Check for updates

RESEARCH ARTICLE

REVISED Association between the body mass index, waist circumference, and body fat percentage with erosive esophagitis in adults with obesity after sleeve gastrectomy

[version 2; peer review: 1 approved, 2 approved with reservations]

Alba S. Zevallos-Ventura[1,2], Gabriel de la Cruz-Ku[1,3,4], Fernando M. Runzer-Colmenares[1,2], Jesús Pinto-Elera[5], Carlos J. Toro-Huamanchumo[5,6]

[1]Universidad cientifica del sur, Lima, Lima, Peru
[2]CHANGE Research Working Group, Universidad Científica del Sur, Lima, Lima, Peru
[3]General Surgery, Mayo Clinic in Rochester, Rochester, Minnesota, USA
[4]General Surgery, University of Massachusetts, Worcester, Massachusetts, USA
[5]Unidad de Investigación Multidisciplinaria, Clínica Avendaño, Lima, Lima, Peru
[6]Unidad para la Generación y Síntesis de Evidencias en Salud, Universidad San Ignacio de Loyola, Lima, Lima, Peru

v2 **First published:** 22 Feb 2022, **11**:214
https://doi.org/10.12688/f1000research.106723.1
Latest published: 01 Jun 2022, **11**:214
https://doi.org/10.12688/f1000research.106723.2

Abstract

Background: High anthropometric indexes before sleeve gastrectomy (SG) are associated with an increased risk of erosive esophagitis (EE) in bariatric surgery candidates. Reasons that explain how these indexes influence the development of esophageal pathology after surgery remains unclear.
Objectives: To assess the association between the body mass index (BMI), waist circumference (WC), and body fat percentage (BFP) with the development of EE in adults with obesity three months after SG.
Setting: Clínica Avendaño, Lima, Peru.
Methods: Retrospective cohort using a database including adults with obesity who underwent SG during 2017-2020. All the patients included had an endoscopy before and after the surgery. Sociodemographic, clinical and laboratory characteristics were compared according to BMI, WC and BFP, as well as by the development of *de novo* esophagitis. The association was evaluated by crude and adjusted generalized linear models with the log-Poisson family.
Results: From a total of 106 patients, 23 (21.7%) developed EE. We did not find significant differences in sociodemographic, clinical and laboratory characteristics between patients with de novo EE compared to those who did not develop EE. After adjustment, BMI (aRR = 0.59, 95% CI = 0.18-1.40), BFP (aRR = 0.41, 95% CI = 0.15-1.19) and WC (aRR = 0.91, 95% CI = 0.69-1.16) were not associated with the development of EE three months post SG.
Conclusions: We found no association between preoperative

Open Peer Review

Approval Status ✓ ? ?

	1	2	3
version 2 (revision) 01 Jun 2022			? view
version 1 22 Feb 2022	✓ view	? view	

1. **Sergio Goicochea-Lugo**, Instituto de Evaluación de Tecnologías en Salud e Investigación, Lima, Peru
2. **Kei Nakajima**, Kanagawa University of Human Services, Yokosuka, Japan
3. **Moisés Apolaya-Segura**, Universidad de San Martín de Porres, Chiclayo, Peru

Any reports and responses or comments on the article can be found at the end of the article.

anthropometric indexes and the development of *de novo* EE; therefore, morbid obesity should not be a criterion to exclude the patients to undergo SG as primary surgery because of the risk of developing EE.

Keywords
Obesity, Esophagitis Peptic, Abdominal fat, Body mass index, Waist circumference

Corresponding author: Alba S. Zevallos-Ventura (albitazev30@gmail.com)

Author roles: Zevallos-Ventura AS: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **de la Cruz-Ku G**: Conceptualization, Investigation, Methodology, Resources, Writing – Original Draft Preparation, Writing – Review & Editing; **Runzer-Colmenares FM**: Investigation, Methodology, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Pinto-Elera J**: Investigation, Methodology, Project Administration, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Toro-Huamanchumo CJ**: Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2022 Zevallos-Ventura AS *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Zevallos-Ventura AS, de la Cruz-Ku G, Runzer-Colmenares FM *et al.* **Association between the body mass index, waist circumference, and body fat percentage with erosive esophagitis in adults with obesity after sleeve gastrectomy [version 2; peer review: 1 approved, 2 approved with reservations]** F1000Research 2022, **11**:214
https://doi.org/10.12688/f1000research.106723.2

First published: 22 Feb 2022, **11**:214 https://doi.org/10.12688/f1000research.106723.1

REVISED **Amendments from Version 1**

We have added information about the weight loss in the results section: *"A higher mean of weight loss at 3 months postoperatively was observed in patients with morbid obesity (26.78 kg vs. 19.50 kg)"*.

We have added the time the anthropometric indexes were measured in the methods section: *"All three anthropometric indexes were measured on the day of surgery."*

Any further responses from the reviewers can be found at the end of the article

Introduction

Obesity is currently considered as a chronic and multifactorial metabolic-related disease, of which prevalence has been increasing along the decades,[1] and has an important impact on morbidity and mortality worldwide.[2,3] Surgical treatment is available and is managed with different techniques by bariatric and minimally invasive procedures. To date, sleeve gastrectomy (SG) is the most commonly used technique (American Society for Metabolic and Bariatric Surgery).[4,5]

There is a direct relationship between obesity and the development of gastroesophageal reflux disease (GERD). In fact, the elevated intra-abdominal pressure and the increased transient lower esophageal sphincter (LES) relaxation[6] in patients with obesity has been described as a pathophysiological mechanism of GERD, and, consequently, esophageal mucosal damage[7] which leads to erosive esophagitis (EE).[8] Moreover, there are several studies that associate high values of body mass index (BMI),[9] waist circumference (WC), abdominal subcutaneous fat, and visceral fat[10–12] with the esophageal pathology. However, in a Swedish community-based study, Lagergren J *et al*. concluded that this parameter is not a sufficient indicator and would even qualify as inaccurate as a predisposing factor for EE.[13] Furthermore, a study among an Iranian population showed that the symptoms of GERD occur independently of the BMI.[14]

There is scarce literature that explores the association between anthropometric indexes and the development of *de novo* EE in gastrectomized patients in a short-term period; Jan S. Burgerhart showed that esophageal acid exposure increased significantly when comparing 24-h pH measurements before and three months after sleeve gastrectomy. Jan S. Burgerhart showed that esophageal acid exposure increased significantly when comparing 24-h pH measurements before and three months after sleeve gastrectomy.[15] Furthermore, because the rate of de novo EE is higher after SG compared to gastric bypass[16,17] evaluating the effect of BMI, WC and body fat percentage (BFP) on the development of *de novo* EE might be invaluable to predict whether patients with high anthropometric indexes can undergo this type of procedure. Hence, we sought to determine the association between BMI, WC and BFP with *de novo* EE three months after undergoing sleeve gastrectomy.

