV-GLS and HOMA-IR and to investigate whether there is any correlation between LV-GLS and HOMA-IR in the individuals who presented to or were referred to our referral obesity clinic.

METHODS

Study Design, Setting, and Population

The present observational study was conducted with a before-and-after design to assess the effect of BS on cardiac function and insulin resistance at Rasoul Akram General Hospital, Tehran, Iran, from February 2018 through June 2022. Ambulatory patients who presented to the obesity clinic of the hospital during this period and were subsequently considered candidates for BS were enrolled. The criterion for being a candidate for surgery was a BMI greater than 35. All patients during this period were initially included to avoid selection bias.

Patients meeting exclusion criteria-including a history or evidence of heart failure (left ventricular ejection fraction [LVEF] $\leq 50\%$), valvular heart disease, cardiomyopathy, hypothyroidism, thyrotoxicosis, chronic kidney or liver disease, obstructive sleep apnea, malignancy, diabetes (hemoglobin A1c $\geq 6.5\%$), hypertension (systolic blood pressure ≥ 140 mm Hg, diastolic blood

pressure ≥ 90 mm Hg), pregnancy, alcohol consumption (≥ 2 drinks/d for men and ≥ 1 drink/d for women), and use of vasoactive or antiobesity medications-were excluded from the study (Figure 1).

Various BS procedures were performed for study participants, including sleeve

gastrectomy, mini-gastric bypass, Roux-en-Y gastric bypass (RYGB), single-anastomosis sleeve ileal bypass (SASI), and single-anastomosis sleeve jejunal bypass (SASJ), based on patient preference and surgeon recommendation.

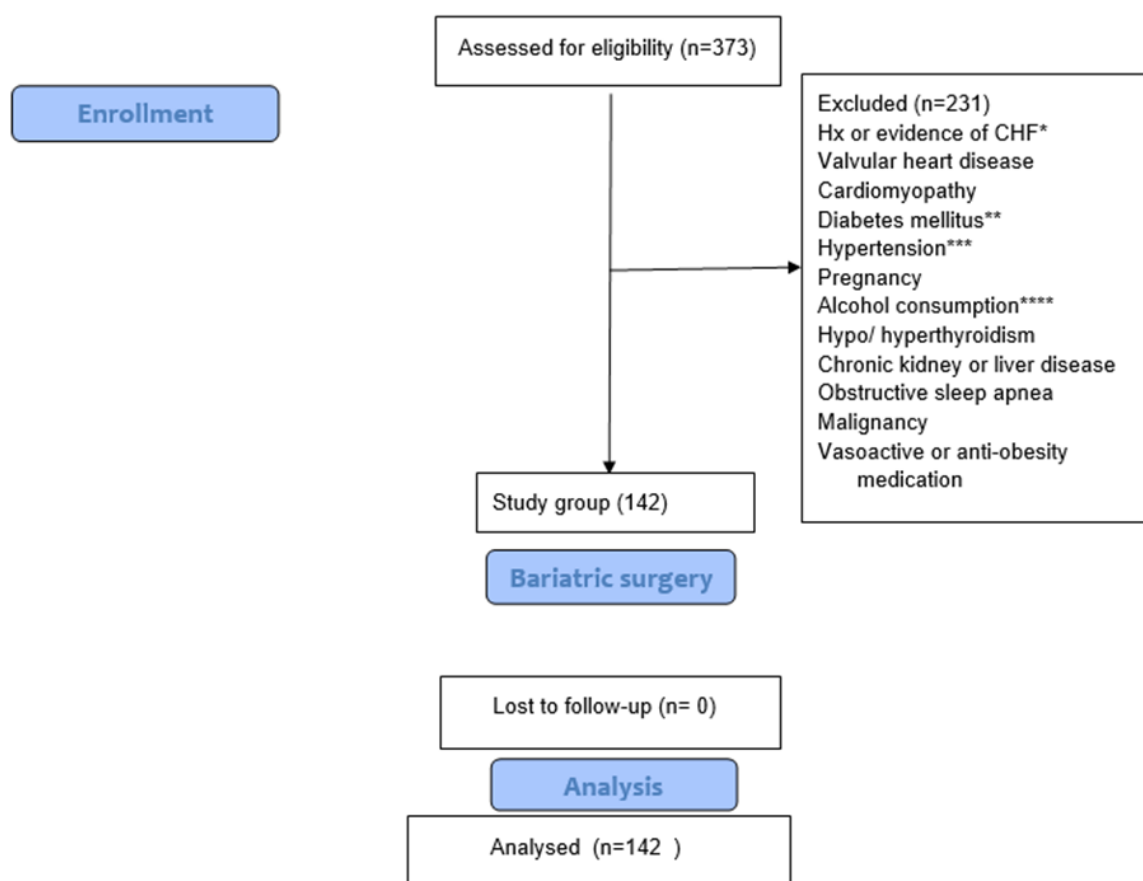


Figure 1. Flowchart of the inclusion of participants

*Left ventricular ejection fraction $\leq 50\%$

**HgbA1c $\geq 6.5\%$

***Systolic blood pressure ≥ 140 mm Hg, diastolic blood pressure ≥ 90 mm Hg, and uncontrolled hypertension despite of medication

