



Body Composition Differences Between Excess Weight Loss $\geq 50\%$ and $< 50\%$ at 12 Months Following Bariatric Surgery

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Abstract

Background The relationship between weight loss and body composition is undefined after bariatric surgery. The objective of this study was to compare body composition changes in patients with excess weight loss $\geq 50\%$ (EWL ≥ 50) and $< 50\%$ at 12 months post-operatively (EWL < 50).

Methods A prospective cohort study was completed on patients undergoing bariatric surgery at two tertiary hospitals between 2017 and 2021. Body composition was measured with dual-energy X-ray absorptiometry immediately before surgery, and at 1, 6, and 12 months post-operatively. Body mass index (BMI), fat mass (FM), lean body mass (LBM), and skeletal muscle index (SMI) trajectories were analysed between patients with EWL $\geq 50\%$ and EWL $< 50\%$.

Results Thirty-seven patients were included in this series (EWL $\geq 50\%$ $n=25$, EWL $< 50\%$ $n=12$), comprising of both primary and revisional bariatric surgery cases, undergoing a sleeve gastrectomy (62.2%), Roux-en-Y gastric bypass (32.4%), or one anastomosis gastric bypass (5.4%). The EWL $\geq 50\%$ group demonstrated a more optimal mean FM-to-LBM loss ratio than the EWL $< 50\%$ group. EWL $\geq 50\%$ patients lost 2.0 kg more FM than EWL $< 50\%$ patients for each 1 kg of LBM lost. EWL $\geq 50\%$ was also associated with an increase in mean SMI% over 12 months (5.5 vs. 2.4%; $p < 0.0009$). Across the whole cohort, the first month after surgery accounted for 67.4% of the total LBM reduction that occurred during the 12-month post-operative period.

Conclusion This data suggests EWL $\geq 50\%$ is associated with a more optimal body composition outcome than EWL $< 50\%$. LBM reduction occurs predominantly in the early post-operative period.

Keywords Body composition · Weight loss · Bariatric surgery

Key Points

- The ratio of mean loss of FM-to-LBM was superior in SWL than USWL (5.3 vs 3.3)
- SWL was associated with a significant improvement in SMI and reduction in %FM
- The first month accounted for 67.4% of total LBM loss at 12 months post-operatively

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Introduction

Bariatric surgery is an effective method of achieving both short- and long-term weight loss in patients with severe obesity. It is also linked with improved control and remission

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rate of obesity-related medical problems [1, 2]. Some authors have suggested that the ideal weight loss after bariatric surgery is achieving 50% excess weight loss (EWL) at 12 months post-operatively [3–5]. While a majority of patients demonstrate this response to bariatric surgery, up to 17% fail to reach 50% EWL in the first year of surgery [6].

Previously, some authors have advocated for targeting modest weight loss goals at 12 months, suggesting this may be associated with preferential loss of adipose tissue with preserved lean mass [7, 8]. The evidence for this is largely based on non-surgical weight loss approaches. There is a lack of data regarding the association between weight loss 12 months following bariatric surgery and body composition.

While absolute weight loss values provide an indication of progress, they do not necessarily reflect the relationships between adipose tissue and lean tissue. A deeper understanding of weight loss with body composition imaging would help inform on the actual quality of different weight loss models [9, 10]. This would also determine which weight loss trajectory is associated with a more optimal body composition pattern, which is a favourable loss of fat mass and relative sparing of functional lean mass, causing a reduction in body fat percentage [11]. Considering recent evidence regarding the loss of lean mass after bariatric surgery [12–14], plotting the trajectory of lean mass changes during the post-operative period may support the development of approaches to alleviate this loss.

This longitudinal study was designed to compare the differences in body composition parameters between EWL \geq 50% and EWL $<$ 50% groups [3, 4, 15].

Methods

Patient Population A prospective cohort study was completed on patients who underwent either primary or revisional bariatric surgery between 2017 and 2021 at two tertiary hospitals. All patients fulfilled the standards established by the International Federation for the Surgery of Obesity and Metabolic Disorders for undergoing surgical treatment of obesity [15–17]. The exclusion criteria consisted of pregnancy during the study period, age under 20, a documented history of cognitive impairment that interferes with the ability to understand the study requirements, and weight over 159 kg, as this is the maximum weight limit of the dual-energy X-ray absorptiometry (DXA) scanner. Patients were only included in the analysis if they completed at least both a baseline pre-operative and 12-month body composition assessment.

