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## **Acute and longer-term body composition changes after bariatric surgery**

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# ABSTRACT

## BACKGROUND:

Bariatric surgery induces weight loss but its acute and longer-term effects on body composition (BC) are largely unknown.

## 5 OBJECTIVES:

To determine the BC changes in obese French patients after sleeve gastrectomy (SG) at 1 and 12 months.

## METHODS:

10 Whole and localized BC (lean tissue mass: LTM and fat mass: FM) and abdominal adiposity including total adipose tissue (TAT), visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) were determined by dual-energy x-ray absorptiometry in 30 obese patients (25 women, 83.3%) just before SG and 1 and 12 months later.

## SETTING:

Obesity Reference Center, University Hospital of Montpellier, France.

## 15 RESULTS:

The mean weight loss was  $-9.7 \pm 2.6$  kg at 1 month and  $-32.1 \pm 10.3$  kg at 12 months. This body weight loss was due to an equivalent decrease in LTM and FM in the acute phase, while FM loss appeared to be the main cause in the chronic phase. For each component (LTM and FM), the loss was relatively homogeneous across sites. Compared with the presurgical values, android and gynoid tissue and TAT, VAT and SAT changed significantly over the 12-month period. No basal clinical parameter was predictive of the variation in LTM, whereas age and the whole-body LTM/FM ratio were associated with the decrease in FM.

## CONCLUSION:

25 This study demonstrates that SG induces a clear modification in BC, characterized by a decrease in LTM in the acute phase and sustained FM loss in the first year. These results suggest that the early phase should be targeted for strategies to reduce LTM loss, which is a longer-term weight-regain criterion. Further studies to investigate the potential advantages of VAT compared to whole-body FM for improving post-SG comorbidities should be performed.

## 30 KEY WORDS:

Sleeve gastrectomy, bariatric surgery, body composition, fat mass, lean tissue mass, gynoid, android and visceral adipose tissue

**RUNNING TITLE:** Body composition change after sleeve gastrectomy

## Introduction

Bariatric surgery (BS) is an option for weight loss in obese patients when other treatments have failed and when the body mass index (BMI) is greater than 40 kg/m<sup>2</sup> (severe obesity) or greater than 35 kg/m<sup>2</sup> with obesity-related comorbidities <sup>(1)</sup>. BS is generally considered successful when weight loss follows. However, the change in weight and the subsequent change in the body mass index (BMI) <sup>(2)</sup> do not reflect the changes in fat mass (FM) and lean tissue mass (LTM), the two compartments of body composition. Yet accurate evaluations of these two compartments following BS may offer advantages because they do not have the same physiological effects. For example, a drop in LTM, the main metabolically active component <sup>(3, 4)</sup>, may reduce resting energy expenditure (REE) <sup>(5)</sup> and thus influence the rate of body weight loss after BS. Moreover, although the FM loss is generally quantified, it would be more pertinent to determine obesity distribution because android rather than gynoid distribution of FM is more often associated with metabolic syndrome, T2D and cardiovascular disease <sup>(6-8)</sup>. More specifically, in abdominal fat, the visceral adipose tissue (VAT) surrounding the internal organs is more associated than subcutaneous adipose tissue (SAT) with higher cardiometabolic risk and insulin resistance <sup>(6, 8)</sup>. Magnetic resonance imaging (MRI) and abdominal X-ray computed tomography (CT) are currently the gold standards for the quantitative assessment of VAT <sup>(9)</sup>, but given their limitations (time-consuming manual analysis, difficulty in accessing or using the clinical equipment, radiation doses), other techniques based on dual-energy X-ray absorptiometry (DXA) with automated analysis have been developed <sup>(10-12)</sup>.

Moreover, the agreement between VAT measurements with DXA and CT is strong across genders and a wide range of BMIs <sup>(10)</sup>. Also, compared with waist circumference, commonly used as a surrogate marker for abdominal obesity, the VAT measured by DXA

appeared to be better correlated with CT values <sup>(10)</sup>. A recent study evaluating the effects of a 12-month non-surgical weight loss program for obese women demonstrated a greater reduction in VAT than in body weight: 12% as opposed to 4.5% <sup>(13)</sup>. The routine and automated evaluation of VAT may provide a better understanding of the effects of BS on  
5 body composition changes and the improvement of the adverse effects of obesity, but few data are currently available <sup>(14-17)</sup> and only a limited number of studies have evaluated VAT with DXA, principally after Roux-en-Y gastric bypass surgery (RYGB) <sup>(15-17)</sup>.

The aim of this longitudinal study was thus to determine the body composition changes in the acute (1 month) and relatively stable (12 months) phases of weight loss  
10 following SG. We also sought to determine the changes in other parameters, such as gynoid and android tissues and VAT, in the same period.

## **Subjects and method**

Study approval was obtained from the Regional Research Ethics Committee and permission for the clinical trials was granted by the French Health Products Safety Agency. Written informed consent was obtained from all participants. The clinical trial number is  
5 NCT02310178.

### ***Subjects***

From October 2014 to June 2015, 30 patients (25 women, 83.3%) from  
10 18.0 to 68.2 years old and drawn from an initial group of 41 patients  
previously described <sup>(18)</sup>, were recruited from a waiting list of candidates  
for obesity surgery at the Obesity Reference Center. Patients were selected  
for surgery if other treatments for weight loss had failed and if BMI was greater than 40  
kg/m<sup>2</sup> (severe obesity) or greater than or equal to 35 kg/m<sup>2</sup> with the presence of obesity-  
15 related comorbidities such as T2D, arterial hypertension or sleep apnea syndrome. All SGs  
were performed in a single institution. This bariatric procedure consists of  
resecting most of the greater curvature, which reduces gastric size and  
leaves a narrow stomach tube.

