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ORIGINAL ARTICLE

One-year outcomes of bariatric surgery in older adults: a case-matched analysis based on the Tehran Obesity Treatment Study

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Abstract

Purpose Knowledge is limited about the efficacy, safety, and long-term outcomes of bariatric surgery in older adult patients with obesity.

Methods Fifty-six patients aged ≥ 60 years who underwent bariatric surgery, as either sleeve gastrectomy or gastric bypass, were matched for sex, baseline body mass index (BMI) and surgery type, with 112 younger controls, aged 18–60 years. We compared complications, weight loss, resolution of co-morbidities, and changes in body composition status (fat mass [FM], fat-free mass [FFM], lean mass [LM] and percentage of fat mass [FM%]) 12 months postoperatively between the groups.

Results Complications were similar in the two groups. Diabetes mellitus (DM) and dyslipidemia showed similar remission and improvement rates postoperatively in the two groups. Remission from hypertension (HTN) was higher in the control group, but improvement rates were similar. Changes from baseline to 12 months postoperatively in weight, BMI, excess weight loss (EWL%), total weight loss (TWL%), FFM, and LM were greater in the control group than in the older-age group. Changes in FM and FM% were similar in the two groups.

Conclusion Bariatric surgery is a safe intervention for the management of obesity and obesity-related co-morbidities in older adults, with similar surgery-risk and complication rates to those of younger adults. Reduction in FM and FM% was equal in two groups and the concern about greater LM loss in older adults seems unfounded.

Keywords Bariatric surgery · Older adult · Complication · Safety · Effectiveness · Weight loss

Introduction

The population is aging worldwide. According to the United Nations, the global population aged 60 years and over has doubled since the 1980s and is expected to have doubled again by 2050, to reach nearly 2.1 billion [1]. Based on a 2016 report from the Statistical Center of Iran [2], 9.27% of Iran's population are aged 60 years and older, and following the global trend, Iran will face a huge population boom of older people in the coming decades [3].

The prevalence of obesity in the older population has increased dramatically and is associated with a high risk of cardiovascular diseases, metabolic diseases, several cancers and other co-morbidities in this age group [4]. The benefits of weight loss for older obese adults are numerous, including reducing the risk of type 2 diabetes mellitis (DM) and cardiovascular events, alongside improvements in respiratory function, depressive symptoms, and functional capacity [5].

Bariatric surgery is often more clinically efficient and cost-effective than non-surgical interventions for obese adults to achieve weight loss [6], but its role in the weight management of older patients with obesity has raised some concerns. Most patients who undergo bariatric surgery are under 60 years old [6], but little is known about the efficacy, safety, complications, and long-term outcomes of bariatric surgery in older patients with obesity. Although some studies have addressed the outcomes of bariatric surgery in older adults, their results are controversial. A systematic review in 2015 assessing weight loss, mortality, and 1-year resolution

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of obesity co-morbidities in patients aged 60 years and older, who underwent bariatric surgery found that their outcomes and complications were comparable to those in younger patients, and concluded that patients should not be denied bariatric surgery based on their age alone [7]. However, the findings of a more recent meta-analysis suggested that bariatric surgery in patients aged ≥ 60 years old is associated with a higher risk of complications and mortality. Moreover, this procedure may not be as effective in older patients as in patients younger than 60 years old [8]. In addition, loss of lean body mass and skeletal muscle mass is an inevitable outcome of weight loss in the elderly, which has an uncertain clinical impact on their health [9]. Hence, weight loss strategies for this age group must be recommended cautiously.

To better understand the possible risks and benefits of performing bariatric surgery in older obese people, because of the inconsistency of past findings, we investigated the complications and 1-year outcomes of bariatric surgery, as co-morbidity resolution and changes in body composition, in older adult patients by matching ≥ 60-year-old obese patients with younger controls.

Materials and methods

Patient selection and study design

This study was conducted within the framework of Tehran Obesity Treatment Study (TOTS), an ongoing prospective bariatric cohort commenced in March 2013. Briefly, TOTS subjects had a BMI level of ≥ 40 kg/m^2 or $35 \leq \text{BMI} < 40$ kg/m^2 with a medical co-morbidity or failure of intensive medical treatment and acceptable surgical risk. More information about study protocol is available elsewhere [10]. For the present study, 56 patients aged 60 years or older (maximum age, 76 years) who underwent bariatric surgery between March 2013 and March 2019 were enrolled in this study. They were matched for sex, baseline BMI, and surgery type with 112 controls (1:2 matching) aged 18–60 years old. The subjects were evaluated preoperatively for demographic data, anthropometric indices, body composition, metabolic and liver status, and co-morbidities. Data about the operation and surgical complications were collected for all the subjects. The resolution of co-morbidities and changes in body composition status were evaluated 6 and 12 months postoperatively.