Ethics This study was approved by the relevant Human Research Ethics Committee in June 2017. All research

procedures were conducted in accordance with the Declaration of Helsinki and guidelines from the National Health and Medical Research Council [18]. Informed written consent was obtained from all individual participants included in the study.

Study Design The type of bariatric procedure was at the discretion of the treating surgeon. Prior to undergoing their bariatric surgery, patients underwent a pre-operative anthropometric and body composition assessment, in the form of a DXA scan. Repeat scans were performed at 1, 6, and 12 months post-operatively. Biochemistry assessments were performed to monitor albumin levels pre-operatively and at 12 months post-operatively. Data collected at baseline includes patient medical conditions, clinical staging of obesity [19], and operative details. Outcomes of interest include EWL at 12 months post-operatively, as well as changes in body mass index (BMI) and body composition parameters during this period. These include fat mass (FM), lean body mass (LBM), bone mineral content (BMC), and body fat percentage (%FM). DXA also aids in calculating the skeletal muscle index (SMI), which has previously been validated for diagnosing sarcopenia in patients with obesity [20, 21], defined as SMI below 37.0% in males and 30.5% in females. Comparisons were made between patients with EWL \geq 50% and EWL $<$ 50%. EWL was calculated as $[(Initial\ EW - Current\ EW)/Initial\ EW] \times 100\%$, where $EW = Actual\ weight - Ideal\ weight$, and $ideal\ weight$ was calculated using Kammerer et al.'s equation [22], which has been found to be the most accurate formula in the bariatric surgical population. A subgroup analysis was performed to assess the trajectory of body composition changes from prior to surgery, through three post-operative timepoints until 12 months post-operatively.

Body Composition Body composition is the quantification of FM, LBM, and BMC, as a proportion of the overall total body mass. This was measured using Lunar Prodigy software version 16 SP1 (GEHealthcare, Madison, WI) DXA scan.

Statistical Analysis Categorical variables are presented as frequency with percentages, and continuous variables as medians with standardised deviations. Baseline data in the two subgroups were assessed for any significant differences using chi-square test for categorical data and Student's *t*-test for continuous data. Changes in anthropometry, body composition, and biochemistry between EWL \geq 50% and EWL $<$ 50% groups were assessed using paired *t*-test. Welch's *t*-test was used to calculate the difference of changes between the two groups at baseline and at 12 months post-operatively. Mixed model for repeated measures was used to compare each group's changes in body composition measurement over time. Adjusted linear prediction with a 95% confidence interval for marginal effects at each timepoint was plotted for each measurement. Statistical significance

was established at $p < 0.05$. All analyses were performed using Stata 17.0 statistical software [23].

Results

A total of 71 patients were enrolled in the study. Thirty-four patients did not undergo a 12-month DXA assessment (Appendix Fig. 1), leaving 37 patients for analysis to compare body composition differences between EWL $\geq 50\%$ ($n = 25$) and EWL $< 50\%$ ($n = 12$). Thirty-three patients completed DXA assessments at 1 and 6 months post-operatively, and were included in the subgroup analysis to assess the trajectory of body composition changes across the four timepoints. There was no significant difference at baseline between patients who were included in the 12-month analysis and those who were not, in terms of demographics, operative characteristics, and body composition (Electronic Supplementary Table 1).

The study population mean age was 44.6 years, predominantly female (78.4%), and 16.2% of patients had type 2 diabetes mellitus. The demographic characteristics from both groups are displayed in Appendix Table 1. The incidence of ischaemic heart disease was the only factor that was significantly different between the EWL $\geq 50\%$ and EWL $< 50\%$ group. Patients underwent one of three laparoscopic bariatric procedures — sleeve gastrectomy (62.2%), Roux-en-Y gastric bypass (32.4%), or one anastomosis gastric bypass (5.4%). There was no statistical difference between the two groups in terms of the number of primary and revisional procedures. The reason for revisional surgeries in this cohort included stomal obstruction due to a slipped gastric band in one patient, and weight regain in the remaining four patients, where the index procedure in all five patients occurred prior to the study period. There was one major complication during the study period, defined as a Clavien-Dindo grade III to V adverse event. This involved a return to theatre in the setting of an anastomotic leak following a one anastomosis gastric bypass in the EWL $\geq 50\%$ group.

There were no statistically significant differences in baseline body composition parameters between the two groups (Appendix Table 2).