Methods

Population and study design

We conducted a retrospective cohort study, analyzing a secondary database to which we had access between January and March 2021. The database was recorded in an Excel 2016 spreadsheet of the Clínica Avendaño that was collected between 2017 and 2020 from patient medical records. The study population consisted of 176 adults with obesity that underwent sleeve gastrectomy as primary surgery during 2017-2020 at the Clínica Avendaño, a specialized bariatric center located in Lima, Perú

The inclusion criteria were: age ≥18 years old, BMI ≥30kg/m^2, sleeve gastrectomy as primary surgery, and endoscopy performed preoperatively and three months post SG. The exclusion criteria were: esophagitis at preoperative endoscopy, diagnosis of hiatal hernia, excessive alcohol consumption (chronic and periodic alcohol consumption of more than three times per week) and heavy smoking (15 cigarettes or more per day). In addition, we excluded patients with missing data, as well as those who were lost to follow-up, which took place in the third postoperative month at Clínica Avendaño where a control endoscopy was performed. (Figure 1).

Variables and measurements

We considered demographic variables (age, sex), comorbidities (type 2 diabetes mellitus (T2DM), hypertension), clinical and laboratory variables (systolic blood pressure (SBP), diastolic blood pressure (DBP), cholesterol, triglycerides, low-density lipoprotein (LDL), high-density lipoprotein (HDL), very low-density lipoprotein (VLDL), glucose, insulin, homeostatic model assessment of insulin resistance (HOMA-IR), anthropometric variables (BMI, WC, percentage of BFP) and endoscopic variables (presence of *Helicobacter pylori* and *de novo* esophagitis at three months)). Blood analyses after fasting for 8 to 12 hours were performed for preoperative control in all patients at approximately 2 to 4 weeks before surgery (COBAS 60000 module C501).

Age was categorized into two groups (18-29 and 30-59 years) while the sex variable was defined as "male" or "female". The BMI was calculated as weight (in kg) /height (in meters)^2 and was categorized into non-morbid (<40.00 kg/m^2) and morbid obesity (≥40.00 kg/m^2). WC was measured between the lowest ribs and the iliac crest, and the measurements were recorded in centimeters.[18] BFP was recorded as a percentage using the ¨TANITA¨ bioelectrical impedance scale (Body Composition Analyzer TBF-310GS) with cut-off points of 25% for men and 35% for women categorized as normal and elevated.[19] All three anthropometric indexes were measured on the day of surgery. The HOMA-IR was calculated as follows: [fasting insulin (μU/ml) × fasting glucose (mg/dl)] /405. A cut-off ≥ 2.5 was considered as insulin resistance.[20]

Procedures

Esophagitis was endoscopically evaluated prior to surgery and at three months after the procedure for each patient. The degree of esophagitis was classified according to the Los Angeles classification system and subsequently categorized as presence or absence of esophagitis.[21] The endoscopies were performed after preparation of the patient with a standardized technique using a flexible endoscope (OLYMPUS EXERA 180). The presence of *H. pylori* was considered if at least 1+ was observed in the preoperative gastric biopsy report. All surgical procedures were performed by the same physicians using a standardized technique that consists of dissection of the greater omentum until the complete visualization of the left pillar of the diaphragm, liberation of the posterior gastric wall, and dissection of the diaphragmatic crura. In case of finding hiatal hernia the correction of the hernia is performed intraoperatively, a 34F calibration bougie is used, the section is 4 cm from the pylorus until 1 cm from his angle. In all patients, reinforcement is performed with absorbable monofilament suture or with staples with polyglycolic acid reinforcement material.

Statistical analysis

We calculated the statistical power with Epidat v4.2 according to the studies of Tai *et al*[22] and Matar *et al.*[23] For all scenarios the statistical power exceeded 90%.

Stata version 16.0 (StataCorp, TX, US) was used for data processing. Numerical variables were presented as mean and standard deviation or median and interquartile range. Categorical variables were presented as frequencies and percentages. The chi-square test was used to compare frequencies between groups; if more than 20% of the expected values were ≤5, the Fisher exact test was used instead.

We performed a first bivariate analysis using the Student's t-test or Mann Whitney U test to evaluate the presence of significant differences between the anthropometric indexes and categorical variables depending on the normal and abnormal distribution of the variable, respectively. Moreover, Spearman correlation was used for assessing the relation between the anthropometric indexes and numerical variables. In addition, a second bivariate analysis was performed between numerical and categorical variables according to the presence of EE.

Finally, in order to assess the association between each index and *de novo* EE, individual generalized linear models (GLM) with the Poisson family, logarithmic link function, and robust variances were used. The WC variable was modeled by adding a quadratic term. Nonparametric bias-corrected and accelerated bootstrap estimation of confidence intervals with 1000 replications were performed for all the models. Crude relative risks (cRR) and adjusted relative risks (aRR) were calculated for the bivariate and multivariable analyses. In addition, these models were adjusted by age and sex. All models were presented with their respective 95% confidence intervals (95% CI), and a p-value <0.05 was considered significant.

Ethical considerations

The present study was approved by the Ethics Committee of the Universidad Científica del Sur on December 1st, 2020 (N° 405-2020-PRE15). We downloaded deidentified information from the database and used codes for each patient, maintaining the confidentiality of the patients.