Measurements

Trained investigators collected anthropometrics according to the World Health Organization guidelines [11]. Blood samples were collected after 12–14 h of overnight fasting and were assessed for general blood chemistry, namely lipid profiles including serum triglyceride [TG], total cholesterol, low-density lipoprotein cholesterol [LDL-C], and high-density lipoprotein cholesterol [HDL-C], fasting plasma glucose [FPG], hemoglobin A1C [HbA1C], aspartate aminotransferase [AST], and alanine aminotransferase [AST]).

Liver ultrasound was done to categorize whether patients had a normal liver or grade I, II or III fatty liver. The percentage of excess weight loss was calculated as EWL% = (preoperative weight − postoperative weight)/(preoperative weight − ideal weight) × 100, where ideal weight is defined by the weight corresponding to a BMI of 25 kg/m^2. The percentage of total weight loss was calculated as TWL% = (preoperative weight − postoperative weight)/preoperative weight × 100. Body composition was assessed by the portable bioelectrical impedance analyzer InBody 370 (Biospace, Seoul, Korea) after overnight fasting, while the subjects were well hydrated. Output data included fat mass (FM, in kg), fat-free mass (FFM, in kg), lean mass (LM, in kg), and fat mass percentage (FM %).

Surgical procedures

A single surgical team completed all the surgical procedures with the patient under general anesthesia. The patients underwent either laparoscopic sleeve gastrectomy (SG) or gastric bypass (GB). SG was performed by creating a gastric tube over a 36-F bougie with exclusion of 80% of the stomach. GB was performed either via the Roux-en-Y (RYGB) method or by one-anastomosis gastric bypass (OAGB). For RYGB, a vertical stomach pouch with anastomosis to a 150-cm roux jejunum limb was constructed and a side-to-side jejunojejunostomy with a 50-cm biliopancreatic limb was created. Mini-gastric bypass was performed using a one-anastomosis gastric bypass (OAGB) technique with a 160-cm biliopancreatic limb. Operative data including surgery time (mean duration of surgical procedure, from the first incision to the last stitch), anesthesia time (mean duration of general anesthesia, from the time of anesthesia induction to recovery), conversion to open surgery, and postoperative hospital stay were collected. Postoperative complications including hemorrhage, myocardial infarction, pulmonary embolism, infection, deep vein thrombosis, prolonged hospitalization and re-intubation, as well as re-operation and mortality rates, were recorded for all the subjects.

Definitions for resolution of co-morbidities

Resolution of DM, hypertension (HTN), and dyslipidemia was defined based on the American Society for Metabolic and Bariatric Surgery (ASMBS) outcome reporting standards [12], and evaluated 6 and 12 months after surgery. Remission from DM was defined as FPG < 125 mg/dl and HbA1c ≤ 6.4% in the absence of anti-diabetic medications.

Improvement in DM was defined as a reduction in HbA1c, and FPG not meeting the criteria for remission or decrease in anti-diabetic medications requirement. Remission from HTN was defined as a BP < 140/89 mmHg and being off medication. Improvement in HTN was defined as a decrease in the dosage or number of antihypertensive medications or a decrease in systolic or diastolic blood pressure on the same medication (better control). Remission from dyslipidemia was defined as a normal lipid panel when off medication (< 150 mg/dL for TG, < 200 mg/dL for total cholesterol, < 100 mg/dL for LDL-C and > 40 mg/dL for HDL-C). Improvement in dyslipidemia was defined as decrease in the number or dosage of lipid-lowering agents required with equivalent control of dyslipidemia or improved control of lipids (TG, total cholesterol, LDL-C, HDL-C) on equivalent medication.