### ***Methods***

20 All patients were evaluated the day before the operation (baseline) and 1 month and 12  
months after the procedure. During the follow-up period, patients were not encouraged to  
modify their physical activity and no protein supplementation was proposed. However, the  
same nutritionist gave the same nutritional recommendations to each patient just after SG,  
with a focus on the importance of adequate protein intake and an overall reduction in fat  
25 intake in order to lose weight while avoiding side effects like muscle mass loss or steatorrhea.

For each visit, standing height was measured with a stadiometer to the nearest 0.1 cm. Weight was determined using a weight scale with a precision of 0.1 kg. BMI was calculated as weight (kg) divided by the square of height (m). The ideal body weight (IBW in kg) was obtained from the Lorentz equations:  $(\text{height [cm]} - 100) - ((\text{height [cm]} - 150)/4)$  for men and  $(\text{height [cm]} - 100) - ((\text{height [cm]} - 150)/2.5)$  for women. The percentage of total weight loss (%TWL), excess body weight (EBW: body weight - IBW), percentage of excess body weight loss (%EWL:  $100 \times [\text{preoperative body weight} - \text{current body weight}]/[\text{preoperative body weight} - \text{ideal body weight}]$ ), and excess BMI (EBMI: current BMI - 25) were also calculated.

The skeletal muscle index (SMI; kg/m<sup>2</sup>) was defined as appendicular skeletal muscle mass (sum of the LTM for the arms and legs/height<sup>2</sup>) (19). As SMI thresholds for the definition of sarcopenia vary according to ethnic group, we chose to use the thresholds from Baumgartner (SMI < 7.26 kg/m<sup>2</sup> for men and < 5.45 kg/m<sup>2</sup> in women (20)) and Bouchard (SMI < 8.51 kg/m<sup>2</sup> in men and 6.29 kg/m<sup>2</sup> in women (21)), which were obtained from Caucasian subjects and well adapted for our obese French patients.

#### 15 *Body fat and fat-free soft tissue evaluation*

The soft tissue body composition (fat mass [FM, kg], percentage of body fat mass [%FM] and LTM [LTM, kg]) were measured using DXA (Hologic QDR-4500A, Hologic, Inc., Waltham, MA). To determine the relative variation in LTM to FM, LTM/FM was calculated. Data at each site (upper limbs, trunk, and lower limbs) were derived from the whole-body scan. The mean values were calculated for the upper and lower limbs. All scanning and analyses were performed by the same operator to ensure consistency, after following standard quality control procedures. Quality control for DXA was checked daily by scanning a lumbar spine phantom consisting of calcium hydroxyapatite embedded in a cube of thermoplastic resin (DPA/QDR-1; Hologic x-caliber anthropometrical spine phantom). The

CVs given by the manufacturer were <1% for LTM and FM. TAT, VAT and SAT were measured according to the method described by Katzmarzyk et al. <sup>(22)</sup>.

5            *Scan procedure*

Participants assumed a stationary supine position and were centered on the scanner table with the head, neck and torso positioned parallel to the long axis of the scan bed and the shoulder and pelvis positioned perpendicular to it. Their arms were out to the side, with the legs internally rotated to 45° and fixed together with strapping tape to minimize incidental movement, with the feet pointed downward. We scrupulously followed the manufacturer's standard scan and positioning protocols. The full-body images were separated into axial (trunk) and appendicular regions (upper and lower limbs) using the predefined and mandatory whole-body model, as required by the software. Identical and accurate positioning of the region of interest was ensured by superimposing the image from the first session (before SG) on the image from the second and third sessions (1 month and 1 year after SG).

20



## Statistical Analysis

Quantitative variables were described with means and standard deviations (SD). The normality of the continuous variables was tested with Shapiro-Wilk's test.

Mann-Whitney or Student's tests were used, according to the normality of the distribution, to compare the percent change from baseline [ $100 * (\text{measure 2} - \text{measure 1}) / \text{measure 1}$ ] between sites for each component (LTM or FM) at 1 month and 12 months following BS. When the global difference between sites was significant, Bonferroni's correction was applied to compare the sites 2x2.

Relationships between the percent change from baseline in body composition parameters at 12 months and the basal parameters (age, weight, BMI, whole-body LTM and FM and LTM/FM ratio) were assessed using Spearman or Pearson correlation coefficients, depending on the normality of the distributions.

All analyses were two-tailed, with a p-value of  $<0.05$  considered statistically significant. Analyses were performed using SAS® Enterprise Guide, Version 4.3 (SAS Institute, Cary, NC, USA) and graphs were generated with R statistical software ([www.r-project.org](http://www.r-project.org), version 3.5.2).

## Results

### Anthropometric parameters

This study included 30 obese patients with a mean age of  $40.9 \pm 15.1$  years and a mean baseline BMI of  $41.9 \pm 4.5$  kg/m<sup>2</sup> (**Table 1**). The mean weight loss was  $9.7 \pm 2.6$  kg after 1 month and  $-32.1 \pm 10.3$  kg after 12 months, corresponding to an EBW of  $44.2 \pm 11.6$  kg and  $21.6 \pm 12.0$  kg, respectively.