Results

A total of 106 patients were included in our study (Figure 1), of which 74 (69.8%) were women, 76 (71.7%) were between 30 and 59 years of age and 32 (30.2%) had morbid obesity. A higher mean of weight loss at 3 months postoperatively was observed in patients with morbid obesity (26.78 kg vs. 19.50 kg). A higher mean of BMI was observed in males (40.28 kg/m^2 vs. 36.85 kg/m^2; p < 0.001) and patients with insulin resistance (38.7 kg/m^2 vs. 33.87 kg/m^2; p < 0.001). Regarding BMI, a negative monotonic correlation was found with HDL (r= -0.35; p < 0.001); on the other hand, a positive monotonic correlation was found with insulin (r= +0.59; p<0.001), and HOMA-IR (r= +0.61; p<0.001). Regarding the BFP, males presented a higher median value compared to females (50% vs. 43%; p<0.001), as well as a positive correlation with SBP (r= +0.36; p<0.001), insulin (r= +0.47; p<0.001) and HOMA-IR (r= +0.48; p<0.001). Regarding WC, we found higher median values in male patients compared to females (126cm vs. 104cm; p<0.001), and in patients

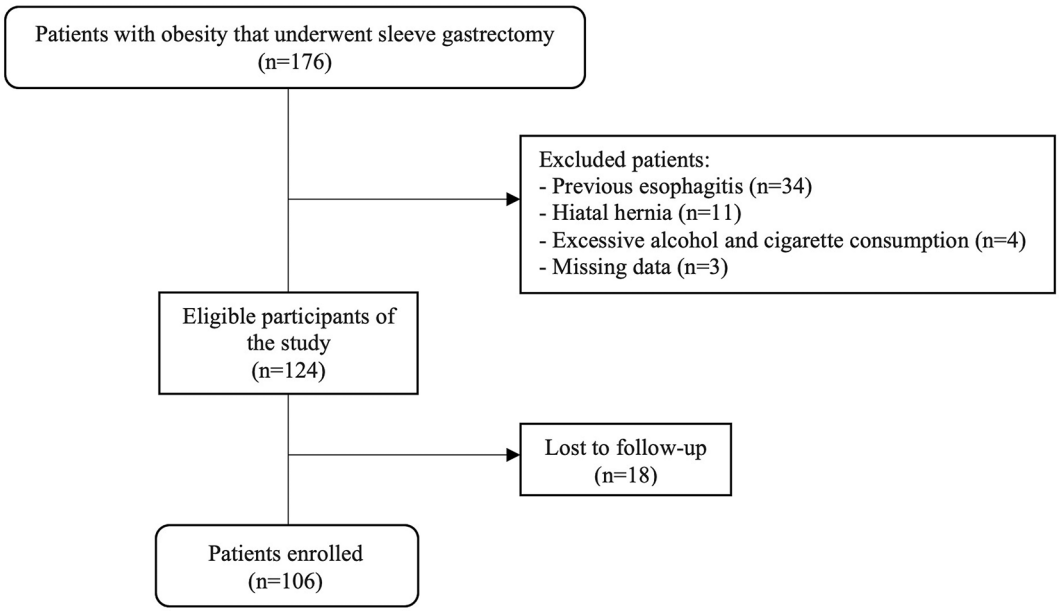


Figure 1. Flowchart of the study population.

with T2DM (134.33cm vs. 111.51cm; p<0.001), presence of *H. pylori* (119.61cm vs. 109.29cm; p<0.001) and insulin resistance (115.31cm vs. 100.52cm; p<0.001). In addition, there was a negative monotonic correlation with HDL (r= -0.44; p<0.001), and a positive monotonic correlation with glucose levels (r= +0.31; p < 0.001), insulin (r= +0.58; p < 0.001) and HOMA-IR (r= +0.61; p<0.001) (Table 1 and 2).

We found that 23 patients (21.7%) developed esophagitis (grade A: 14, grade B: 9, grade C:0, grade D:0). There were no significant differences for the sociodemographic, clinic and laboratory characteristics according to the development of EE after SG. In spite of these results, the group which did not develop EE had a higher median BMI (38 kg/m^2 vs. 36 kg/m^2, p=0.26), WC (113cm vs. 107cm, p=0.12), and BFP (46% vs. 44%, p=0.18) compared to the group who developed EE (Table 3).

On the multivariable analyses, after adjusting for age and sex, we found that a BMI ≥ 40 kg/m^2 (aRR = 0.59, 95% CI = 0.18-1.40), an elevated BFP (aRR = 0.41, 95% CI = 0.15-1.19) and the WC (aRR = 0.91, 95% CI = 0.69-1.16) were not associated with a higher risk of developing EE at three months after sleeve gastrectomy. Conversely, these high anthropometric indexes seemed to reduce the risk of *de novo* EE, but these results were not significant (Table 4).

Discussion

In this study, we assessed the association between BMI, WC, and BFP and the development of *de novo* EE in adults with obesity three months after undergoing sleeve gastrectomy. Although none of the variables showed significant differences according to the development of *de novo* EE, we found that the female patients more frequently developed EE and patients without EE had higher anthropometric indexes. We did not find any association in crude and adjusted models between BMI, WC and BFP with the development of *de novo* EE.

Our study showed that male patients presented a higher BMI, WC, and BFP compared to women, results that are similar to previous literature.[24–26] The BMI represents the overall body mass that includes visceral and subcutaneous fat, muscle, bone, and major organs, among others. Due to genetic, environmental, and behavioral factors men tend to have a greater fat amount and distribution.[27] In addition, the sexual hormonal responses lead to obesogenic changes[28] and sexual dimorphism with a high impact in the WC.[27,29] However, Lihua *Hu et al.* found that women present a greater proportion of visceral fat than men, being the only anthropometric measurement that prevails between the two sexes, and this tends to increase over time.[30] High adiposity values in the abdominal circumference stimulates the release of fatty acids, thereby increasing the availability of glucose and hyperinsulinism[31,32] and favoring the development of T2DM due to low sensitivity of the glucose transporter receptors of the organs to insulin,[33] which may explain and correlate with the results described in our study.

Table 1. Body mass index, body fat percentage and waist circumference according to sociodemographic, comorbidities, presence of *Helicobacter pylori*, insulin resistance and *de novo* esophagitis (n=106).