Statistical analysis

Quantitative variables are expressed as means ± SD or median (25–75 interquartile range) and categorical ones as percentages. These variables were compared in the older adult and control groups using *t*-test for continuous variables and chi-square test for categorical variables. The resolution rate of co-morbidities in the older adult group and the matched control group, 6 and 12 months postoperatively was calculated by conditional logistic regression. Patients in the study group were aged ≥ 60 years old. Each study group patient was matched based on age, sex, BMI at baseline, and surgery type, with two randomly selected controls. Body composition status in the older adult group and the matched control group, preoperatively as well as 6 and 12 months postoperatively, was analyzed using a paired *t*-test.

Longitudinal differences in body composition status including BMI, weight, FM, FM%, FFM, and LM in the older group and the matched control group during follow-up were analyzed using the generalized estimated equation (GEE) method. Trends were analyzed using GEE with autoregressive working correlation structures through a linear model with identity link function. *P*-values were calculated for trends during follow-up ($P_{\text{Within-group}}$). All analyses were performed using SPSS, version 20 (SPSS, Chicago, IL, USA) and Stata software, version 14.0 (StataCorp LLC, TX, USA), and differences with *P*-values greater than 0.05 were considered significant (two-tailed test).

Results

Table 1 summarizes the baseline characteristics of the patients. Fifty-six patients aged ≥ 60 years (mean age: 64.5 ± 4.4 years) and 112 patients aged 18–60 years (mean age: 39.4 ± 10.1 years) were matched for baseline sex ratio (89.3% female), surgery type (71.4% SG), and BMI (47.3 ± 7.2 kg/m^2). The mean FPG, SBP, and HbA1C values were higher in the older adult group than in the control group (126.8 ± 40.3 mg/dl vs. 111.0 ± 50.2 mg/dl, 131.6 ± 15.1 mmHg vs. 123.6 ± 14.0 mmHg, and 6.4 ± 1.5 vs, 5.8 ± 1.2%, respectively). There was no significant difference in any other baseline characteristics between the groups. The preoperative prevalence of obesity-related co-morbidities is also presented in Table 1. The older adult group had a higher prevalence of DM (59.3% vs 27.5%) and HTN (80.4% vs 35.6%). The prevalence of dyslipidemia was similar in the two groups.

Table 2 shows data on the operation and surgery complications of the study participants. There was no difference between the older adult group and the control group in mean operative time (65.5 ± 17.1 min vs. 63.6 ± 21.8 min), anesthesia time (118.4 ± 29.3 min vs. 117.0 ± 26.9 min), or postoperative hospital stay (2.4 ± 0.8 days vs. 2.4 ± 1.4 days). Postoperative complications and re-operations were rare in both groups, without a significant difference. There was no mortality in either group.

Table 3 summarizes the remission and improvement rates of obesity-related co-morbidities at 6 and 12 months postoperatively, and Fig. 1 illustrates the resolution rates at 12 months in the two groups. The 6- and 12-month remission and improvement rates for DM and dyslipidemia were similar in the two groups. The rate of remission from HTN both 6 and 12 months postoperatively was higher in the control group (*P*-value = 0.03 and 0.02, respectively), but there was no difference in the HTN improvement rate between the groups.

Table 4 and Fig. 2 show the body composition status of the older adult and control groups before surgery and 6 and 12 months postoperatively. The weight change from baseline was lower in the older adult group than in the control group (− 31.3 ± 10.9 kg vs. − 9.5 ± 12.1 kg; Fig. 2a). The BMI change, EWL%, and TWL% were greater in the control group (Fig. 2b, c, d). Changes in FM and FM% were similar between the groups (Fig. 2e, f), but the decrease in FFM and LM was greater in the control group than in the older adult group (Fig. 2g, h). Within-group changes of all the parameters were significant for both groups.

Discussion

Historically, it was thought that bariatric surgery for weight management was suitable only for people younger than 60 years old [13]. In this study, we challenged this idea by comparing the 12-month postoperative outcomes of patients aged ≥ 60 years undergoing bariatric surgery with those of younger matched patients. We found that bariatric surgery resulted in resolution of obesity-related co-morbidities in

Table 1 Baseline characteristics of the older adult group and the matched control group