At 12 months post-operatively, there was a mean EWL of 58.6% and a mean BMI reduction of 10.7 kg/m², as well as a statistically significant reduction of all body composition parameters across the entire cohort. The changes in body composition parameters over 12 months are presented in Appendix Table 3, and a comparison between EWL $\geq 50\%$ and EWL $< 50\%$ is shown in Appendix Table 4. The ratio of mean loss of FM-to-LBM was superior in EWL $\geq 50\%$ and EWL $< 50\%$ (5.3 vs 3.3); the former group lost 2.0 kg more FM for each 1 kg of LBM reduction. EWL $\geq 50\%$ was associated with an improvement in SMI (5.5% vs 2.4%; $p = 0.0009$) and reduction in %FM (13.5% vs 6.2%; $p = 0.0065$). Despite

the relative preservation of LBM with EWL $\geq 50\%$, there were no differences between groups in terms of serum albumin or protein levels (Appendix Table 5). A subgroup analysis of patients who underwent only primary bariatric surgery was conducted where results were similar overall, as shown in the Electronic Supplementary Tables 2–4. In this analysis, the EWL $\geq 50\%$ group lost an additional 1.9 kg more FM for each 1 kg of LBM loss, which also equated to a more significant rise in SMI (5.65% vs 2.35%; $p = 0.0020$).

Appendix Fig. 2 presents the trajectory of EWL $\geq 50\%$ and EWL $< 50\%$ changes in weight, BMI, FM, LBM, BMC, and SMI over the 12-month post-operative period, based on adjusted linear prediction for factor-variable notation. As demonstrated in this graph, the first month after surgery for EWL $\geq 50\%$ patients accounted for 21.1% of 12-month weight, 16.5% of 12-month FM, and 54.1% of 12-month LBM. The most significant corresponding body composition losses for EWL $< 50\%$ patients also occurred in during this early post-operative phase for weight (44.4%), FM (25.6%), and LBM (90%).

Discussion

There is a paucity of research on the association between body composition changes and weight loss following bariatric surgery. This study found that patients in EWL $\geq 50\%$ group post-bariatric surgery attained a more optimal body composition than those with EWL $< 50\%$. While EWL $\geq 50\%$ was associated with a greater absolute decline in LBM than EWL $< 50\%$, the FM-to-LBM loss ratio was notably higher in the former group, indicating that patients lose weight in variable proportions of fat and lean mass. The positive effect of EWL $\geq 50\%$ is reinforced by the improvement in SMI over the 12-month period.

Two prior studies in this area explored the influence of short-term surgical weight loss on body composition changes, with inconsistent findings [5, 24]. Vázquez-Velázquez et al. retrospectively studied body composition with bioelectrical impedance in 36 patients who underwent a Roux-en-Y gastric bypass, where groups were also classified based on a threshold of 50% EWL at 12 months [5]. While both subgroups had comparable body composition parameters at baseline, EWL $\geq 50\%$ expectedly demonstrated a significantly lower post-surgical FM than EWL $< 50\%$ (26.8–30.1 vs 43.1–46.3 kg). There was also no difference in LBM between either group (52.5–70.8 vs 57.7–70.5 kg), causing a statistically significant reduction in %FM for EWL $\geq 50\%$. A second study was undertaken by Zalesin et al. where 32 post-Roux-en-Y gastric bypass surgery patients were stratified into tertiles of weight loss over a mean follow-up period of 13.9 ± 6.0 months [24]. Patients that experienced the largest post-operative weight loss demonstrated a FM-to-LBM loss ratio of 3:1 compared with a ratio of 4:1 in those that demonstrated the least weight reduction.

Although some lean mass catabolism is expected during weight loss, the present analysis supports the findings of Vázquez-Velázquez et al. in proposing that a significant loss of LBM is not an obligatory consequence of $\text{EWL} \geq 50\%$, and that $\text{EWL} \geq 50\%$ may even be associated with more optimal body composition pattern [5]. In terms of trying to reconcile the contradictory findings of Zalesin et al. [24], this may be due to methodological limitations of their study. Zalesin et al. assessed patients' body composition with variable follow-up periods, suggesting significant heterogeneity when comparing patient data within their own cohort. One critical difference was that baseline body composition assessments were undertaken at an average of 3.2 ± 3.5 months after surgery. This may be after the period where the most significant shifts in LBM occur, and so was not accounted for.

The differences in $\text{EWL} \geq 50\%$ and $\text{EWL} < 50\%$ in the present analysis may be explained by the plateauing of LBM after reaching a particular threshold [25–28]. This concept of biphasic weight loss has been previously reported [29, 30], whereby the acute weight loss period involves both FM and LBM reduction to a certain capacity in the initial months after surgery, followed by sustained reduction in FM alone during the subsequent prolonged weight loss period, which is more pronounced with $\text{EWL} \geq 50\%$. This is supported by the weight loss trajectory charts from our analysis in which a progressive reduction in FM was observed whereas LBM did not decrease further in the late post-operative period. These findings collectively suggest that $\text{EWL} \geq 50\%$ may promote more favourable changes in body composition as excess weight loss occurs largely at the expense of FM.