Variables		BMI	p	Body fat mass	P	Waist circumference	p
Age			0.621††		0.641††		0.104†
	18-29	36 [34-41]		43 [36-5]		108.43 ± 14.33	
	30-59	38 [33-41]		46 [37-52]		114.52 ± 18.19	
Sex			**<0.001†**		**<0.001††**		**<0.001††**
	Male	40.28 ± 5.51		50 [44-58]		126 [115-134]	
	Female	36.85 ± 5.40		43 [36-50]		104 [96-115]	
Arterial hypertension			0.041††		0.019††		0.009††
	No	37 [33-41]		44 [36-51]		108 [98-120]	
	Yes	39 [37-41]		48 [43-58]		117 [111-132]	
Diabetes mellitus			0.021††		0.015††		**<0.001†**
	No	37 [33-41]		45 [37-52]		111.51 ± 16.76	
	Yes	41 [40-41]		59 [46-82]		134.33 ± 12.61	
Helicobacter pylori			0.019††		0.201††		**<0.001†**
	No	36 [33-40]		44 [36-53]		109.29 ± 17.16	
	Yes	39 [35-41]		47 [41-56]		119.61 ± 15.79	
Insulin resistance			**<0.001†**		0.024††		**<0.001†**
	No	33.87 ± 3.06		38 [36-47]		100.52 ± 9,17	
	Yes	38.70 ± 5.70		46 [38-56]		115.31 ± 17.58	
de *novo* esophagitis			0.264††		0.186††		0.119††
	No	38 [34-41]		46 [37-55]		113 [100-123]	
	Yes	36 [33-39]		44 [35-48]		107 [95-116]	

BMI body mass index
†Student's t-test
††Mann Whitney U

Table 2. Body mass index, body fat percentage and waist circumference according to clinic and laboratory characteristics (n=106).

Variables	BMI	p	Body fat mass	P	Waist circumference	p
Clinic and laboratory characteristics						
SBP	0.25	0.010‡	0.36	**<0.001‡**	0.27	0.006‡
DBP	0.2	0.039‡	0.26	0.006‡	0.2	0.038‡
Glucose	0.23	0.019‡	0.16	0.100‡	0.31	**<0.001‡**
Cholesterol	-0.15	0.114‡	-0.1	0.300‡	-0.12	0.205‡
HDL	-0.35	**<0.001‡**	-0.27	0.005‡	-0.44	**<0.001‡**
LDL	-0.06	0.532‡	-0.06	0.557‡	-0.01	0.956‡
VLDL	0.09	0.351‡	0.17	0.089‡	0.16	0.106‡
Triglycerides	0.09	0.321‡	0.18	0.069‡	0.17	0.077‡
Insulin	0.59	**<0.001‡**	0.47	**<0.001‡**	0.58	**<0.001‡**
HOMA-IR	0.61	**<0.001‡**	0.48	**<0.001‡**	0.61	**<0.001‡**

BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure HDL high-density lipoprotein, LDL low-density lipoprotein, VLDL, very low-density lipoprotein, HOMA-IR homeostatic model assessment-insulin resistance
‡Spearman's correlation coefficient

Table 3. ***De novo*** **esophagitis according to sociodemographic,clinic and laboratory characteristics, comorbidities, presence of** ***Helicobacter pylori*** **and anthropometric characteristics (n=106).**

Variables	*de novo* esophagitis		
	Yes (n=23)	No (n=83)	p
Age n(%)			0.500‡
18-29	6 (20.0)	24 (80.0)	
30-59	17 (22.4)	59 (77.6)	
Sex			0.500‡
Male	8 (25.0)	24 (75.0)	
Female	15 (20.3)	59 (79.7)	
Arterial hypertension			0.500‡‡
No	19 (22.4)	66 (77.6)	
Yes	4 (19.1)	17 (80.9)	
Diabetes Mellitus			0.600‡‡
No	22(22.0)	78 (78.0)	
Yes	1 (16.7)	5 (83.3)	
Insulin resistance			0.500‡‡
No	4(22.2)	14 (77.8)	
Yes	19 (21.6)	69(79.4)	
Helicobacter pylori			0.600‡
No	16 (22.9)	54 (77.1)	
Yes	7 (19.4)	29 (80.6)	
Anthropometric characteristics			
BMI	36 [33-39]	38 [34-41]	0.260††
Abdominal circumference	107 [95-116]	113 [100-123]	0.120††
Body fat percentage	44 [35-48]	46 [37-55]	0.180††
Clinical and laboratorial characteristics			
SBP	124.82 ± 15.85	120.2 ± 14.3	0.190†
DBP	79.82 ± 8.9	77.54 ± 10.02	0.330†
Glucose	85 [81-92]	89 [81-95]	0.380††
Cholesterol	202 [172-228]	189 [164-227]	0.310††
HDL	45 [36-54]	46 [37-55]	0.820††
LDL	117 [109-132]	112 [91-136]	0.330††
VLDL	26 [19-37]	29 [21-37]	0.960††
Triglycerides	129 [96-185]	146 [104-185]	0.890††
Insulin	18 [14-28]	19 [14-39]	0.460††
HOMA-IR	4 [3-6]	4 [3-8]	0.450††

BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure HDL high-density lipoprotein, LDL low-density lipoprotein, VLDL, very low-density lipoprotein, HOMA-IR homeostatic model assessment- insulin resistance
†Student's t-test
††Mann Whitney U
‡Chi^2 test
‡‡Fisher's exact test

Currently, there are several parameters for measuring obesity, and among these, the measurement of visceral body fat percentage by computed tomography is considered one of the best predictors of GERD.[34] However, the BMI, WC and the percentage of BFP are more accessible and less costly parameters to obtain. Several studies reported that an elevation of these anthropometric indexes was associated with the development of EE in bariatric surgery candidates.[7,9,35,36] In fact,

Table 4. Association between the body mass index, waist circumference, body fat mass and the development of esophagitis.