The body composition preoperatively and the changes at 1 and 12 months after SG are presented in **Table 2**. At 1 month, no significant percent change from baseline in LTM/FM or %FM was observed except at the lower limbs, whereas LTM and FM decreased significantly ( $p < 0.001$ ) at all anatomical sites. At 1 month, the percent change from baseline at the different sites ranged between  $-6.3\%$  ( $\pm 5.1\%$ ) and  $-8.6\%$  ( $\pm 6.0\%$ ) for FM (kg) and between  $-9.5\%$  ( $\pm 5.4\%$ ) and  $-10.4\%$  ( $\pm 4.2\%$ ) for LTM (kg). At 12 months, all the parameters related to FM and LTM decreased significantly, but the percent change from baseline in FM exceeded that of LTM, which was confirmed by the increase in LTM/FM. At 12 months, the percent change from baseline in the different sites ranged between  $-38.2\%$  ( $\pm 19.2\%$ ) and  $-48.2\%$  ( $\pm 14.4\%$ ) for FM (kg) and between  $-16.5\%$  ( $\pm 7.7\%$ ) and  $-19.2\%$  ( $\pm 4.9\%$ ) for LTM.

The comparison of percent change from baseline between sites is presented in Figure 1. At both 1 and 12 months, the LTM percent change from baseline was homogeneous across sites. Conversely, at 12 months, a higher % relative decrease ( $p < 0.05$ ) was observed for FM (kg) at the trunk compared with the upper and lower limbs and for FM (%) at the trunk compared with the lower

limbs. The increase in LTM/FM was accentuated at the trunk at 12 months compared with the upper and lower limbs.

5

### ***Prevalence of sarcopenia***

The reduction in LTM in the upper and lower limbs resulted in a significant reduction in SMI, but the percent change from baseline between presurgery and 1 month and between 1 month and 12 months was comparable, around 10%. Only one female patient presented sarcopenia as defined by Bouchard's thresholds (21), whereas no males were sarcopenic. At 1 year, the SMI values ranged from 5.93 to 10.06 kg/m<sup>2</sup> for women and 8.73-9.83 kg/m<sup>2</sup> for men.

### **Android, gynoid and abdominal variations in lean tissue mass and fat mass at 1 and 12 months after sleeve gastrectomy**

Compared with presurgical values, all parameters (total mass, LTM and FM) relative to android or gynoid localizations significantly decreased at 1 and 12 months and were accentuated with the time from surgery. The abdominal lipid depots changed significantly over this period, with a progressive FM loss ( $p < 0.001$ ) from TAT (-6.7% at 1 month, -41.2% at 12 months), VAT (-5.4% at 1 month, -44.6 at 12 months) and SAT (-6.6% at 1 month, -39.7% at 12 months). The percent change from baseline was greater for VAT than for SAT ( $p < 0.05$ ).

### **Relationship between preoperative parameters and variations at 12 months**

The correlation analysis between the percent change from baseline at the different anatomical sites and the basic preoperative parameters revealed only a few relationships with FM and

LTM/FM, but none for LTM (**Table 4**). Briefly, age was positively correlated with the percent change from baseline in FM and negatively with the percent change from baseline in LTM/FM at trunk, lower limbs and whole-body FM. BMI and whole-body FM were positively correlated with abdominal adiposity parameters, SAT excepted. Last, whole-body LTM/FM was negatively correlated with the percent change from baseline in FM at each site (upper limbs excepted) and the percent change from baseline in all abdominal adiposity parameters, and it was positively correlated with the percent change from baseline in LTM/FM at each site.

## 10 Discussion

The major finding of this study was the dramatic modification in body composition, characterized by reductions in LTM and FM, in addition to the weight loss following SG. Nevertheless, both components showed specific kinetics of variation, with a more intense loss of LTM during the acute phase, whereas FM presented a more gradual and sustained loss. Moreover, other parameters were also modified, including VAT, which is strongly associated with metabolic disease and cardiovascular risk in obese patients but has been little evaluated after BS.

Our results confirmed that SG induces an acute and long-term decrease in weight loss. After 1 year, the percent change from baseline in excess body weight and weight were -60% and -28.4%, respectively, showing that the surgery could be classified as satisfactory as ponderal loss was higher than 25% <sup>(23)</sup>. Our results confirmed the magnitude of weight loss observed by other studies 12 months after SG <sup>(24-26)</sup>. We recently demonstrated that the evaluation of body weight or BMI variation alone does not reflect the dramatic modification in body composition following SG <sup>(18)</sup> and suggested that DXA analysis should be performed before and after surgery to precisely quantify the whole-body and the localized loss of LTM

and FM <sup>(24)</sup>. In the present study, we confirmed an acute reduction in LTM (range -9.5% to -10.4%) and FM (range -6.3% to -8.6%) after 1 month. Although the magnitude of variation was relatively comparable between FM and LTM in the acute phase, the loss measured after 12 months was more marked for FM. It is difficult to compare our results with those of earlier studies because, despite the extensive reports <sup>(15, 25, 27, 28)</sup> on body composition changes after BS, bias may be introduced by the surgical technique <sup>(15, 24, 29, 30)</sup>, the duration of investigation, and the method of body composition evaluation (bioelectrical impedance analysis: BIA vs. DXA) <sup>(31)</sup>. In this context, Frisard et al. <sup>(31)</sup> reported poor agreement between BIA, the principal technique generally used in the clinical follow-up of postsurgical body composition change, and the more advanced and precise techniques like DXA as used in our study. Nevertheless, various studies using BIA have reported similar profiles of variation for the two components, characterized by a maximum decrease in body cell mass, cell proportion and LTM in the first 6 weeks to 3 months, respectively, after SG, with a slow-down until 12 months <sup>(25, 27, 32)</sup>. Calleja-Fernandez et al. <sup>(28)</sup> reported that weight loss 12 months after biliopancreatic diversion was mainly at the expense of FM. Moize et al. <sup>(24)</sup> reported that % whole-body LTM loss was greater at 4 months than at 12 months after SG, as determined with DXA <sup>(24)</sup>. Our longitudinal evaluation provides new relevant information by reporting the localized variations in body composition and suggests that the two components (i.e., FM and LTM) present distinct kinetics, with an acute loss of LTM and a sustained loss of FM for at least the first 12 months. The continued increase in LTM/FM highlights this body composition change with postsurgical duration.