The present study helps inform surgeons, bariatric practitioners, and dieticians of the expected body composition patterns based upon post-operative weight loss [31, 32]. With recent commentary of the influence of bariatric surgery on sarcopenia [14, 33, 34], this should reinforce the health benefits of patients whose weight trajectory falls in the $\text{EWL} \geq 50\%$ group, as the additional weight loss occurs predominantly at the expense of fat mass alone and does not appear to compromise lean mass. In addition to demonstrating an improved FM-to-LBM loss ratio, the relatively larger weight loss observed in these patients is associated with a decline in markers of oxidative stress, which has been shown to reduce insulin resistance, total cholesterol, triglyceride, and HbA1c levels [35–37].

The findings of this study may also guide future approaches to achieve a healthier body composition following bariatric surgery. Given it is a major determinant of resting metabolic rate, preserving LBM is expected to result in a greater and more durable weight loss, and enhanced health-related quality of life [38–42]. The trajectory of body composition parameters in the present study highlights that LBM depletion occurs predominantly in the first 6 months of weight loss, and most noticeably in the initial month. It seems plausible then that strategies to mitigate this loss should subsequently be implemented during this early post-operative period. There is evidence to suggest that exercise interventions, particularly resistance training, are associated with attenuation of lean mass loss in the first year after

bariatric surgery [43, 44]. International clinical practice guidelines recommend a minimum of 60–80 g of protein per day [45–49], and while Moize et al. demonstrated its favourable role in preservation of LBM post-operatively [25], this is still controversial as few patients experience protein malnutrition after surgery [50]. This analysis demonstrated no significant losses in serum protein during the study period, indicating that a sufficient amount of substrate was available for visceral protein synthesis and lean mass preservation.

This is the first study to compare the differences between $\text{EWL} \geq 50\%$ and $\text{EWL} < 50\%$ using a DXA scan. DXA is considered a reference technique for the evaluation of tissue mass in cohorts with obesity and evaluates the properties of underlying soft tissue through measuring the attenuation of X-rays with high and low photon energies [51]. It is more accurate than conventional body composition analysis methods for quantifying FM and LBM [52], allowing a reproducible estimation of body composition parameters [53]. The principal strength of this study is that it is a prospective longitudinal design with repeated measurements at dedicated time intervals to assess weight loss and body composition. A key limitation of this study was that physical activity levels and dietary intake were not controlled or measured. Post-operative exercise may have affected lean mass preservation in our cohort as a potential confounder, although its precise relationship with body composition is still under investigation [54–56]. Another limitation to note is the incomplete data for the measurement of serum albumin and repeated body composition assessments, as well as the challenges in enrolling participants and retaining them in the study up to the 12-month mark, which is reflection of the unprecedented impact of the COVID-19 pandemic whereby patient travel and healthcare resource allocation was restricted by local government protocols [57]. While this impact has led to a study retention rate of just over 50%, it is reassuring that there were no significant differences in terms of demographic factors or baseline body composition parameters between patients that were included and those that were excluded from the analysis.

Another potential confounder to consider is that both $\text{EWL} \geq 50\%$ and $\text{EWL} < 50\%$ groups were not evenly matched in terms of procedure type; however, this is unlikely to have a significant impact on the present analysis given that gastric bypass and sleeve gastrectomy have previously demonstrated similar body composition changes 12 months post-operatively [26].

Conclusion

$\text{EWL} \geq 50\%$ is associated with more optimal changes in body composition with a higher ratio of FM-to-LBM loss than $\text{EWL} < 50\%$, suggesting relative LBM preservation. Lean mass was also most impacted during the acute weight loss period. This study provides an insight into post-operative body composition trajectories, which may in turn aid the research and development of interventions to mitigate LBM loss, after bariatric surgery.