		Crude model**		Adjusted model**	
Variables		**cRR**	**95% CI**	**aRR†**	**95% CI**
Body mass index					
	< 40 kg/m^2	Ref.		Ref.	
	≥ 40 kg/m^2	0.64	0.20-1.46	0.59	0.18-1.40
Body fat mass (%)					
	Normal	Ref.		Ref.	
	Elevated	0.50	0.23-1.27	0.41	0.15-1.19
Waist circumference (cm)*		0.94	0.75-1.33	0.91	0.69-1.16

RR: relative risk CI: 95% Confidence Interval
*It was modeled by adding a quadratic variable.
**Non-parametric bias-corrected and accelerated bootstrap confidence interval estimation with 1000 replications for generalized linear models with Poisson link-log family and robust standard errors.
†Adjusted by age and sex

previous studies have shown that men with higher obesity values[37] and the presence of hiatal hernia[38] are more likely to develop EE. However, in our study, firstly we excluded the patients with preoperative hiatal hernia in order to avoid this as a confounder, and regarding the anthropometric indexes, we did not find a significant association with de novo esophagitis, which could be explained by the fact that the EE group was composed of a higher proportion of women with lower-than-expected anthropometric indexes.

There are different pathophysiological mechanisms to explain how obesity can cause GERD. Previous studies have indicated that obesity may cause EE by mechanical factors such as high intra-abdominal and intragastric pressure,[39] an increased LES relaxation, a high gastroesophageal pressure gradient[40]; as well as physiological factors such as increased bile and pepsin composition of gastric contents[41] and high leptin levels.[42] Sleeve gastrectomy is currently leading up to 80% of weight loss in a long-term setting.[43] A recent study demonstrated that a substantial reduction in BMI is required to induce the resolution of esophagitis, especially in individuals with obesity. Moreover, a study reported that the resolution rate was twice as high in subjects who achieved a BMI reduction of more than 2 kg/m^2.[44] Nevertheless, in our study, we found that higher anthropometric indexes were not associated with the development of EE after sleeve gastrectomy. This could be explained by the fact that patients with higher levels of obesity tend to have a greater and more rapid weight loss compared to those with a lower BMI who tend to achieve a more sustained weight loss. Indeed, this suggests that a controlled reduction of the BMI by sleeve gastrectomy may constitute an effective measure to prevent the development of esophagitis by the alleviation and control of the pathophysiologic factors involved in this outcome.

To our knowledge, this is the first study to show that having a higher obesity index is not a risk factor for the development of *de novo* EE at three months post sleeve gastrectomy. However, the present study has some limitations. First, external validity is limited because the results come from a single center and are limited to adult patients with obesity. Second, the patients were followed for only three months, and thus, long-term results were not available. Third we could not include the assessment of proton bump inhibitor (PPI) use within the period of evaluation, however, according to clinic protocol, lansoprazole 30 mg is indicated for the first postoperative month and omeprazole 20 mg for the following two months, and depending on the reflux symptoms after three months of treatment, the use of PPIs can be postponed. Finally, in spite of the usage of the bioelectrical impedance scale for the measurement of BFP, a computed tomography would have been better to measure the visceral BFP as it has been reported to be more accurate as a predictor of EE according to the literature.

Conclusion

In conclusion, there were no significant differences between anthropometric indexes and the development of *de novo* EE esophagitis at three months post sleeve gastrectomy. Based on these results, we consider that morbid obesity should not be an excluding factor for undergoing sleeve gastrectomy as the surgery of choice for weight loss because of the risk of developing EE. Nonetheless, further studies are needed to evaluate this association in gastrectomized patients over a longer follow-up period.

Data availability statement

Undelying data

Harvard Database: Association between the body mass index, waist circumference, and body fat percentage with erosive esophagitis in adults with obesity after sleeve gastrectomy. https://doi.org/10.7910/DVN/ZBVTY4

This project contains the following files:

- Association between the body mass index, waist circumference, and body fat percentage with erosive esophagitis in adults with obesity after sleeve gastrectomy.tab (raw data file)
- README_Association between the body mass index, waist circumference, and body fat percentage with erosive esophagitis in adults with obesity after sleeve gastrectomy.txt (data key)

Data are available under the terms of the Creative Commons Zero "No rights reserved" data waiver (CC0 1.0 Public domain dedication).