The reduction in LTM that was mainly observed in the lower limbs led to a reduction in SMI. This result might be particularly disturbing because it could lead to more advanced stages of sarcopenia. However, when the sarcopenia prevalence was calculated, only one woman met the criteria of Bouchard et al. <sup>(21)</sup> after 1 year ( $5.94 \text{ kg/m}^2 < 6.29 \text{ kg/m}^2$ ). We note

that this patient also presented the lowest presurgical SMI value (7.70 kg/m<sup>2</sup>). This result suggests two relevant points for consideration: (1) patients with low initial LTM, most likely elderly obese patients, are particularly at risk of developing postsurgical sarcopenia and (2) DXA, which is the only technique that measures localized LTM, may help to better discriminate patients at risk and should thus be performed at the initial medical check-up of candidates for BS. The discovery of low LTM might prompt presurgical medical care or nutritional supplementation that it will be necessary to define. A very recent study using BIA suggested that the initial LTM value may indicate LTM loss at one year <sup>(33)</sup>. In our study, however, we did not identify any basic clinical parameters that would influence the LTM variation. Conversely, the percent change from baseline in FM appeared positively correlated with age and negatively correlated with the whole-body LTM/FM ratio. The percent change from baseline in FM was also positively correlated with the percent change from baseline in LTM/FM but negatively correlated with abdominal adiposity, suggesting that it is, for the time being, the best predictive parameter for FM and LTM/FM variation at 12 months. Moreover, it would be interesting to determine whether the reduction in LTM is associated with the reduction in functional parameters, such as muscle strength, that are also included in the definition of sarcopenia <sup>(34)</sup>. Although our follow-up was limited to 12 months, it was unlikely that the prevalence of sarcopenia would not be accentuated with the postsurgical duration because the greatest losses in weight and LTM occur in the first year after surgery <sup>(26, 35)</sup>. In our study, it is interesting to note that the magnitude of LTM loss in the first month was equivalent to the magnitude of loss over the next 11 months, which indicates that the acute period is crucial for interventions to minimize LTM loss. This early dramatic modification in body composition is usually attributed to an unbalanced diet and nutritional deficiencies, especially protein malnutrition (36). The potentially favorable role of protein was identified by Moize et al. {Moize, 2013 #1009}, who demonstrated that patients

with a protein intake >60 g/d or 1.1 g/kg of ideal body weight/day presented better preservation of LTM at 4 and 12 months following bariatric surgery than those with lower nutritional intake. Although protein supplementation thus seems to be an attractive approach, various studies have reported the difficulty of reaching the suggested dose for protein intake with conventional nutritional techniques after bariatric surgery {Moize, 2003 #1486; Bavaresco, 2010 #1487}. These results should encourage us to develop new forms of protein supplements, particularly for the acute phase, which is the most affected by LTM loss and the most restrictive period. Exercise programs could also be considered to protect LTM, but this approach remains unthinkable just after surgery.

10 In addition to the potential for sarcopenia, LTM loss may have other consequences. Notably, LTM conditions the basal metabolic rate (BMR) and a reduction in LTM is associated with a decline in BMR after BS <sup>(25)</sup>. In the longer term, undesirable LTM loss associated with a concomitant increase in nutritional intake due to an increase in stomach volume may lead to weight regain. Indeed, patients with higher BMR show greater weight loss and those with lower BMR are most susceptible to weight regain <sup>(4, 37-39)</sup>.

We demonstrated that android and gynoid tissues decreased after surgery, following a profile similar to that for the whole body: acute LTM loss and sustained and accentuated FM loss that yields approximately twofold more percent change from baseline than that of LTM at 12 months. In addition, we reported that SG induced a marked reduction in abdominal adipose tissue, including TAT (-41.2%), VAT (-44.6%) and SAT (-39.7%). Few studies have evaluated abdominal adipose tissue variations after BS {Bazzocchi, 2015 #976; Favre, 2018 #1457; Heath, 2009 #1451; Zang, 2017 #1459; Gletsu-Miller, 2009 #1485} and only Zang et al. <sup>(17)</sup> evaluated VAT in the same context (i.e., DXA technique and surgical procedure). These authors reported an approximately 22.5% reduction in VAT 3 months after laparoscopic sleeve gastrectomy {Zang, 2017 #1459}. Using MRI, Health et al. <sup>(14)</sup> reported that the

proportional reduction in abdominal lipid was greater from the visceral than the subcutaneous compartment in obese women at 3 and 12 months after laparoscopic adjustable gastric banding surgery. Our and previous findings <sup>(14)</sup> have suggested that fat localized at visceral sites is more mobilized than subcutaneous fat depots. This may be because VAT is more metabolically active and more sensitive to lipolysis than SAT <sup>(41)</sup>. Moreover, as an accumulation of VAT is more closely associated with insulin resistance than SAT accumulation <sup>(42)</sup>, reducing VAT may improve insulin sensitivity. Nevertheless, although most studies show an improvement in insulin sensitivity, a direct link between VAT and insulin sensitivity has not been clearly demonstrated <sup>(14, 40, 43)</sup>. Recently, Favre et al. <sup>(15)</sup> reported that VAT mass was greater in T2D than in normoglycemia before surgery, but this difference did not persist 12 months after RYGB. We observed a VAT reduction of about 5 and 45% after 1 and 12 months, respectively, and this latter value was lower than the 65% to 72% reported after 12 months following RYGB <sup>(15, 16)</sup>. The discrepancy may be attributed to the type of BS, because a greater loss of trunk fat was observed 24 months after surgery in patients after RYGB than after SG, despite comparable body weight loss between groups <sup>(44)</sup>. These results thus suggest the need for further investigation into the effects of each type of surgery on body composition and abdominal parameters.