**** ≥ 2 drinks /d for men and ≥ 1 drink /d for women

CHF: congestive heart failure

Data Collection

Anthropometric assessments-including height, weight, and hip and waist circumferences-were performed for eligible patients at admission. Blood samples were collected between 8 and 9 AM after 8 hours of fasting as well as 30 minutes before sleep. We

measured lipid profiles, fasting glucose levels, and fasting insulin levels, and then calculated the HOMA-IR index by multiplying fasting insulin ($\mu\text{U/mL}$) by fasting glucose (mg/dL) divided by 405. Furthermore, participants underwent conventional transthoracic echocardiography to measure chamber

dimensions, wall thickness, LV mass, and EF. Speckle-tracking 3D echocardiography with the Philips EPIQ CVx cardiovascular ultrasound system was then performed to evaluate GLS preoperatively. Subsequently, all patients underwent BS. At the 12-month follow-up, BMI, percentage of weight loss, lipid profiles, and HOMA-IR index were calculated for each patient. Patients also underwent repeat echocardiography to remeasure the aforementioned parameters. None of the study participants experienced acute cardiovascular complications during data collection.

Primary and Secondary Endpoints

The primary endpoints were defined as changes in HOMA-IR and GLS after BS. Secondary endpoints were the effect of BS subtypes on HOMA-IR and GLS and the correlation among changes in BMI, HOMA-IR, and GLS.

Statistical Analysis

Data were recorded in a Microsoft Excel spreadsheet, and IBM SPSS Statistics version 22 was employed for analysis. Qualitative variables were reported as frequencies with percentages, and quantitative variables as mean (SD). Paired sample *t* test was utilized to evaluate mean changes in numeric observations before and after BS, and the Pearson χ^2 test was applied to assess distributions across categorical variables. For correlations between 2 numerical measurements, the Spearman rank correlation coefficient (Spearman ρ) was used. Analysis of variance (ANOVA) and repeated-measures ANOVA were performed to determine differences in the distribution of observations across BS subtypes. The significance level was set at a *P* value below .05. For longitudinal comparisons, paired *t* tests were performed only among patients with both baseline and 12-month follow-up measurements available for the variable of

interest. Accordingly, the number of observations included in each paired analysis varied depending on data completeness.

Ethical Considerations

We complied with the ethics of research involving human participants as well as the Declaration of Helsinki in the design and conduct of our research, and the Ethics Committee of Iran University of Medical Sciences approved the study (ethical code: IR.IUMS.REC.1395.29915). Informed written consent was obtained from all participants, and they could withdraw from the study at any time without reprisal.

RESULTS

Distribution of Sexes and Surgical Techniques

A total of 142 patients who underwent BS were included in the study, comprising 30 males and 112 females. Gastric sleeve was the most prevalent surgical technique, performed in 43.7% of patients, followed by mini gastric bypass and RYGB, performed in 28.2% and 24.6% of patients, respectively. Only 3.5% of patients underwent single-anastomosis sleeve jejunal or ileal bypass. The frequencies of various surgical procedures by sex are presented in Table 1.

Mean Differences Between Pre- and Post-Surgery Variables

Metabolic panel including HOMA-IR and GLS before and after BS are indicated in Table 2, and the mean differences of each variable before and after these surgical procedures are shown in Table 3. All patients demonstrated a statistically significant decrease in BMI, with a mean difference of 15.44 and a *P* value of less than .001. Except for high-density lipoprotein, which did not demonstrate a statistically significant difference between pre- and postoperative measurements (*P* = .231), the means of the indices evaluating