References

1. Hales CM, Carroll MD, Fryar CD, *et al.*: **Prevalence of Obesity and Severe Obesity Among Adults: United States, 2017-2018.** *NCHS Data Brief.* 2020 Feb; **360**: 1–8.
2. Zhou Y, Chi J, Lv W, *et al.*: **Obesity and diabetes as high-risk factors for severe coronavirus disease 2019 (Covid-19).** *Diabetes Metab. Res. Rev.* 2021 Feb; **37**(2): e3377. PubMed Abstract | Publisher Full Text
3. Hruby A, Manson JE, Qi L, *et al.*: **Determinants and Consequences of Obesity.** *Am. J. Public Health.* 2016 Sep; **106**(9): 1656–1662. PubMed Abstract | Publisher Full Text
4. Ozsoy Z, Demir E: **Which Bariatric Procedure Is the Most Popular in the World? A Bibliometric Comparison.** *Obes. Surg.* 2018 Aug; **28**(8): 2339–2352. PubMed Abstract | Publisher Full Text
5. Khorgami Z, Shoar S, Andalib A, *et al.*: **Trends in utilization of bariatric surgery, 2010-2014: sleeve gastrectomy dominates.** *Surg Obes Relat Dis Off J Am Soc Bariatr Surg.* 2017 May; **13**(5): 774–778. PubMed Abstract | Publisher Full Text
6. Richter JE, Rubenstein JH: **Presentation and Epidemiology of Gastroesophageal Reflux Disease.** *Gastroenterology.* 2018 Jan; **154**(2): 267–276. PubMed Abstract | Publisher Full Text
7. Singh S, Sharma AN, Murad MH, *et al.*: **Central adiposity is associated with increased risk of esophageal inflammation, metaplasia, and adenocarcinoma: a systematic review and meta-analysis.** *Clin Gastroenterol Hepatol Off Clin Pract J Am Gastroenterol Assoc.* 2013 Nov; **11**(11): 1399–1412.e7. Publisher Full Text
8. Kim TJ, Lee H, Baek S-Y, *et al.*: **Metabolically Healthy Obesity and the Risk of Erosive Esophagitis: A Cohort Study.** *Clin. Transl. Gastroenterol.* 2019 Sep; **10**(9): e00077. PubMed Abstract | Publisher Full Text
9. Cai N, Ji G-Z, Fan Z-N, *et al.*: **Association between body mass index and erosive esophagitis: a meta-analysis.** *World J. Gastroenterol.* 2012 May 28; **18**(20): 2545–2553. PubMed Abstract | Publisher Full Text
10. Kang MS, Park DI, Oh SY, *et al.*: **Abdominal obesity is an independent risk factor for erosive esophagitis in a Korean population.** *J. Gastroenterol. Hepatol.* 2007 Oct; **22**(10): 1656–1661. PubMed Abstract | Publisher Full Text
11. Matsuzaki J, Suzuki H, Kobayakawa M, *et al.*: **Association of Visceral Fat Area, Smoking, and Alcohol Consumption with Reflux Esophagitis and Barrett's Esophagus in Japan. Maeda N, editor.** *PLoS One.* 2015 Jul 30; **10**(7): e0133865. PubMed Abstract | Publisher Full Text
12. Mazzoleni F, Mazzoleni LE, de Magalhães Francesconi CF, *et al.*: **Potential roles of Helicobacter pylori treatment, body mass index and waist circumference in the causation of erosive esophagitis: a randomized clinical trial (HEROES-GERD).** *Int J Obes 2005.* 2020 Jan; **44**(1): 147–158. Publisher Full Text
13. Lagergren J, Bergström R, Nyrén O: **No relation between body mass and gastro-oesophageal reflux symptoms in a Swedish population based study.** *Gut.* 2000 Jul; **47**(1): 26–29. PubMed Abstract | Publisher Full Text | Free Full Text
14. Solhpour A, Pourhoseingholi MA, Soltani F, *et al.*: **Gastro-esophageal reflux symptoms and body mass index: no relation among the Iranian population.** *Indian J Gastroenterol Off J Indian Soc Gastroenterol.* 2008 Aug; **27**(4): 153–155.
15. Burgerhart JS, Schotborgh CAI, Schoon EJ, *et al.*: **Effect of sleeve gastrectomy on gastroesophageal reflux.** *Obes. Surg.* 2014 Sep; **24**(9): 1436–1441. Publisher Full Text
16. Tai C-M, Huang C-K, Lee Y-C, *et al.*: **Increase in gastroesophageal reflux disease symptoms and erosive esophagitis 1 year after laparoscopic sleeve gastrectomy among obese adults.** *Surg. Endosc.* 2013 Apr; **27**(4): 1260–1266. PubMed Abstract | Publisher Full Text
17. Signorini F, Olguín S, Viscido G, *et al.*: **Esophagitis evolution after sleeve gastrectomy or gastric bypass in consecutive cases.** *Surg. Endosc.* 2020 Oct; **34**(10): 4330–4335. Publisher Full Text
18. Orces CH, Montalvan M, Tettamanti D: **Optimal waist circumference cutoff values for predicting metabolic syndrome among older adults in Ecuador.** *Diabetes Metab. Syndr.* 2019 Apr; **13**(2): 1015–1020. PubMed Abstract | Publisher Full Text
19. Snitker S: **Use of body fatness cutoff points.** *Mayo Clin. Proc.* 2010 Nov; **85**(11): 1057; author reply 1057-1058. PubMed Abstract | Publisher Full Text
20. Motamed N, Miresmail SJH, Rabiee B, *et al.*: **Optimal cutoff points for HOMA-IR and QUICKI in the diagnosis of metabolic syndrome and non-alcoholic fatty liver disease: A population based study.** *J. Diabetes Complicat.* 2016 Mar; **30**(2): 269–274. PubMed Abstract | Publisher Full Text
21. Lundell LR, Dent J, Bennett JR, *et al.*: **Endoscopic assessment of oesophagitis: clinical and functional correlates and further validation of the Los Angeles classification.** *Gut.* 1999 Aug 1; **45**(2): 172–180. PubMed Abstract | Publisher Full Text | Free Full Text
22. Tai C-M, Lee Y-C, Tu H-P, *et al.*: **The Relationship Between Visceral Adiposity and the Risk of Erosive Esophagitis in Severely Obese Chinese Patients.** *Obesity.* 2010 Nov; **18**(11): 2165–2169. PubMed Abstract | Publisher Full Text
23. Matar R, Maselli D, Vargas E, *et al.*: **Esophagitis After Bariatric Surgery: Large Cross-sectional Assessment of an Endoscopic Database.** *Obes. Surg.* 2020 Jan; **30**(1): 161–168. PubMed Abstract | Publisher Full Text

24. Xi B, Liang Y, He T, *et al.*: **Secular trends in the prevalence of general and abdominal obesity among Chinese adults, 1993-2009.** *Obes Rev Off J Int Assoc Study Obes.* 2012 Mar; **13**(3): 287–296.
PubMed Abstract | Publisher Full Text

25. Wu Y, Ma G, Hu Y, *et al.*: **The current prevalence status of body overweight and obesity in China: data from the China National Nutrition and Health Survey.** *Zhonghua Yu Fang Yi Xue Za Zhi.* 2005 Sep; **39**(5): 316–320.
PubMed Abstract

26. Cai L, Han X, Qi Z, *et al.*: **Prevalence of overweight and obesity and weight loss practice among Beijing adults, 2011.** *PLoS One.* 2014; **9**(9): e98744.
PubMed Abstract | Publisher Full Text

27. Tchernof A, Després J-P: **Pathophysiology of human visceral obesity: an update.** *Physiol. Rev.* 2013 Jan; **93**(1): 359–404.
PubMed Abstract | Publisher Full Text

28. Yoo S, Cho H-J, Khang Y-H: **General and abdominal obesity in South Korea, 1998-2007: gender and socioeconomic differences.** *Prev. Med.* 2010 Dec; **51**(6): 460–465.
PubMed Abstract | Publisher Full Text

