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Percentage of excess body mass index loss and cardiometabolic risk reduction in Peruvian adults undergoing sleeve gastrectomy

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ABSTRACT

Objective: To assess the association between the percentage of excess body mass index loss (%EBMIL) and cardiometabolic risk reduction in Peruvian adults undergoing laparoscopic sleeve gastrectomy (LSG).
Methods: Retrospective cohort study conducted with adult patients who underwent LSG in a bariatric clinic during 2016–2020. The outcome variable was cardiometabolic risk change (expressed in Δ) 1 year after LSG. To that effect, the variables total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein (LDL) cholesterol, very LDL (VLDL) cholesterol, triglycerides, glucose, insulin, and HOMA-IR at baseline and after 12 months were considered. The exposure variable was %EBMIL. Crude and adjusted β coefficients were estimated with linear regression models.
Results: Of the 110 patients analyzed, 68.2% were women, and the median patient age was 34.5 years. In the model adjusted for sex, age, and baseline BMI, we noted that each 25% increase in %EBMIL resulted in a decrease in the values for total cholesterol, LDL, triglycerides, and insulin by 10.36 mg/dL ($p < 0.001$), 7.98 mg/dL ($p = 0.001$), 13.35 mg/dL ($p = 0.033$), and 3.63 uU/mL ($p = 0.040$), respectively.
Conclusion: %EBMIL was associated with a decrease in total cholesterol, LDL, triglycerides, and insulin levels, which could suggest a favorable cardiometabolic evolution during the first 12 months following LSG.

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1. Introduction

Over the last few years, obesity has become a health concern worldwide. According to the World Health Organization, there has been a three-fold increase in obesity cases since 1975, affecting more than 650 million adults in 2016, which accounted for 13% of the population (World Health Organization, 2020). In Latin America, the burden of obesity has increased in recent years, with high percentages varying by region and socioeconomic status (Jiwani et al., 2019; Popkin and Reardon, 2018; Lanas et al., 2016). In 2016, the Panorama of Food and Nutrition Security in Latin America and the Caribbean noted that nearly 140 million people (~23% of the region's inhabitants) had obesity (Organización de las Naciones Unidas, 2016).

Obesity is a chronic and multifactorial condition that affects several body systems and is associated with significant morbidity and mortality. It has been associated with cardiovascular diseases, different types of cancer, and endocrine and locomotor alterations (World Health Organization, 2020; Lavie et al., 2017). Furthermore, it is described as a pro-inflammatory state which involves several mediators, such as cytokines (TNF-alpha, interleukin 1), and growth factors such as VEGF-A, which cause vascular changes through the constant tissue destruction and repair (García de la Torre et al., 2008). Bariatric surgery is considered an effective long-term treatment against obesity, and its main purpose is to achieve gradual weight loss by reducing and remitting its comorbidities (Wolfe et al., 2016). This is especially important because sustained weight loss has been reported to be associated with delayed onset and remission of cardiometabolic disease (Bailey-Davis et al., 2022; Iwamoto et al., 2021; Schauer et al., 2016). In fact, some evidence suggests that patients undergoing bariatric surgery have a lower risk of myocardial infarction and other cardiovascular events compared to patients who did not undergo this procedure (Kwok et al., 2014). The most common types of bariatric surgery are Roux-en-Y gastric bypass (RYGB) and LSG, the latter being the most commonly performed in Peru (The International Federation for the, 2019).

For a long time, studies seeking to establish an association between weight loss and remission of comorbidities have been based on parameters with limited accuracy and usefulness, such as weight loss, and BMI loss, and comparisons between actual and ideal weight, with the latter being measured in absolute numbers (Lynch and Belgaumkar, 2012; Dixon et al., 2005). These parameters have been described as inconsistent by some studies since it was not possible to standardize ideal weight as an assessment and follow-up parameter for post-surgical results. Moreover, ideal weight is not a range *per sé*, and there is not enough evidence to support its association with good clinical outcomes (Dixon et al., 2005).