Appendix

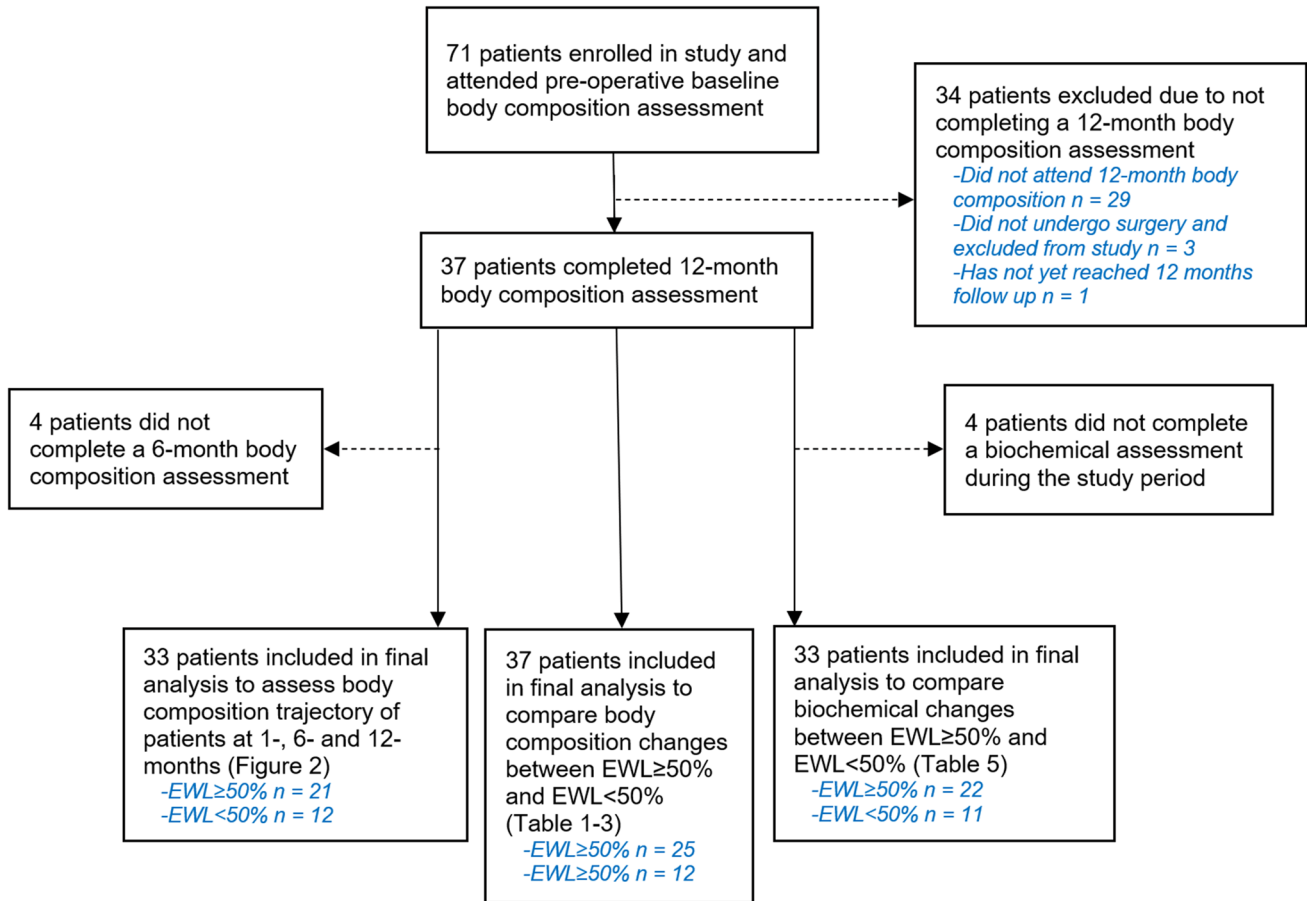


Fig. 1 Process of patient selection for analysis

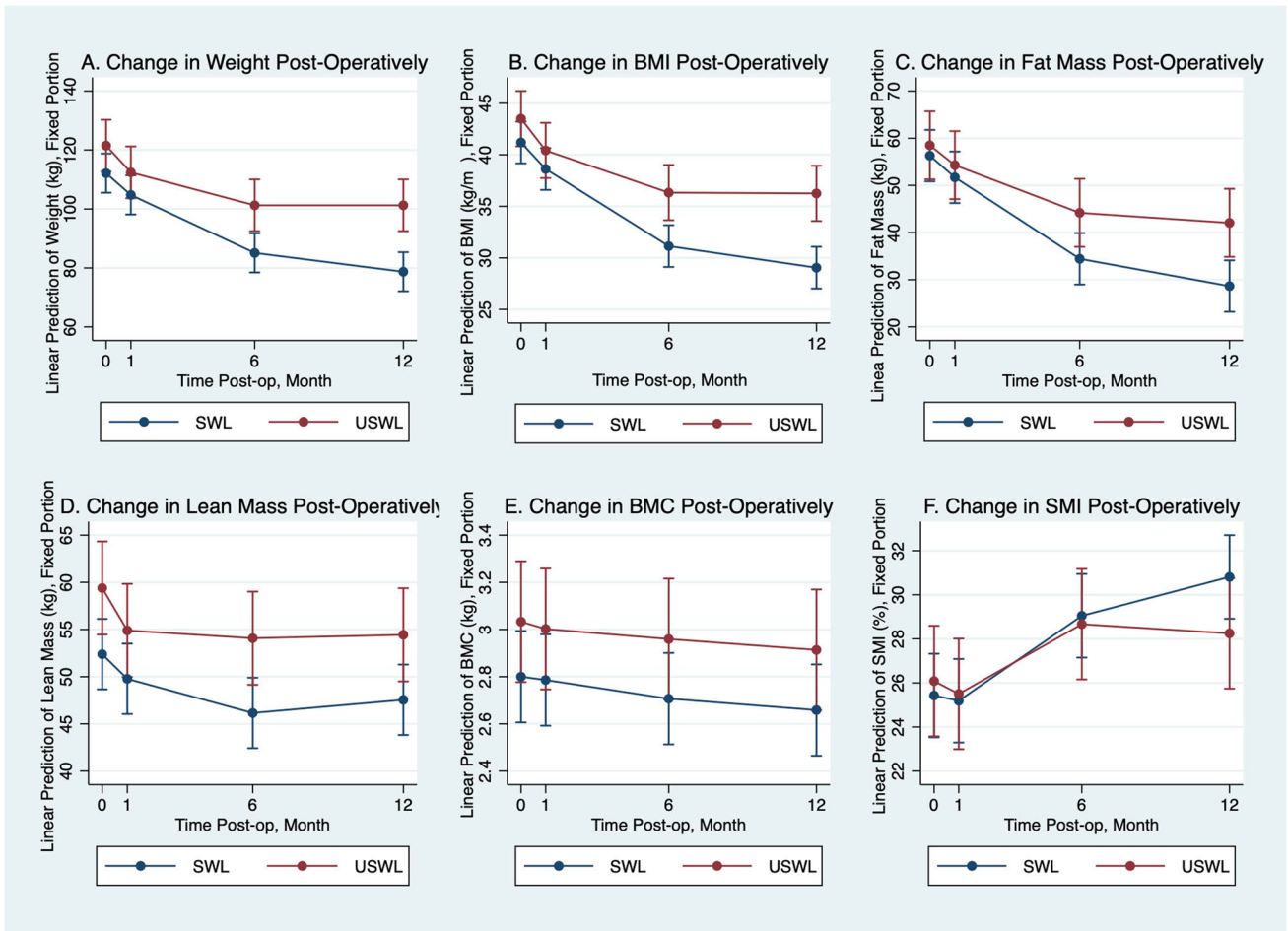


Fig. 2 Linear prediction of changes in key anthropometry and body composition measurements at regular timepoints over 12 months post-operatively. EWL $\geq 50\%$, excess weight loss $\geq 50\%$ at 12 months

post-operatively; EWL $< 50\%$, excess weight loss $< 50\%$ at 12 months post-operatively; BMI, body mass index; BMC, bone mineral content; SMI, skeletal muscle index

Table 1 Baseline demographic and operative characteristics, by EWL \geq 50% and EWL < 50% groups

	EWL \geq 50% (n = 25)	EWL < 50% (n = 12)	p-value
Demographics			
Age, Mean (SD)	43.2 (10.9)	47.43(1.2)	0.194
Gender, n (%)			0.2305
Female	21 (84)	8 (66.7)	
Male	4 (16)	4 (33.3)	
Clinical staging of obesity, n (%)			
1	1	0	0.635
2	9	3	
3	11	8	
4	2	0	
Unknown	2	1	
Congestive heart failure, n (%)	1 (4.0)	0	0.4824
Diabetes without end-organ failure, n (%)	4 (16.0)	1 (8.3)	0.5231
Diabetes with end-organ failure, n (%)	0	1 (8.3)	0.1434
Hyperlipidaemia, n (%)	5 (20.0)	2 (16.7)	0.8990
Hypertension, n (%)	9 (36.0)	3 (25.0)	0.5034
Obstructive sleep apnoea, n (%)	3 (12.0)	4 (33.3)	0.1209
Ischaemic heart disease, n (%)	0 (0)	2 (16.7)	0.0282
Operative			
Operation type, n (%)			
Sleeve gastrectomy	16 (64.0)	7 (58.4)	
Roux-en-Y gastric bypass	8 (32.0)	4 (33.3)	0.8487
One anastomosis gastric bypass	1 (4.0)	1 (8.3)	
Primary vs revisional, n (%)			
Primary	22 (88.0)	10 (83.3)	1.000
Revisional	3 (12.0)	2 (16.7)	