Although we did not evaluate the correlations between VAT and the many biological or clinical parameters that characterize both metabolic and cardiovascular risk after BS, our study showed that DXA is a useful screening tool for quantifying and following up on VAT and other adipose tissue in a clinical setting. Moreover, as we demonstrated that the relative variation in VAT mass exceeded the relative variation in weight loss, VAT might emerge as an unavoidable clinical parameter to follow the efficacy of BS and predict the evolution of comorbidities. This will have to be confirmed in the future by longitudinal studies. To our knowledge, two studies have evaluated the variation in VAT after BS. However, the



technique for VAT evaluation (computed tomography), the surgical procedure (RYGB), and the time points for evaluation all differed, making it difficult to compare with our results {Gletsu-Miller, 2009 #1485; Torriani, 2015 #1488}. Yet VAT and SAT also decreased with the time since surgery, and their subjects lost a higher percentage of VAT than SAT, as  
5 observed in our study. VAT appeared more strongly associated with oxidative stress than abdominal SAT or general adiposity during weight loss {Gletsu-Miller, 2009 #1485}. In addition, VAT and SAT density, which reflects an increase in fat vascularity and adipocyte volume, increased concurrently with the fat loss, correlating with improved metabolic indices independent of BMI {Torriani, 2015 #1488}.

10 Our study presents limitations that should be pointed out. Men and women were both evaluated and they may present specificities in terms of initial and postsurgical body composition changes <sup>(18)</sup>. However, the limited number of male patients (n=5) did not allow us to perform a subgroup analysis based on gender. We nevertheless found in an earlier study that the percent change from baseline in LTM did not differ between genders after 1 month of  
15 surgery and showed only a minor percent change from baseline in trunk FM <sup>(18)</sup>. We therefore suspect that any gender specificities would not alter the main message of our findings. Also, this study was not designed to identify factors that can modify body composition change, but it might be important to specify the effects of lifestyle (i.e., leisure-time physical activity, time watching TV <sup>(45)</sup>, nutritional habits) on the body composition changes specifically after SG.  
20 As we did not evaluate physiological and metabolic parameters in this study, we were unable to determine whether the VAT change is more relevant than whole-body FM for following obesity-related comorbidities variations after BS.

In conclusion, we demonstrated that SG induces a marked modification in body composition characterized by a decrease in LTM in the acute period and a sustained loss of  
25 FM in the first year. These results suggest that the early phase should be targeted to

implement strategies to reduce LTM loss, which is a longer-term weight-regain criterion. Further studies investigating the potential advantages of VAT compared to whole-body FM in the improvement of comorbidities after SG should be performed.

5            **Conflict of interest**

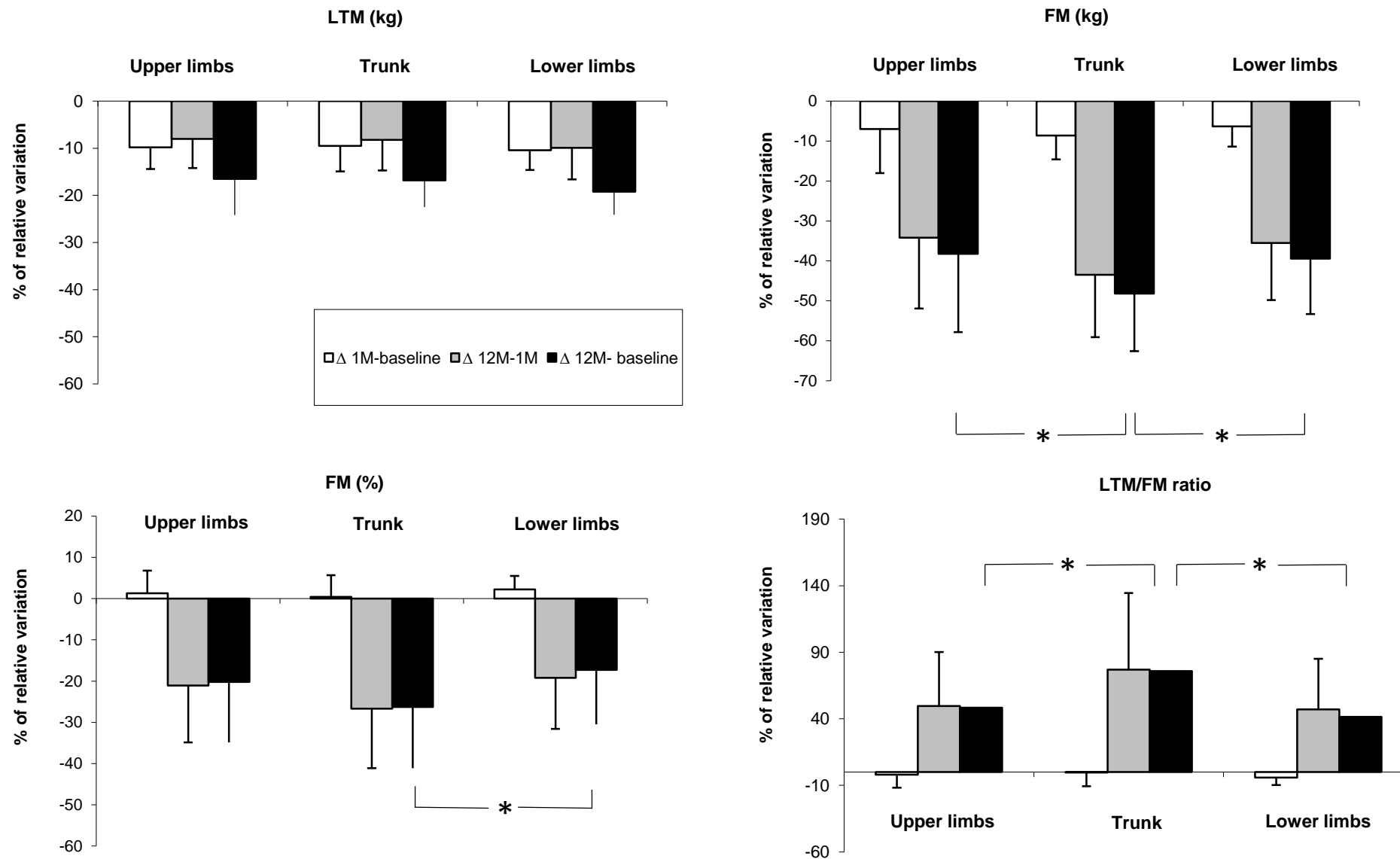
Authors have no conflict of interest.