patients' metabolic status, including fasting blood sugar, insulin level, total serum triglyceride, cholesterol, and low-density lipoprotein, improved after surgery. Considering the mean difference of 3.79 and the P value below .001 for HOMA-IR, BS significantly reduced the insulin resistance index. As a measure of left ventricular dysfunction, the mean GLS of the patients improved significantly following surgery, with a mean difference of -3.25 and a P value less than .001. In addition, all patients with either borderline or abnormal GLS (GLS < 18 , $n = 18$) had improvement of GLS to normal range in postoperative follow-up, from mean baseline of 16.92 (1.2) to 23.22 (2.0) with a mean difference of -6.3 (paired t test: $t_{17} = -11.08$; $P < .01$). Moreover, a substantial proportion of laboratory and echocardiographic follow-up data was unavailable because of incomplete

attendance at the 12-month follow-up visits and the unavailability of some laboratory and echocardiographic assessments despite patient follow-up, which may have introduced attrition bias. For the evaluation of the potential impact of loss to follow-up, baseline characteristics were compared between patients with available 12-month follow-up data and those without follow-up measurements. No statistically significant differences were observed in demographic, clinical, laboratory, or echocardiographic baseline variables, including age, sex, BMI, HOMA-IR, and GLS (all $P > .05$). These findings suggest that patients who completed follow-up were broadly comparable to those who did not, reducing the likelihood that the observed postoperative changes were substantially influenced by differential loss to follow-up.

Table 1. Frequencies and Sex Distribution of Different Surgical Methods

Surgery Methods	Female, No. (%)	Male, No. (%)	Total, No. (%)
Gastric sleeve	47 (75.8)	15 (24.2)	62 (43.7)
Mini gastric bypass	29 (72.5)	11 (27.5)	40 (28.2)
RYGB	32 (91.4)	3 (8.6)	35 (24.6)
SASI	2 (66.7)	1 (33.3)	3 (2.1)
SASJ	2 (100.0)	0 (0.0)	2 (1.4)
Total	112 (78.9)	30 (21.1)	142 (100)

RYGB: ROUX-EN-Y gastric bypass; SASI: single anastomosis sleeve ileal bypass; SASJ: single anastomosis sleeve Jejunal bypass

Table 2. Baseline Demographics and Post-Surgery Measurements of Patients

Variable	Descriptive Statistics					
	Time of Assessment	N	Minimum	Maximum	Mean	SD
Age	-	142	13	62	34.27	9.12
BMI	Pre-op	142	35.6	78.4	46.46	6.03
	Post-op	139	22.10	48.28	31.09	4.80
FBS	Pre-op	141	70.0	257	100.85	21.26
	Post-op	100	68.00	255	90.26	20.93
Insulin	Pre-op	116	3.9	208	20.31	20.53
	Post-op	71	2.40	44.60	7.68	5.46
HOMA-IR	Pre-op	116	0.76	60.09	5.37	6.50
	Post-op	70	0.47	9.25	1.73	1.36
TG	Pre-op	141	52.0	1106	152.50	103.13
	Post-op	95	48.00	698	103.76	73.27
Cholesterol	Pre-op	141	110.0	326	188.48	35.96

	Post-op	97	111.00	277	168.91	28.56
HDL	Pre-op	141	25.0	133	48.95	13.13
	Post-op	96	30.00	74.5	47.85	9.71
LDL	Pre-op	141	19.0	175	103.07	21.58
	Post-op	95	54.50	154.5	97.98	19.09
GLS	Pre-op	136	11.7	55	20.98	4.30
	Post-op	86	20.00	29.4	24.48	2.05

BMI: body mass index; FBS: fasting blood glucose; GLS: global longitudinal strain; HDL: high-density lipoprotein; HOMA-IR: homeostatic model assessment of insulin resistance; LDL: low-density lipoprotein; TG: triglycerides

Table 3. Paired *t* Test Analysis of Mean Differences Between Preoperative and Postoperative Measurements

Variable	Mean, Pre-op	Mean, Post-op	Mean Differences	<i>t</i>	df	<i>P</i>
BMI	46.53	31.09	15.44473	48.043	138	<.001
FBS	100.96	90.26	10.69113	6.321	99	<.001
Insulin	20.44	7.51	12.93468	3.951	61	<.001
TG	154.96	103.76	51.20702	7.769	94	<.001
Cholesterol	191.43	168.91	22.51632	6.919	96	<.001
HDL	49.60	47.85	1.75521	1.204	95	.23
LDL	104.61	97.98	6.62789	2.751	94	.007
HOMA-IR	5.64	1.71	3.93000	3.794	60	<.001
GLS	21.22	24.48	-3.25581	-6.362	85	<.001

BMI: body mass index; df: degrees of freedom; FBS: fasting blood glucose; GLS: global longitudinal strain; HDL: high-density lipoprotein; HOMA-IR: homeostatic model assessment of insulin resistance; LDL: low-density lipoprotein; TG: triglycerides

Correlation Between Changes in BMI, HOMA-IR, and GLS

Changes in BMI and GLS were statistically associated; however, the strength of this association was low (Spearman $\rho = -0.213$; $P = .049$). Changes in GLS and HOMA-IR, as well as BMI and HOMA-IR, did not show a significant correlation with one another ($P = .748$ and $P = .117$, respectively).