Characteristics	Older adult group (age ≥ 60) *N* = 56	Control group (age 18–60) *N* = 112	*P* value
Age (years)	64.5 ± 4.4	39.4 ± 10.1	**< 0.001**
Sex, *n* (%)			0.99
Male	6 (10.7%)	12 (10.7%)	
Female	50 (89.3%)	100 (89.3%)	
Surgery type, *n* (%)			0.99
SG	40 (71.4%)	80 (71.4%)	
GB	16 (28.6%)	32 (28.6%)	
BMI (kg/m^2)	47.3 ± 7.2	47.3 ± 7.2	0.97
Weight (kg)	113.3 ± 16.2	123.1 ± 20.8	**0.001**
WC (cm)	128.8 ± 14.5	124.8 ± 13.2	0.08
FPG (mg/dl)	126.8 ± 40.3	111.0 ± 50.2	**0.04**
Total cholesterol (mg/dl)	191.1 ± 45.5	189.5 ± 36.0	0.806
HDL-C (mg/dl)	51.9 ± 13.0	50.0 ± 10.5	0.31
LDL-C (mg/dl)	105.4 ± 38.5	112.3 ± 32.4	0.22
TG (mg/dl)	149.0 (117.0–189.2)	135.0 (104.0–181.0)	0.23
SBP (mmHg)	131.6 ± 15.1	123.6 ± 14.0	**0.001**
DBP (mmHg)	81.1 ± 8.5	79.9 ± 10.0	0.46
HbA1C (%)	6.4 ± 1.5	5.8 ± 1.2	**0.01**
AST (mg/dl)	21.7 ± 7.8	22.6 ± 11.1	0.52
ALT (mg/dl)	14.0 ± 12.6	27.1 ± 16.8	0.19
Fatty liver grade			0.73
No fatty liver	9 (16.4)	25 (22.3)	
Grade I	10 (18.2)	23 (20.5)	
Grade II	23 (41.8)	43 (38.4)	
Grade III	13 (23.6)	21 (18.8)	
Co-morbidities			
DM	32 (59.3)	30 (27.5)	**< 0.001**
HTN	45 (80.4)	37 (35.6)	**< 0.001**
Dyslipidemia	51(91.1)	94(84.7)	0.24

Bold values indicates statistical significance

Values are expressed as mean ± SD, number (%) or median (25–75 inter-quartile range)

SG sleeve gastrectomy; *GB* gastric bypass; *BMI* body mass index; *WC* waist circumference; *FPG* fasting plasma glucose; *HDL-C* high density lipoprotein cholesterol; *LDL-C* low density lipoprotein cholesterol; *TG* triglyceride; *SBP* systolic blood pressure; *DBP* diastolic blood pressure; *HbA1C* Hemoglobin A1C; *AST* aspartate aminotransferase; *ALT* alanine aminotransferase; *DM* diabetes mellitus; *HTN* hypertension

the older adult and younger groups, with similar resolution of DM and dyslipidemia between two groups, but a lower remission rate for HTN in older patients. Operative data, such as operative time, anesthesia time, and length of hospitalization, and postoperative complication rates were also similar in the two groups. Both the older adult and matched control groups achieved significant reduction in weight, BMI, LM, and FFM, and increases in EWL% and TWL%, which were greater in the younger group. The FM and FM% reduction were similar in the two groups. Overall, both older and younger patients benefited from bariatric surgery, and the greater risk of complications and LM loss in older adults appears to be of minor concern.

A meta-analysis of comparative studies identified a 1% increased risk of mortality and a 3% increased risk of overall complications 30 days post-bariatric surgery in patients aged over 60 years old compared with younger matches, which prompted the speculation that this procedure may be riskier for patients older than 60 years [8]. Conversely, the 1-year follow-up results in the present study showed comparable postoperative complication and re-operation rates of bariatric surgery in patients older than 60 years and the younger patients, in accordance with the findings of many other

Table 2 Operative data and complications in the older adult group and the matched control group

Characteristics	Older adult group $N=56$	Control group $N=112$	P value
Surgery time (min)	65.5 ± 17.1	63.6 ± 21.8	0.60
Anesthesia time (min)	118.4 ± 29.3	117.0 ± 26.9	0.77
Conversion to open	0	0	–
Postoperative hospital stay (day)	2.4 ± 0.8	2.4 ± 1.4	0.96
Postoperative complications, *n* (%)			
Hemorrhage (transfusion only)	2 (3.1)	1 (0.9)	0.59
Myocardial infraction	0	0	–
Pulmonary embolism	0	1 (0.9)	–
Infectious	1 (1.7)	0	–
Deep vein thrombosis	0	0	–
Re-intubation	0	0	–
Prolonged hospitalization (> 7 days)	4 (7.1)	5 (4.5)	0.44
Re-operation, *n* (%)			
Hemorrhage	0	2 (1.8)	–
Small bowel obstruction	0	0	–
Stricture	0	1 (0.9)	–
Abscess/Infection	1 (1.7)	0	–
Staple line leak	0	0	–
Marginal ulcer perforation	0	0	-
Internal hernia	0	0	–
Mortality	0	0	-