29. Després J-P: **Body fat distribution and risk of cardiovascular disease: an update.** *Circulation.* 2012 Sep 4; **126**(10): 1301–1313.
Publisher Full Text

30. Hu L, Huang X, You C, *et al.*: **Prevalence of overweight, obesity, abdominal obesity and obesity-related risk factors in southern China.** *PLoS One.* 2017; **12**(9): e0183934.
PubMed Abstract | Publisher Full Text

31. Vasques AC, Rosado L, Rosado G, *et al.*: **Indicadores antropométricos de resistência à insulina.** *Arq. Bras. Cardiol.* 2010 Jul; **95**(1): e14–e23.
Publisher Full Text

32. Aguilar-Roa P, Echavarría-Sánchez M: **Relación circunferencia abdominal e insulinorresistencia y su impacto en parámetros seminales.** *Perinatol Reprod Humana.* 2016 Jun; **30**(2): 75–81.
Publisher Full Text

33. Carrera Boada CA, Martínez-Moreno JM: **Pathophysiology of diabetes mellitus type 2: beyond the duo "insulin resistance-secretion deficit.".** *Nutr. Hosp.* 2013 Mar; **28 Suppl 2**: 78–87.
PubMed Abstract | Publisher Full Text

34. Green HD, Beaumont RN, Wood AR, *et al.*: **Genetic evidence that higher central adiposity causes gastro-oesophageal reflux disease: a Mendelian randomization study.** *Int. J. Epidemiol.* 2020 Aug 1; **49**(4): 1270–1281.
PubMed Abstract | Publisher Full Text

35. Pandolfino JE, El-Serag HB, Zhang Q, *et al.*: **Obesity: a challenge to esophagogastric junction integrity.** *Gastroenterology.* 2006 Mar; **130**(3): 639–649.
Publisher Full Text

36. Ze EY, Kim BJ, Kang H, *et al.*: **Abdominal Visceral to Subcutaneous Adipose Tissue Ratio Is Associated with Increased Risk of Erosive Esophagitis.** *Dig. Dis. Sci.* 2017 May; **62**(5): 1265–1271.
PubMed Abstract | Publisher Full Text

37. Fass R: **Erosive esophagitis and nonerosive reflux disease (NERD): comparison of epidemiologic, physiologic, and therapeutic characteristics.** *J. Clin. Gastroenterol.* 2007 Feb; **41**(2): 131–137.
Publisher Full Text

38. Yu H-X, Han C-S, Xue J-R, *et al.*: **Esophageal hiatal hernia: risk, diagnosis and management.** *Expert Rev. Gastroenterol. Hepatol.* 2018 Apr; **12**(4): 319–329.
Publisher Full Text

39. El-Serag HB, Tran T, Richardson P, *et al.*: **Anthropometric correlates of intragastric pressure.** *Scand. J. Gastroenterol.* 2006 Aug; **41**(8): 887–891.
Publisher Full Text

40. Wu JC-Y, Mui L-M, Cheung CM-Y, *et al.*: **Obesity is associated with increased transient lower esophageal sphincter relaxation.** *Gastroenterology.* 2007 Mar; **132**(3): 883–889.
PubMed Abstract | Publisher Full Text

41. Anand G, Katz PO: **Gastroesophageal reflux disease and obesity.** *Gastroenterol. Clin. N. Am.* 2010 Mar; **39**(1): 39–46.
Publisher Full Text

42. Abdelkader NA, Montasser IF, Bioumy EE, *et al.*: **Impact of anthropometric measures and serum leptin on severity of gastroesophageal reflux disease.** *Dis Esophagus Off J Int Soc Dis Esophagus.* 2015 Oct; **28**(7): 691–698.
PubMed Abstract | Publisher Full Text

43. Kheirvari M, Dadkhah Nikroo N, Jaafarinejad H, *et al.*: **The advantages and disadvantages of sleeve gastrectomy; clinical laboratory to bedside review.** *Heliyon.* 2020 Feb; **6**(2): e03496.
PubMed Abstract | Publisher Full Text

44. Bang KB, Park JH: **Weight Loss as a Nonpharmacologic Strategy for Erosive Esophagitis: A 5-Year Follow-up Study.** *Gut Liver.* 2018 Nov 15; **12**(6): 633–640.
PubMed Abstract | Publisher Full Text

Open Peer Review

Current Peer Review Status: ✔ ? ?

Version 2

Reviewer Report 05 October 2022

https://doi.org/10.5256/f1000research.134543.r150289

© **2022 Apolaya-Segura M.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Moisés Apolaya-Segura
Facultad de Medicina, Universidad de San Martín de Porres, Chiclayo, Peru

The research allows evaluating the main biophysical variables and their association with the incidence of erosive esophagitis in an obese population after sleeve gastrectomy; it uses adequate selection criteria, being the preoperative evaluation a strength. However, it is necessary to add in the discussion aspects related to the short follow-up time carried out in the present study, with respect to other studies that have a longer follow-up time, and to discuss the postoperative treatment received, such as proton pump inhibitors, because perhaps these drugs can explain the results found (non-association), since in the limitations it is understood that the patients received as protocol the use of proton pump inhibitors is used for 2 to 3 months after surgery. Therefore, the conclusion should be conservative, until studies are developed with a longer follow-up time and consider the postoperative treatment received.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: epidemiology and public health physician

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Version 1

Reviewer Report 25 April 2022

https://doi.org/10.5256/f1000research.117659.r135643

© **2022 Nakajima K.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Kei Nakajima
[1] School of Nutrition and Dietetics, Faculty of Health and Social Services, Kanagawa University of Human Services, Yokosuka, Japan
[2] School of Nutrition and Dietetics, Faculty of Health and Social Services, Kanagawa University of Human Services, Yokosuka, Japan

This study aims to assess the association between the body mass index (BMI), waist circumference (WC), and body fat percentage (BFP) with the development of EE in adults with obesity three months after SG in a retrospective cohort of 106 obese patients. In conclusion, the authors found no association between preoperative anthropometric indexes and the development of de novo EE. This article is well written and of clinical interest. However, I have some concerns.

Major comments:

1. It is unclear why the authors selected the time point of three months after the surgery. I wonder if gastric function does not reach full recovery at the time point.