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**Figure 1.** Comparison of percent change from baseline between sites for each component [lean tissue mass (LTM) or fat mass (FM)] 1 and 12 months following bariatric surgery.

**LEGEND:** \* indicates a significant difference (p<0.05) between two sites.

## TABLES AND LEGENDS

**TITLE: Table 1.** Clinical characteristics of the patients at baseline and 1 and 12 months after sleeve gastrectomy.

**LEGEND** Data are presented as mean  $\pm$  SD. BMI: body mass index,  $\Delta$  1m-baseline represents the difference between values at 1 month and baseline;  $\Delta$  12m-1m represents the difference between values at 12 months and 1 month;  $\Delta$  12m-baseline represents the difference between values at 12 months and baseline; \* indicates a significant variation for  $p < 0.05$ , \*\*\* for  $p < 0.01$  and \*\*\*\* for  $p < 0.001$ .

**TITLE: Table 2.** Body composition of the patients at baseline and 1 and 12 months after sleeve gastrectomy.

**LEGEND:** Data are presented as mean  $\pm$  SD. LTM: lean tissue mass; FM: fat mass; SMI: skeletal muscle index (sum of LTM at arms and legs/height<sup>2</sup>);  $\Delta$  1m-baseline represents the % relative difference between values at 1 month and baseline;  $\Delta$  12m-1m represents the % relative difference between values at 12 months and 1 month;  $\Delta$  12m-baseline represents the % relative difference between values at 12 months and baseline; the % relative variation was defined as  $[100 * (\text{measure 2} - \text{measure 1}) / \text{measure 1}]$ ; \* indicates a significant variation for  $p < 0.05$ , \*\*\* for  $p < 0.01$  and \*\*\*\* for  $p < 0.001$ .

**TITLE: Table 3.** Android, gynoid and abdominal adipose tissue at baseline and 1 and 12 months after sleeve gastrectomy.

**LEGEND:** Data are presented as mean  $\pm$  SD. Android: waist and abdomen area, gynoid: hip area, TAT: total adipose tissue; VAT: visceral adipose tissue, SAT: subcutaneous adipose tissue.  $\Delta$  1m-baseline represents the % relative difference between values at 1 month and baseline;  $\Delta$  12m-1m represents the % relative difference between values at 12 months and 1 month;  $\Delta$  12m-baseline represents the % relative difference between values at 12 months and baseline; the % relative variation was defined as  $[100 * (\text{measure 2} - \text{measure 1}) / \text{measure 1}]$ ; \* indicates a significant variation for  $p < 0.05$ , \*\*\* for  $p < 0.01$  and \*\*\*\* for  $p < 0.001$ .

**TITLE: Table 4.** Correlation between preoperative characteristics and variations in body composition parameters.

**LEGEND:** Data are presented as Spearman or Pearson correlation coefficients.

\* indicates a significant variation for  $p < 0.05$ , \*\* for  $p < 0.01$ .

**TITLE: Figure 1.** Individual variations in whole-body composition [lean tissue mass (LTM) and fat mass (FM)] and adipose tissue in the trunk region 1 and 12 months following bariatric surgery. The red line represents the mean variation.

**TITLE: Figure 2.** Comparison of % relative variation between sites for each component [lean tissue mass (LTM) and fat mass (FM)] 1 and 12 months following bariatric surgery.

**LEGEND:** \* indicates a significant difference of variation ( $p < 0.05$ ) between two sites.

**Table 1.** Clinical characteristics of the patients at baseline and 1 and 12 months after sleeve gastrectomy.

	Baseline	1-month	12-months	<u>% change</u> ( $\Delta$ 1m-baseline/baseline)	<u>% change</u> ( $\Delta$ 12m-1m/1m)	<u>% change</u> ( $\Delta$ 12m-baseline/baseline)
Age, yr	40.9 $\pm$ 15.1	-	-	-	-	-
Height, m	1.64 $\pm$ 0.08	-	-	-	-	-
Weight, kg	112.6 $\pm$ 13.9	103.1 $\pm$ 13.0	80.5 $\pm$ 11.4	-8.6 $\pm$ 1.8***	-21.8 $\pm$ 7.2***	-28.3 $\pm$ 7.0***
BMI, kg/m <sup>2</sup>	41.9 $\pm$ 4.5	38.4 $\pm$ 4.6	30.1 $\pm$ 4.6	-8.6 $\pm$ 1.8***	-21.8 $\pm$ 7.2***	-28.3 $\pm$ 7.0***
Ideal body weight, kg	58.9 $\pm$ 5.6	-	-	-	-	-
Excess body weight, kg	53.7 $\pm$ 11.7	44.2 $\pm$ 11.6	21.6 $\pm$ 12.0	-18.53 $\pm$ 4.95***	-53.16 $\pm$ 20.48***	-60.96 $\pm$ 17.44***
Excess BMI, kg/m <sup>2</sup>	16.9 $\pm$ 4.5	13.4 $\pm$ 4.6	5.1 $\pm$ 4.6	-22.36 $\pm$ 6.64***	-68.17 $\pm$ 30.44***	-73.56 $\pm$ 23.46***

Data are presented as mean  $\pm$  SD.  $\Delta$  1m-baseline represents the difference between values at 1 month and baseline;  $\Delta$  12m-1m represents the difference between values at 12 months and 1 month;  $\Delta$  12m-baseline represents the difference between values at 12 months and baseline; \* indicates a significant variation for  $p < 0.05$ , \*\*\* for  $p < 0.01$  and \*\*\*\* for  $p < 0.001$ .