Values are expressed as mean ± SD or number (%)

studies [7, 14–18]. In comparing the intra-operative data of older and younger adults, Robert et al. [18] and Bhandari et al. [16] reported similar operative time and length of hospital stay in the two age groups, in agreement with our results. We also observed equal anesthesia time in the older and younger adults. These findings may be attributed to the recent improvements in surgical and anesthetic techniques and the experience of surgical teams, demonstrating equal safety of bariatric procedures for older and younger adults.

One of the main objectives of our study was to compare obesity-related co-morbidities in older and younger adults. Despite the higher prevalence of co-morbidities in the older adult group at baseline, they shared similar resolution rates to their younger matches for most co-morbidities 6 and 12 months postoperatively. In line with previously published studies [15, 16, 18], we observed comparable resolution of DM and dyslipidemia in both groups, although the 6- and 12-month rates of remission from HTN were significantly greater in the younger control group. Interestingly, the rate of improvement in hypertension was greater in the older adult group, but without significance. The lower remission rate of HTN in the older group might be explained by the fact that patients aged over 60 years old are more prone to some HNT-inducing mechanisms which cannot be reversed by excess weight reduction, such as arterial stiffness, glomerulosclerosis of the kidney, and neurohormonal and autonomic dysregulation [19].

It has been long assumed that weight loss in the elderly is associated with a specific pattern of body composition change, namely loss of muscle mass and lean body mass, contributing to a state called "sarcopenia" [9, 20]. This phenomenon predisposes the geriatric population to a number of health conditions including functional limitation, mobility disability, enhanced fracture risk, and increased mortality [21, 22]. Therefore, weight-reduction strategies for older adults need to be assessed by changes in body composition. In this study, we found that both older and younger adults had significant total weight and BMI reduction 12 months after the bariatric surgery, which was greater in the younger group (31.3 vs. 39.5 kg weight loss and 13.1 vs. 15.2 kg/m^2 BMI loss, respectively). Although the baseline weight of the older group was lower than that of the younger control group, the weights of both groups were similar 12 months postoperatively because the older adult patients had less weight change from baseline. One of the main objectives of performing bariatric surgery was to reduce body fat mass. We observed that the FM and FM% reduction were similar in the two groups, implying similar benefits of this

Table 3 Resolution rate of co-morbidities in the older adult group and the matched control group 6 and 12 months postoperatively

Characteristics	Older adult group	Control group	*P* value
Diabetes mellitus, *n* (%)			
Remission at 6 months	11/25 (44.0)	12/17 (70.6)	0.55
Remission at 12 months	13/26 (50.0)	18/21 (85.7)	0.11
Improvement at 6 months	12/25 (48.0)	5/17 (29.4)	0.55
Improvement at 12 months	11/26 (42.3)	3/21(14.3)	0.17
Hypertension, *n* (%)			
Remission at 6 months	11/40 (27.5)	17/24 (70.8)	**0.03**
Remission at 12 months	17/43 (39.5)	21/29 (72.4)	**0.02**
Improvement at 6 months	22/40 (55.0)	6/24 (25.0)	0.09
Improvement at 12 months	21/43 (48.8)	8/29 (27.6)	0.07
Dyslipidemia, *n* (%)			
Remission at 6 months	9/36 (25.0)	15/64 (23.4)	0.62
Remission at 12 months	10/39 (25.6)	15/60 (25.0)	0.64
Improvement at 6 months	26/36 (72.2)	49/64 (76.6)	0.36
Improvement at 12 months	28/39 (71.8)	45/60 (75.0)	0.92

Bold font indicates statistical significance

procedure for both age groups (10.6 vs 11.9% reduction in FM%, respectively). Despite the major concerns about excess LM loss following bariatric surgery in older adult patients, we found that LM and FFM reduction were lower in the older adult group than in their younger counterparts (7.0 vs 9.4 kg LM loss and 6.9 vs. 9.5 kg FFM loss, respectively). Although this is the first study to compare body composition change following bariatric surgery in older and younger adults, a few studies have addressed this subject in the general population. In line with our findings, Silva et al. reported a large decrease in BMI and FM% in the first 12 months after SG and GB (13.2–15.4 kg/m^2 reduction in BMI and 14.3%–17.3% reduction in FM%) [23]. In another study assessing body composition change 30 days after bariatric surgery, 2.8 FM% reduction and 4.4 ± 3.4 kg LM reduction were detected [24]. These small changes in body composition status are most likely due to shorter postoperative follow-up periods than in our study.