Correlation Analysis of BS Techniques and BMI, HOMA-IR, and GLS

Improvement in GLS and HOMA-IR scores did not differ significantly between BS subtypes ($P = .78$ and $.83$, respectively); notwithstanding, the mean difference in BMI was influenced by the BS technique ($F = 4.51$; $P = .005$). Mini gastric bypass led to a considerably higher decrease in BMI than gastric sleeve bypass and RYGB ($P = .003$ and $P = .043$, respectively), although there was no difference between gastric sleeve

bypass and RYGB in terms of BMI reduction ($P = .962$).

DISCUSSION

Our study showed that BS significantly reduced HOMA-IR, an index of insulin resistance, and improved LV-GLS to the normal range, an index of left ventricular function, in patients with abnormal LV-GLS. Nonetheless there was no statistically significant correlation between HOMA-IR and GLS. Moreover, there was no statistically significant difference among various subtypes of BS in improving GLS and HOMA-IR.

BS and LV-GLS

Obesity and being overweight are associated with impaired LV mechanics, including reduced GLS.^{16, 17} Conversely, BS is associated with a significantly reduced incidence of cardiovascular disease and mortality in patients with obesity.^{18,19} Studies have shown that LVEF lacks

sufficient sensitivity to serve as a marker for evaluating improvements in LV function, as LVEF did not alter significantly following BS. Unlike LVEF, LV-GLS has emerged as a sensitive parameter for detecting changes in LV systolic function between pre- and post-BS periods.^{13, 16} A systematic review and meta-analysis of 13 studies indicated significant GLS improvement after BS; this finding is in line with our study results.¹⁶ This observation suggests that GLS should be assessed at baseline and during follow-up for patients undergoing BS to evaluate LV function improvement.

It remains indistinguishable from the studies included in the meta-analysis by Gherbesi et al¹⁶ whether the favorable effect of BS on LV mechanics is due to the direct effect of weight reduction or the simultaneous improvement of comorbidities, such as hypertension and diabetes.

A strength of our study was the exclusion of patients with comorbidities, including hypertension and diabetes; consequently, the correlation between the direct weight-reducing effect of BS and GLS could be more accurately investigated. Our study findings regarding the improvement of LV-GLS following BS in patients without cardiovascular risk factors or features of metabolic syndrome other than obesity indicate that obesity might have a direct hemodynamic effect on LV function (ie, LV-GLS) independent of its other consequences or comorbidities, such as hypertension and diabetes.

Grymyr et al¹³ assessed LV mechanics using mid-wall shortening and GLS in 94 patients with severe obesity who underwent gastric bypass surgery. They observed that the proportion of patients with low GLS was reduced by 80% at the 1-year control, whereas 100% of our patients with abnormal GLS improved to the normal range at the 1-year follow-up. This difference may be ascribed to the presence of preoperative

hypertension and its subsequent adverse effects on myocardial structure in their study participants, whereas patients with hypertension were excluded from our study.¹³

BS and Insulin Resistance (HOMA-IR)

HOMA-IR has been validated as a tool for the surrogate evaluation of insulin resistance.²⁰ In a retrospective cohort study by Stenberg et al,¹⁴ all patients, including those without diabetes who underwent laparoscopic Roux-en-Y gastric bypass (LRYGB), sustained improvements in HOMA-IR. This improved insulin homeostasis was retained at 1-year and 2-year follow-ups.¹⁴ The results of this study were consistent with our findings. Additionally, the mean difference between baseline and 1-year postoperative HOMA-IR was 3.5 in patients without diabetes undergoing LRYGB in the study by Stenberg et al,¹⁴ which was similar to the mean HOMA-IR difference obtained in our study. Nevertheless, a major discrepancy between that study and ours was that the patients in the study by Stenberg and colleagues underwent only LRYGB, whereas our study participants underwent various types of BS. This favorable effect of BS on HOMA-IR may be attributed to improved pancreatic β -cell function following BS, which appears to be the most important mechanism among patients without diabetes and patients with recent-onset diabetes, where β -cell dysfunction is limited.^{14, 21}