Some studies have analyzed the remission of comorbidities associated with weight loss as an absolute number in the past. However, current evidence suggests that this may not be the best parameter (Deitel et al., 2007; Rossi et al., 2009). For this reason, other anthropometric indicators are now being used, such as the percentage of excess body mass index loss (%EBMIL), owing to the fact it has higher sensitivity and specificity for some comorbidities such as metabolic syndrome (Wolfe et al., 2016). In addition, the evidence currently available is scarce for the Latino population.

In patients undergoing bariatric surgery, cardiometabolic risk (which indicates the presence of a set of risk factors that usually explain the early subclinical expression of cardiovascular disease (CVD) risk in the populations) (Gesteiro et al., 2021; Laing et al., 1540), should be assessed comprehensively through clinically important biochemical markers that have been shown to have a significant impact on morbidity and mortality, especially in patients with obesity (Santos et al., 2020; Indumathy et al., 2018; Ali et al., 2018; Florez et al., 2006; Kimball et al., 2019).

For the abovementioned reasons, the purpose of this study was to assess the association between the %EBMIL and cardiometabolic risk reduction in Peruvian adults undergoing sleeve gastrectomy.

2. Methods

2.1. Study design and context

This was a retrospective cohort study conducted on adult patients who underwent sleeve gastrectomy (LSG) in the Clínica Avendaño from 2016 to 2020. Clínica Avendaño is a major outpatient surgery center in Lima, the capital city of Peru. It is mainly dedicated to bariatric surgery and follows a multidisciplinary approach. Most surgeries are LSGs, although RYGB surgery is also performed.

2.2. Population and sample

We included patients aged ≥18 years with a BMI of ≥30 kg/m^2. All patients had undergone LSG with a 1-year follow-up at the clinic.

Estimations based on a hypothetical scenario were performed *a priori* based on Cohen's proposal (Serdar et al., 2021). Therefore, a minimum sample size of 94 patients was estimated to detect a moderate (reverse) correlation of at least 0.3 ("conservative scenario") between exposure (%EBMIL) and cardiometabolic risk reduction, with 80% potency and adding 10% to the result obtained to account for incomplete or inconsistent data.

Patients with history of unstable angina, acute myocardial infarction, cerebrovascular accident over the last 12 months before surgery, chronic kidney failure or insulin-dependent diabetes were excluded. Patients who had undergone bariatric surgery in the past were also excluded.

2.3. Outcome

The outcome variable was cardiometabolic risk change (expressed in Δ) 1 year after LSG. The following variables were considered: total cholesterol (mg/dL), high-density lipoprotein (HDL) cholesterol (mg/dL), low-density lipoprotein (LDL) cholesterol (mg/dL), very LDL cholesterol (mg/dL), triglycerides (mg/dL), glucose (mg/dL), insulin (uU/mL) and HOMA-IR, both at baseline (before surgery) and at follow-up (12 months after LSG). All laboratory tests were taken after fasting for at least 8 h.

2.4. Exposure

The exposure variable was %EBMIL, which was estimated with the following formula: [(BMI before surgery − BMI during follow-up)/(BMI before surgery − 25) × 100]. BMI before surgery was measured before the surgical procedure (within a period of no more than two months), and BMI follow-up BMI was measured 12 months after surgery.

2.5. Other variables

The following variables were also considered: sex (female/male), age (years), and history of hypertension (yes/no), type 2 diabetes (yes/no), hypothyroidism (yes/no), and obstructive sleep apnea (yes/no).

2.6. Study procedures

This study analyzed secondary data obtained from the clinic's institutional database. This database is fed by the information obtained by the clinic's clinical and epidemiological surveillance system, which uses information from physical and electronic medical records. Patients' basic characteristics, comorbidities, surgery characteristics, and laboratory and anthropometric tests before and after surgery were obtained. Data included %EBMIL and laboratory values related to cardiometabolic risk.