This study has several limitations, the most important of which was the relatively small sample size, limiting the statistical power for the assessment of complications, co-morbidity resolution, and body composition change after surgery. Our surgical team followed strict criteria when selecting the patients for inclusion in this study from among many ≥ 60-year-old candidates for bariatric surgery, ensuring none had any serious underlying diseases predisposing to complications and outcomes, such as heart failure or chronic obstructive pulmonary disease. Therefore, the ≤ 60-year-old subjects of this study were probably healthier than most such individuals with morbid obesity in the general population, leading to potential selection bias. Another limitation is the 1-year duration of the study, as longer follow-up might reveal different postoperative outcomes. Moreover, skeletal muscle mass and strength are used mainly for defining sarcopenia [25], but we could not assess these parameters in this study.

On the other hand, our study has several strengths. The first is the prospective design of the study, resulting in the

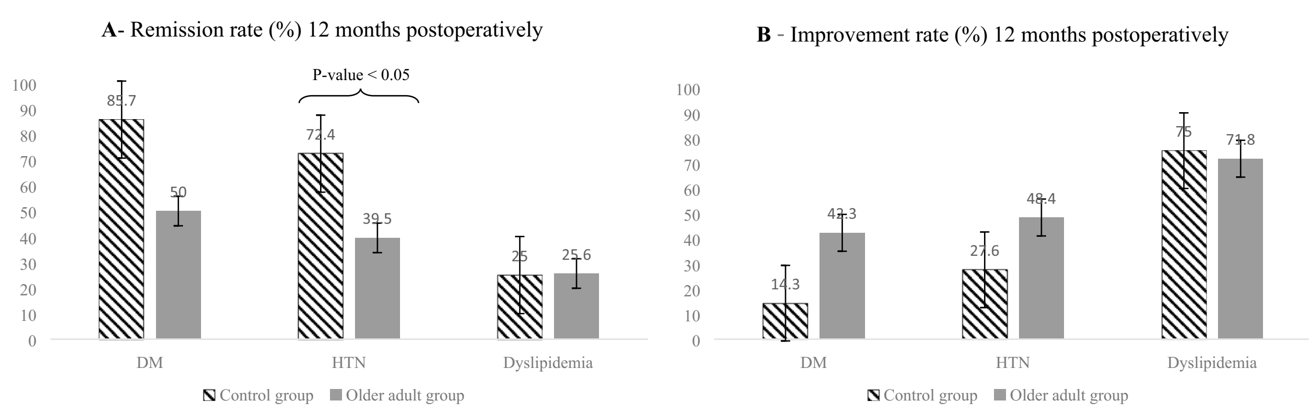

Fig. 1 Resolution rate of co-morbidities 12 months postoperatively in the ≥ 60-year-old group and the matched younger control group. **a** Remission rate (%) 12 months postoperatively. **b** Improvement rate (%)12 months postoperatively. *DM* diabetes mellitus; *HTN* hypertension

Table 4 Body composition status in the older adult group and the matched control group preoperatively and 6 and 12 months postoperatively