EWL \geq 50%, excess weight loss \geq 50% at 12 months post-operatively; EWL < 50%, excess weight loss < 50% at 12 months post-operatively; SD, standard deviation

Table 2 Baseline body composition parameters of EWL \geq 50% and EWL < 50% groups

	EWL \geq 50% (n = 25)	EWL < 50% (n = 12)	p-value
Anthropometrics			
BMI (kg/m ²), mean (SD)	41.4 (5.2)	43.4 (5.6)	0.2925
Excess weight (kg), mean (SD)	51.5 (15.9)	56.7 (16.5)	0.3638
Body composition			
Total mass (kg), mean (SD)	113.3 (18.5)	120.9 (16.0)	0.2875
Tissue mass (kg), mean (SD)	110.5 (18.2)	117.9 (15.9)	0.2369
Fat mass (kg), mean (SD)	57.5 (13.5)	58.5 (14.2)	0.8368
Lean mass (kg), mean (SD)	53.1 (9.0)	59.4 (10.9)	0.0711
Fat free mass (kg), mean (SD)	55.9 (9.4)	62.4 (11.1)	0.0717
Bone mineral content (kg), mean (SD)	2.82 (0.48)	3.03 (0.3)	0.1747
ALST (kg), mean (SD)	25.3 (4.8)	27.6 (5.6)	0.2045
Total skeletal mass (kg), mean (SD)	28.8 (5.6)	31.4 (6.6)	0.2203
Skeletal muscle index (%), mean (SD)	25.3 (3.6)	26.0 (4.9)	0.6260
SMI-based sarcopenia, n (%)	24 (96)	12 (100)	-

EWL \geq 50%, excess weight loss \geq 50% at 12 months post-operatively; EWL < 50%, excess weight loss < 50% at 12 months post-operatively; SD, standard deviation; BMI, body mass index; ALST, appendicular lean soft tissue

Table 3 Changes in each body composition measurement from baseline to 12 months post-operatively in EWL ≥ 50% and EWL < 50% groups

	EWL ≥ 50% (n = 25)				EWL < 50% (n = 12)			
	Pre-operative	12 months post-operative	Change	p-value	Pre-operative	12 months post-operative	Change	p-value
<i>Anthropometrics</i>								
BMI (kg/m ²), mean (SD)	41.4 (5.2)	29.1 (4.3)	-12.3 [-13.5, -11.2]	<0.001	43.4 (5.6)	36.2 (4.3)	-7.2 [-8.8, -5.7]	<0.0001
Excess weight (kg), mean (SD)	51.5 (15.9)	18.6 (14.0)	-32.9 [-36.9, -28.8]	<0.001	56.7 (16.5)	36.5 (12.5)	-20.3 [-24.4, -16.1]	<0.0001
EWL percentage (%), mean (SD)	-	69.5 (20.2)	-	-	-	35.9 (8.2)	-	-
<i>Body composition</i>								
Total mass (kg), mean (SD)	113.3 (18.5)	79.6 (13.9)	-33.8	<0.001	120.9 (16.0)	99.4 (14.3)	-21.5	<0.0001
Tissue mass (kg), mean (SD)	110.5 (18.2)	77.2 (13.9)	-33.3	<0.001	117.9 (15.9)	96.5 (14.1)	-21.4	<0.0001
Fat mass (kg), mean (SD)	57.5 (13.5)	29.5 (10.9)	-27.9	<0.001	58.5 (14.2)	42.1 (11.6)	-16.4	<0.0001
Lean mass (kg), mean (SD)	53.1 (9.0)	47.7 (7.6)	-5.3	<0.001	59.4 (10.9)	54.4 (9.6)	-5.0	0.0003
Fat free mass (kg), mean (SD)	55.9 (9.4)	50.4 (8.0)	-5.4	<0.001	62.4 (11.1)	57.4 (9.8)	-5.1	0.0002
Bone mineral content (kg), mean (SD)	2.8 (0.5)	2.7 (0.5)	-0.1	<0.001	3.0 (0.3)	2.9 (0.4)	-0.1	<0.001
ALST (kg), mean (SD)	25.3 (4.8)	21.4 (3.7)	-3.9	<0.001	27.6 (5.6)	25.2 (5.5)	-2.4	0.0009
Total skeletal mass (kg), mean (SD)	28.8 (5.6)	24.4 (4.3)	-4.4	<0.001	31.4 (6.6)	28.6 (6.5)	-2.9	0.0008
Skeletal muscle index (%), mean (SD)	25.3 (3.6)	30.8 (4.3)	5.5	<0.001	26.0 (4.9)	28.4 (4.9)	2.4	0.0003
Tissue fat percentage (%), mean (SD)	51.7 (5.8)	38.1 (9.1)	-13.6	<0.0001	49.3 (8.5)	43.3 (7.9)	-6.1	0.0004