**Table 2.** Body composition of the patients at baseline and 1 and 12 months after sleeve gastrectomy.

	Baseline	1-month	12-months	<u>% change</u> ( $\Delta$ 1m-baseline/baseline)	<u>% change</u> ( $\Delta$ 12m-1m/1m)	<u>% change</u> ( $\Delta$ 12m-baseline/baseline)
<b>LTM (kg)</b>						
Upper limbs	3.01 $\pm$ 0.77	2.72 $\pm$ 0.65	2.49 $\pm$ 0.61	-9.8 $\pm$ 4.6***	-8.0 $\pm$ 6.2***	-16.5 $\pm$ 7.7***
Trunk	30.14 $\pm$ 4.21	27.33 $\pm$ 3.85	24.97 $\pm$ 3.25	-9.5 $\pm$ 5.4***	-8.2 $\pm$ 6.5***	-16.8 $\pm$ 5.7***
Lower limbs	10.04 $\pm$ 1.70	8.99 $\pm$ 1.59	8.10 $\pm$ 1.42	-10.4 $\pm$ 4.2***	-9.9 $\pm$ 6.7***	-19.2 $\pm$ 4.9***
Whole body	59.80 $\pm$ 8.86	54.06 $\pm$ 7.94	49.30 $\pm$ 6.90	-9.7 $\pm$ 3.3***	-8.7 $\pm$ 4.7***	-17.4 $\pm$ 4.4***
<b>FM (kg)</b>						
Upper limbs	2.79 $\pm$ 0.71	2.60 $\pm$ 0.69	1.71 $\pm$ 0.69	-7.0 $\pm$ 11.0**	-34.2 $\pm$ 17.7***	-38.2 $\pm$ 19.6***
Trunk	26.44 $\pm$ 4.96	24.21 $\pm$ 4.93	13.81 $\pm$ 4.96	-8.6 $\pm$ 6.0***	-43.5 $\pm$ 15.6***	-48.2 $\pm$ 14.4***
Lower limbs	8.77 $\pm$ 2.57	8.17 $\pm$ 2.40	5.39 $\pm$ 2.33	-6.3 $\pm$ 5.1***	-35.5 $\pm$ 14.3***	-39.4 $\pm$ 13.9***
Whole body	50.51 $\pm$ 9.54	46.71 $\pm$ 9.50	28.87 $\pm$ 10.25	-7.7 $\pm$ 4.3***	-39.1 $\pm$ 14.4***	-43.5 $\pm$ 13.9***
<b>FM (%)</b>						
Upper limbs	46.73 $\pm$ 7.72	47.42 $\pm$ 8.67	38.04 $\pm$ 11.67	1.3 $\pm$ 5.5	-21.1 $\pm$ 13.8***	-20.2 $\pm$ 14.7***
Trunk	46.05 $\pm$ 4.73	46.16 $\pm$ 5.33	34.31 $\pm$ 8.96	0.4 $\pm$ 5.3	-26.7 $\pm$ 14.4***	-26.3 $\pm$ 14.8***
Lower limbs	45.10 $\pm$ 6.84	46.01 $\pm$ 6.90	37.75 $\pm$ 9.75	2.2 $\pm$ 3.3**	-19.2 $\pm$ 12.4***	-17.3 $\pm$ 13.2***
Whole body	44.75 $\pm$ 5.04	45.48 $\pm$ 5.54	35.24 $\pm$ 8.72	1.7 $\pm$ 5.3	-23.4 $\pm$ 13.6***	-22.1 $\pm$ 13.5***
<b>LTM/FM</b>						
Upper limbs	1.14 $\pm$ 0.37	1.12 $\pm$ 0.42	1.76 $\pm$ 1.03	-2.0 $\pm$ 9.8	49.6 $\pm$ 40.6 ***	48.3 $\pm$ 47.4***
Trunk	1.17 $\pm$ 0.22	1.17 $\pm$ 0.25	2.12 $\pm$ 1.05	-0.4 $\pm$ 10.3	77.0 $\pm$ 57.5***	75.9 $\pm$ 60.4***
Lower limbs	1.22 $\pm$ 0.38	1.17 $\pm$ 0.37	1.80 $\pm$ 0.98	-4.2 $\pm$ 5.5***	47.0 $\pm$ 38.0***	41.5 $\pm$ 39.1***
Whole body	1.22 $\pm$ 0.26	1.20 $\pm$ 0.27	1.97 $\pm$ 0.92	-1.9 $\pm$ 6.9	59.2 $\pm$ 42.5***	56.4 $\pm$ 44.8***
<b>SMI</b>	9.66 $\pm$ 1.29	8.67 $\pm$ 1.22	7.86 $\pm$ 1.1	-10.2 $\pm$ 3.6***	-9.5 $\pm$ 6.0***	-18.5 $\pm$ 5.1***

Data are presented as mean  $\pm$  SD. LTM: lean tissue mass; FM: fat mass; SMI: skeletal muscle index (sum of LTM at arms and legs/height<sup>2</sup>);  $\Delta$  1m-baseline represents the % change between values at 1 month and baseline;  $\Delta$  12m-1m represents the % change between values at 12 months and 1 month;  $\Delta$  12m-baseline represents the % change between values at 12 months and baseline; the % change variation was defined as [100\*(measure 2 – measure 1) / measure 1]; \* indicates a significant variation for  $p < 0.05$ , \*\* for  $p < 0.01$  and \*\*\* for  $p < 0.001$ .