Variable	Age group	Preoperative	Post operation		12th month change from baseline	$P_{\text{Within-group}}$
			6 months	12 months		
Weight (kg)	Older	113.3 ± 16.2	88.9 ± 13.1	82.0 ± 11.4	− 31.3 ± 10.9	< 0.001
	Control	123.1 ± 20.8	90.52 ± 15.7	83.6 ± 15.3	− 39.5 ± 12.1	< 0.001
	$P_{\text{Between-groups}}$	**0.001**	0.527	0.449	**< 0.001**	–
BMI (kg/m^2)	Older	47.3 ± 7.2	36.9 ± 5.9	34.3 ± 5.0	− 13.1 ± 4.6	< 0.001
	Control	47.3 ± 7.2	34.8 ± 5.9	32.1 ± 5.4	− 15.2 ± 4.5	< 0.001
	$P_{\text{Between-groups}}$	0.97	**0.04**	**0.01**	**0.005**	–
EWL%	Older	–	49.3 ± 14.2	60.3 ± 15.7	–	< 0.001
	Control	–	59.2 ± 15.9	71.0 ± 17.7	–	< 0.001
	$P_{\text{Between-groups}}$	–	**< 0.001**	**< 0.001**	–	–
TWL%	Older	–	22.1 ± 5.1	27.7 ± 7.2	–	< 0.001
	Control	–	26.3 ± 5.2	32.6 ± 7.0	–	< 0.001
	$P_{\text{Between-groups}}$	–	**< 0.001**	**< 0.001**	–	–
FM (kg)	Older	59.6 ± 10.7	40.0 ± 10.5	34.9 ± 9.1	− 25.6 ± 9.8	< 0.001
	Control	62.5 ± 13.3	38.8 ± 12.1	31.8 ± 10.2	− 28.9 ± 9..9	< 0.001
	$P_{\text{Between-groups}}$	0.17	0.587	0.112	0.101	–
FM%	Older	52.3 ± 4.3	45.3 ± 8.2	42.0 ± 8.2	− 10.6 ± 6.2	< 0.001
	Control	50.6 ± 49.0	42.4 ± 7.8	38.3 ± 7.3	− 11.9 ± 7.5	< 0.001
	$P_{\text{Between-groups}}$	**0.03**	**0.06**	**0.01**	0.36	–
FFM (kg)	Older	53.8 ± 7.2	47.1 ± 6.5	47.2 ± 6.5	− 6.9 ± 3.7	< 0.001
	Control	60.0 ± 9.9	51.3 ± 9.3	49.7 ± 8.4	− 9.5 ± 4.6	< 0.001
	$P_{\text{Between-groups}}$	**< 0.001**	**0.010**	0.11	**0.005**	–
LM (kg)	Older	52.1 ± 7.2	45.8 ± 6.1	45.2 ± 6.0	− 7.0 ± 3.1	< 0.001
	Control	57.2 ± 10.2	47.4 ± 8.0	46.8 ± 8.25	− 9.4 ± 3.9	< 0.001
	$P_{\text{Between-groups}}$	**0.07**	0.39	0.35	**0.04**	–

Bold values indicates statistical significance for *P* values between the two groups

Data are expressed as mean ± SD

BMI body mass index; *EWL%* percentage of excess weight loss; *TWL%* percentage of total weight loss; *FM* fat mass; *FM%* percentage of fat mass; *FFM* fat free mass; *LM* lean mass

better judgment of bariatric surgery outcomes than in many retrospective studies. As our study is an ongoing longitudinal cohort, bariatric surgery was performed by the same surgical team in the same period for both the older and control groups. The number of operations performed for older and younger patients was equally distributed in each year between March 2013 and March 2019; therefore, the surgical team had similar experience and equipment when performing the surgical procedures and managing the complications of both groups. We also matched the subjects and controls for baseline BMI, sex, and type of surgery. To our knowledge, this is the first study comparing post-bariatric surgery changes of body composition status in older and younger adults.

Conclusion

This study demonstrates that bariatric surgery is a safe intervention for the management of obesity in older adults, with risk and complication rates similar to those of younger adults. In the present study, bariatric surgery achieved the desired weight loss and resolution rate of obesity-related co-morbidities 1 year postoperatively in the ≥ 60-year-old patients. Both age groups gained equal reduction in FM and FM%. Despite the concerns about bariatric surgery causing excess LM loss in the elderly, the older-age group in this study had less reduction in LM and FFM than the younger control group, suggesting that obese patients should not be excluded from bariatric surgery based on their age alone.