EWL ≥ 50%, excess weight loss ≥ 50% at 12 months post-operatively; EWL < 50%, excess weight loss < 50% at 12 months post-operatively; SD, standard deviation; BMI, body mass index; EWL, excess weight loss; ALST, appendicular lean soft tissue

Table 4 Comparison of changes in each body composition measurements from baseline to 12 months post-operatively, by EWL ≥ 50% and EWL < 50% groups

	EWL ≥ 50% change over 12 months (n = 25)	EWL < 50% change over 12 months (n = 12)	Difference	p-value
<i>Anthropometrics</i>				
BMI (kg/m ²), mean (SD)	-12.3 (2.8)	-7.2 (2.4)	5.1 [3.19, 7.01]	<0.0001
Excess weight change (kg), mean (SD)	-32.8 (9.8)	-20.3 (6.48)	12.5 [6.20, 18.88]	0.0003
<i>Body composition</i>				
Total mass (kg), mean (SD)	-33.6 (10.6)	-21.7 (10.5)	11.9 [5.63, 18.17]	0.0005
Tissue mass (kg), mean (SD)	-33.3 (9.3)	-21.4 (10.0)	11.9 [5.11, 18.7]	0.0011
Fat mass (kg), mean (SD)	-27.9 (8.5)	-16.4 (8.5)	11.5 [5.44, 7.56]	0.0005
Lean mass (kg), mean (SD)	-5.3 (3.0)	-4.9 (3.3)	0.4 [-1.81, 2.61]	0.7153
Fat free mass (kg), mean (SD)	-5.4 (3.0)	-5.0 (3.3)	0.4 [-1.81, 2.61]	0.7153
Bone mineral content (kg), mean (SD)	-0.1 (0.09)	-0.1 (0.1)	0.0 [-0.04, 0.075]	0.5576
ALST (kg), mean (SD)	-3.8 (2.0)	-2.4 (1.8)	1.4 [0.02, 2.78]	0.0473
Total skeletal mass (kg), mean (SD)	-4.4 (2.3)	-2.7 (2.0)	1.7 [0.13, 3.29]	0.0343
Skeletal muscle index, mean (SD)	5.5 (2.7)	2.4 (1.64)	3.1 [1.36, 4.80]	0.0009
Tissue fat percentage (%), Mean (SD)	-13.6 (1.6)	-6.1 (1.2)	7.5 [6.44, 8.56]	<0.0001

EWL ≥ 50%, excess weight loss ≥ 50% at 12 months post-operatively; EWL < 50%, excess weight loss < 50% at 12 months post-operatively; SD, standard deviation; BMI, body mass index; ALST, appendicular lean soft tissue

Table 5 Comparison of changes in albumin and protein from baseline to 12 months post-operatively in EWL $\geq 50\%$ and EWL $< 50\%$ groups

Biochemistry	EWL $\geq 50\%$ (n = 22)			EWL $< 50\%$ (n = 11)			Difference	p-value		
	Baseline	12-month	Change	p-value	Baseline	12-month			Change	
Albumin (g/L), mean (SD)	38.0 (2.9)	38.8 (2.4)	0.8 (3.2)	0.2419	37.0 (2.6)	37.9 (2.1)	0.9 (2.5)	0.2498	-0.1 [-2.16, 1.98]	0.9295
Protein (g/L), mean (SD)	70.4 (4.1)	68.6 (4.2)	-1.8 (3.9)	0.0402	69.1 (2.6)	68.2 (3.3)	-0.9 (4.0)	0.4723	-0.9 [-3.99, 2.17]	0.5444

EWL $\geq 50\%$, excess weight loss $\geq 50\%$ at 12 months post-operatively; EWL $< 50\%$, excess weight loss $< 50\%$ at 12 months post-operatively; SD, standard deviation

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11695-022-06128-3>.

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest The authors declare no competing interests.

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