**Table 3.** Android, gynoid and abdominal adipose tissue at baseline and 1 and 12 months after sleeve gastrectomy.

	Baseline	1-month	12-months	<u>% change</u> (Δ 1m-baseline/baseline)	<u>% change</u> (Δ 12m-1m/1m)	<u>% change</u> (Δ 12m-baseline/baseline)
<b>Android region</b>						
Total mass, kg	9.90 ± 1.80	8.78 ± 1.62	6.16 ± 1.24	-11.4 ± 5.2***	-29.3 ± 11.3***	-37.3 ± 9.8***
LTM, kg	4.84 ± 0.79	4.23 ± 0.70	3.61 ± 0.53	-12.8 ± 6.2***	-14.0 ± 8.5***	-25.0 ± 6.3***
FM, kg	5.06 ± 1.20	4.55 ± 1.10	2.55 ± 0.96	-9.8 ± 6.1***	-44.2 ± 16.9***	-49.6 ± 15.2***
Fat, %	50.75 ± 4.12	51.47 ± 4.14	40.16 ± 8.88	1.2 ± 3.8*	-22.7 ± 14.1***	-21.3 ± 14.3***
<b>Gynoid region</b>						
Total mass, kg	18.43 ± 3.05	16.81 ± 2.91	12.86 ± 2.26	-8.8 ± 4.0***	-23.3 ± 8.2***	-30.0 ± 7.0***
LTM, kg	9.86 ± 1.59	8.87 ± 1.39	7.71 ± 1.06	-10.2 ± 4.7***	-12.9 ± 5.3***	-21.4 ± 5.6***
FM, kg	8.57 ± 2.21	7.94 ± 2.08	5.15 ± 1.91	-6.8 ± 5.2***	-35.7 ± 14.3***	-40.3 ± 12.3***
Fat, %	46.17 ± 5.97	46.84 ± 5.61	39.23 ± 8.35	2.1 ± 3.6**	-17.1 ± 11.4***	15.7 ± 11.0 ***
<b>Abdominal adipose tissue</b>						
TAT mass, kg	4.15 ± 0.59	3.87 ± 0.60	2.47 ± 0.83	-6.7 ± 4.0***	-37.4 ± 16.6***	-41.2 ± 15.9 ***
VAT mass, kg	1.04 ± 0.30	0.98 ± 0.29	0.58 ± 0.25	-5.4 ± 13.7**	-41.8 ± 15.0***	-44.6 ± 17.1***
SAT mass, kg	3.11 ± 0.57	2.89 ± 0.56	1.89 ± 0.68	-6.6 ± 5.7***	-35.7 ± 18.1***	-39.7 ± 17.0 ***

Data are presented as mean ± SD. Android: waist and abdomen area, gynoid: hip area, TAT: total adipose tissue; VAT: visceral adipose tissue SAT: subcutaneous adipose tissue. Δ 1m-baseline represents the % change between values at 1 month and baseline; Δ 12m-1m represents the % change between values at 12 months and 1 month; Δ 12m-baseline represents the % change between values at 12 months and baseline; the % change was defined as  $[100 * (\text{measure 2} - \text{measure 1}) / \text{measure 1}]$ ; \* indicates a significant variation for  $p < 0.05$ , \*\* for  $p < 0.01$  and \*\*\* for  $p < 0.001$ .

**Table 4.** Correlation between preoperative characteristics and variations in body composition parameters.

		<b>Basal parameters</b>					
		Age	Weight	BMI	Whole body LTM	Whole body FM	Whole body LTM/FM ratio
<b>% change</b>	<b>LTM</b>						
	Upper limbs	0.08	-0.15	-0.02	0.05	-0.10	0.01
	Trunk	0.05	-0.18	0.02	-0.26	-0.09	-0.10
	Lower limbs	0.03	-0.19	-0.08	-0.19	0.10	-0.11
	Whole body	0.11	-0.25	-0.01	-0.25	0.00	-0.15
	<b>FM</b>						
	Upper limbs	0.10	-0.01	0.30	0.00	0.28	-0.20
	Trunk	0.52**	-0.12	0.20	-0.27	0.26	-0.51**
	Lower limbs	0.51**	-0.18	0.19	-0.35	0.24	-0.48**
	Whole body	0.53**	-0.12	0.24	-0.25	0.26	-0.49**
	<b>LTM/FM</b>						
	Upper limbs	-0.21	-0.14	-0.44*	0.03	-0.31	0.45*
	Trunk	-0.57**	0.10	-0.21	0.23	-0.29	0.51**
	Lower limbs	-0.57**	0.13	-0.18	0.33	-0.24	0.53**
	Whole body	-0.52**	0.08	-0.25	0.25	-0.31	0.56**
	<b>Abdominal adiposity</b>						
	TAT	0.32	0.06	0.39*	-0.20	0.45*	-0.64**
	VAT	0.32	0.13	0.38*	-0.09	0.40*	-0.41*
	SAT	0.32	0.01	0.27	-0.27	0.37*	-0.57**

Data are presented as Spearman or Pearson correlation coefficients.\* indicates a significant variation for  $p < 0.05$ , \*\* for  $p < 0.01$ .