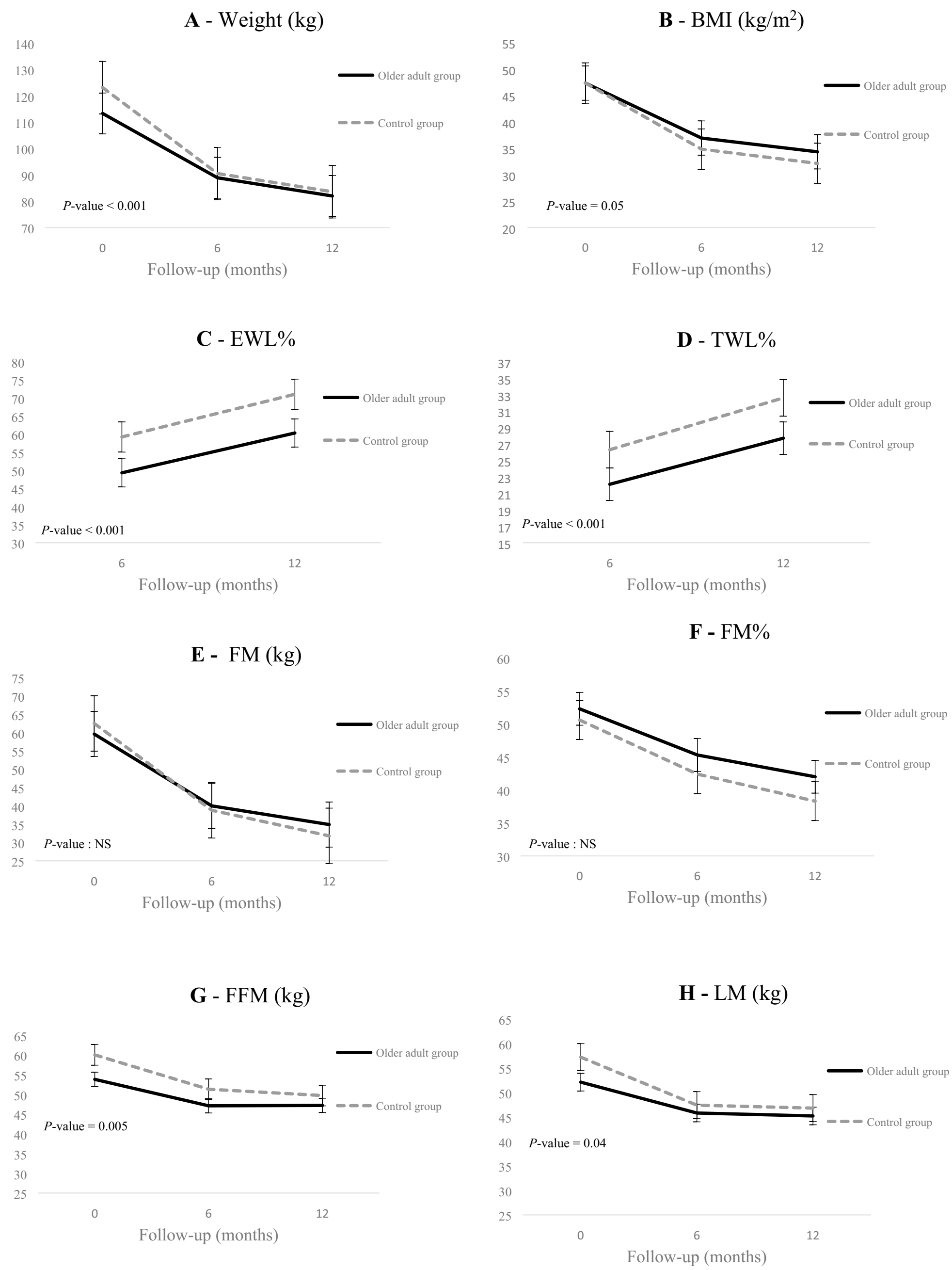

Fig. 2 Body composition status pre- and postoperatively. **a**Weight (kg). **b** BMI (kg/m2). **c** EWL%. **d** TWL%. **e** FM (kg). **f** FM (%). **g** FFM (kg). **h** LM (kg). *BMI* body mass index; *EWL%* percentage of excess weight loss; *TWL%* percentage of total weight loss; *FM* fat mass; *FM%* percentage of fat mass; *FFM* fat-free mass; *LM* lean mass

Further longitudinal studies with larger sample sizes and longer follow-up are needed to confirm our findings.

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Compliance with ethical standards

Conflict of interest We have no conflicts of interest to declare.

Ethical approval This study was approved by the institutional review board (no. IR.SBMU.ENDOCRINE.REC 1397.0592018-05-08). Informed consent was obtained from all the participants in the study. All procedures performed were conducted in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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