The Swedish Obese Subjects (SOS) study assessed the weight change-adjusted effects of gastric bypass, compared with restrictive surgical procedures including banding and vertical banded gastroplasty, on long-term changes in fasting glucose, fasting insulin, and HOMA-IR. In contrast with our analysis, which revealed no significant correlation between BMI and HOMA-IR, their results showed that reductions in HOMA-IR increased with greater weight loss, and

alterations were typically related to weight change within each surgery group.²² This discrepancy may be attributed to 2 factors: (1) the different BS subtypes the study participants underwent, and (2) the longer follow-up duration. Their analyses were based on data acquired at 2 years and 10 years postoperatively. Therefore, these comparisons suggest that the degree of weight loss is more crucial for long-term reductions in fasting insulin and glucose levels.²²

Correlation Between Changes in HOMA-IR and GLS Following BS

Given the association between HOMA-IR and GLS, Hirose et al²³ observed that patients with abnormal HOMA-IR had significantly diminished LVGLS, and the prevalence of impaired LVGLS was higher in participants with abnormal HOMA-IR than in those with normal HOMA-IR. Another study by Cauwenberghs et al²⁴ also showed higher HOMA-IR at baseline, and a longitudinal increase in HOMA-IR over time independently predicted a greater increase in LV mass index and decline in EF and 4-chamber longitudinal strain during follow-up. Be that as it may, our study results denoted there was no significant independent correlation between changes in GLS and HOMA-IR in patients undergoing BS. The aforementioned studies assessed the correlation between the deterioration of HOMA-IR and GLS, but we evaluated the possible presence of correlation in reversal changes between HOMA-IR and GLS after BS, and there was no similar study to the best of our knowledge. In addition, this discrepancy could be attributable to the greater extent of the beneficial effect of BS on GLS rather than HOMA-IR as evidenced by our statistical findings (Table 3), and different intermediary mechanisms through which cardiac function improved following BS.^{9,12,13,19}

Effects of Differences in BS Subtypes on HOMA-IR and GLS

Our study results revealed no significant difference in the effect of various BS methods on changes in HOMA-IR and GLS. A systematic review and network meta-analysis indicated that HOMA-IR values for RYGB, RYGB with omentectomy, single-anastomosis (mini) gastric bypass (SAGB), and SG were significantly lower than those of a control group consisting of patients with obesity with or without type 2 diabetes; however, no statistical difference was shown among these surgical procedures.¹⁰ Moreover, the Swedish Obese Subjects (SOS) study found that changes in HOMA-IR did not differ among the 3 surgery groups, including gastric bypass, vertical banded gastroplasty, and gastric banding.²² As this lack of difference was also observed in our study, we can presume that favorable outcomes of BS on HOMA-IR ensue regardless of the method employed. Regarding the effect of BS method variability on GLS, we found no similar study in the literature. Still, similar to HOMA-IR, the favorable effect on GLS likely does not differ by surgical approach.

Study Limitations

The present study has several limitations. First, it was conducted at a single center with a moderate sample size, which limited the ability to perform subgroup analyses according to BS type or patient characteristics. Second, the lack of a control group precludes determination of whether the observed improvements in HOMA-IR and GLS were attributable to BS itself, weight loss, postoperative lifestyle modifications, or other time-related factors. Therefore, these findings should be interpreted as associations rather than evidence of a causal effect of surgery. In addition, our analyses were not adjusted for potential confounding factors, such as age, sex, baseline BMI, degree of weight loss, and baseline metabolic status. Consequently,

independent predictors of changes in GLS and HOMA-IR could not be determined. Finally, outcomes were assessed only at the 1-year follow-up; thus, the durability of the observed improvements in HOMA-IR and GLS over longer periods remains uncertain.

CONCLUSIONS

In conclusion, the findings of the current study indicate that GLS may be assessed before and after BS to evaluate changes in LV function in patients with obesity without comorbidities, given that obesity may exert direct hemodynamic effects on LV function independent of associated conditions, such as hypertension and diabetes. BS was associated with statistically significant improvements in both GLS and HOMA-IR, although the improvement appeared more pronounced for GLS. Nonetheless, owing to the absence of a control group, these findings should be interpreted as associations rather than evidence of a direct causal effect of surgery. Furthermore, although improvements were observed across the entire cohort, the present study was not adequately powered to determine whether the magnitude of these effects differed among specific BS techniques because certain surgical subgroups were small. To validate our findings, additional multicenter comparative cohort studies and randomized clinical trials with larger sample sizes and longer follow-up periods are needed.

Conflict of Interest

None declared.

Authors' Contributions

SH conceived the study and developed the research questions. AI collected the data and wrote the paper. SR and AM curated the experimental data, ensuring accuracy and consistency. ES and AS performed the statistical analysis of the data.

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