2. The primary purpose of sleeve gastrectomy is for weight loss. However, such data is not provided in this study. It may be interesting if weight loss is associated (inversely?) with the incidence of erosive esophagitis.

3. I suggest that the reference of BMI should be less than 30 or 35 in the regression model. In addition, I would like to know whether a dose effect association exists after classification into three or four groups, for instance, <30, 30-35, 35-40, > 40 BMI.

4. It may be better to include helicobacter pylori infection as a confounding factor in the logistic regression model.

Is the work clearly and accurately presented and does it cite the current literature?
No

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
No

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Obesity, diabetes, nutrition, cardiovascular risk factors

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 27 May 2022

Alba Zevallos

Thank you for the review of our manuscript. We would like to express our gratitude for your time invested in reading the paper. We are also thankful for the comments. Please, find our point-by-point response to the comments provided below. All changes made are included in the new version of the manuscript.

R2C1: It is unclear why the authors selected the time point of three months after the surgery. I wonder if gastric function does not reach full recovery at the time point.

AR1: Thank you so much for the comment. We would have liked to evaluate a longer follow-up; however, we have limited data to perform this analysis. Furthermore, we considered evaluating erosive esophagitis at three months cause the study by Jan.S Burgerhart showed an increase in acid exposure time at 3 months post sleeve gastrectomy measured by manometry, which is why we consider that there could be endoscopic signs of erosive esophagitis as early as 3 months post sleeve gastrectomy. We have added this information in the introduction: *"Jan S. Burgerhart showed that esophageal acid exposure increased significantly when comparing 24-h pH measurements before and 3 months after sleeve gastrectomy.[15] "*

R2C2: The primary purpose of sleeve gastrectomy is for weight loss. However, such data is not provided in this study. It may be interesting if weight loss is associated (inversely?) with the incidence of erosive esophagitis.

AR2: Thank you very much for the comment. We have added information about the weight loss in the results section: *"A higher mean of weight loss at 3 months postoperatively was observed in morbidly obese patients (26.78 kg vs. 19.50 kg)."* We agree that it would be interesting to evaluate whether weight loss is associated with the development of erosive esophagitis, however, that is beyond the scope of our study.

R2C3: I suggest that the reference of BMI should be less than 30 or 35 in the regression model. In addition, I would like to know whether a dose effect association exists after classification into three or four groups, for instance, <30, 30-35, 35-40, > 40 BMI.

AR3: Thank you very much for your suggestion, we will consider the new cut-off point for BMI for future studies. On the other hand, we believe that polytomizing the BMI variable would result in a loss of statistical power since the number of patients enrolled is not very large.

R2C4: It may be better to include helicobacter pylori infection as a confounding factor in the logistic regression model.

AR4: Thank you for the suggestion. According to our DAG (directed acyclic graph), the H. pylori infection was not considered as a confounder. We do believe that H. pylori is associated with obesity; however, it is important to mention that all our study participants had obesity. In addition, we had to mention that, since we only had 23 events, adding one more variable to our regression model could have generated overfitting.

Competing Interests: No competing interests were disclosed.

Reviewer Report 11 March 2022

https://doi.org/10.5256/f1000research.117659.r124758

© **2022 Goicochea-Lugo S.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Sergio Goicochea-Lugo
[1] EsSalud, Instituto de Evaluación de Tecnologías en Salud e Investigación, Lima, Peru
[2] EsSalud, Instituto de Evaluación de Tecnologías en Salud e Investigación, Lima, Peru

Congratulations for the article, it is important to be able to identify potential risk factors

associated with erosive esophagitis, even more so, using a design that can estimate relative risks.

I would also like to make the following comments that I hope will be useful.

Regarding the methods section:
I would recommend specifying the moment in which the data of the body mass index, waist circumference, and body fat percentage were obtained since it was not clear to me if these values were obtained before performing the gastrectomy (and at what time) or were obtained after performing the gastrectomy (and at what time).

This seemed important to clarify the discussion since you mention that not finding statistical differences could be due to the fact that the patients have a rapid and progressive weight loss. If it is possible to show the data of these variables three months after surgery in a table or as a narrative part, it would support this hypothesis.

Regarding the statistical analyses:
In the bivariate analyses, you found statistical differences between men and women. Have you raised the possibility that sex is an effect modifier rather than a confounder? It could be important to carry out an analysis with the regression model for men and women separately, taking into account the statistical and biological basis that you comment on in the discussion.

Other than that, I found the limitations mentioned and how they were dealt with to be correct.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: evidence based medicine

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 27 May 2022

Alba Zevallos

Thank you for the review of our manuscript. We would like to express our gratitude for your time invested in reading the paper. We are also thankful for the comments. Please, find our point-by-point response to the comments provided below. All changes made are included in the new version of the manuscript.

R1C1: I would recommend specifying the moment in which the data of the body mass index, waist circumference, and body fat percentage were obtained since it was not clear to me if these values were obtained before performing the gastrectomy (and at what time) or were obtained after performing the gastrectomy (and at what time). This seemed important to clarify the discussion since you mention that not finding statistical differences could be due to the fact that the patients have a rapid and progressive weight loss. If it is possible to show the data of these variables three months after surgery in a table or as a narrative part, it would support this hypothesis.

AR1: Thank you very much for the comment. We have added the time the anthropometric indexes were measured in the methods section: "*All three anthropometric indexes were measured on the day of surgery.*" Moreover, added information about the weight loss in the results section: "A higher mean of weight loss at 3 months postoperatively was observed in patients with morbid obesity (26.78 kg vs 19.50 kg)."

R1C2: In the bivariate analyses, you found statistical differences between men and women. Have you raised the possibility that sex is an effect modifier rather than a confounder? It could be important to carry out an analysis with the regression model for men and women separately, taking into account the statistical and biological basis that you comment on in the discussion.

AR2: Thank you for your comment. We agree that a sex-stratified analysis would have been interesting. Unfortunately, due to our limited sample size, we consider that this would have affected our estimates (and our confidence intervals). However, we hope to consider these analyses in further studies.

Competing Interests: No competing interests were disclosed.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research