2.7. Statistical analysis

The database underwent a quality control process to identify missing and implausible values. The complete medical record was reviewed if inconsistencies were identified. Once this process was completed, the coded database was imported to Stata v17.0 statistical software (StataCorp, TX, USA) for its analysis.

For descriptive analysis, median and 25th–75th percentiles were used for age, and means and standard deviations (SD) were used for all cardiometabolic risk variables, both at baseline and follow-up. Moreover, a paired Student's t-test was performed to identify any significant difference between variables at both times, and Δ was presented and expressed as mean and SD. However, categorical variables were presented as absolute and relative frequencies.

The Pearson's correlation test was used to determine the correlation between %EBMIL and the Δ of each cardiometabolic risk component. Finally, to assess the association of interest, raw (rβ) and adjusted (aβ) coefficients were estimated with bivariate and multivariate linear regression models, respectively. An epidemiological approach was adopted to estimate the latter, adjusting the confounding variables age, sex, and baseline BMI.

Multicollinearity was determined based on the variance inflation factor, and values lower than 10 were deemed acceptable. "Conditioning" on the independent variables matrix was also assessed. No collinearity issues were observed in any scenario. It is worth mentioning that, for model construction, compliance with the linearity, homoscedasticity (using Breusch–Pagan/Cook–Weisberg test), and normality of studentized residuals was considered. In some cases, the homoscedasticity assumption was not met, and regression models included robust standard errors were used. Independent models were presented for each cardiometabolic risk component, as described above. All estimations were presented with their respective 95% confidence intervals (95% CI), and $p < 0.05$ indicated statistical significance.

2.8. Ethical considerations

This study was approved by the Ethics Committee of the of Universidad Católica Santo Toribio de Mogrovejo (N° 500-2020-USAT-FMED). Patients' personal data were not revealed and all the information remained as confidential.

3. Results

3.1. General characteristics

The study population consisted of 110 patients with a 12-month follow-up after LSG. Their mean age was 34.5 years (25th–75th percentiles: 27–39 years), and 75 patients (68.2%) were female. Regarding their comorbidity history, 12 patients (10.9%) had hypertension, 5 (4.6%) had type 2 diabetes mellitus, 6 (5.6%) had hypothyroidism, and 23 (20.9%) had obstructive sleep apnea.

3.2. Cardiometabolic risk at baseline and after 12 months

Table 1 shows average values for each cardiometabolic risk and BMI marker, both at baseline and after 12 months. All markers decreased significantly at follow-up ($p < 0.001$) except for HDL cholesterol, whose value increased ($p < 0.001$).

3.3. %EBMIL and change in cardiometabolic risk markers

%EBMIL showed a significant and negative correlation with total cholesterol ($r = -0.351$, $p < 0.001$), LDL cholesterol ($r = -0.384$, $p < 0.001$), and triglyceride ($r = -0.197$, $p = 0.039$) values (Table 2). In the linear regression analysis adjusted by sex, age, and baseline BMI, our results demonstrated that every 25% increase in %EBMIL resulted in a decrease in the total cholesterol, LDL cholesterol, triglyceride, and insulin values by 10.36 mg/dL (<0.001), 7.98 mg/dL ($p = 0.001$), 13.35 mg/dL ($p = 0.033$), and 3.63 uU/mL ($p = 0.040$), respectively (Table 3).

Table 1
Cardiometabolic risk variables at baseline and at 12 months in the study population (n = 110).

Variable	Baseline	At 12 months	Δ*
Total cholesterol (mg/dl)	192.9 ± 40.3	167.3 ± 29.9	−25.6 ± 35.1
HDL (mg/dl)	46.2 ± 12.6	56.2 ± 18.2	10.0 ± 14.5
LDL (mg/dl)	117.0 ± 33.4	91.8 ± 22.4	−25.2 ± 29.0
VLDL (mg/dl)	29.9 ± 12.8	19.9 ± 8.3	−10.0 ± 10.2
Triglycerides (mg/dl)	160.4 ± 84.6	101.3 ± 44.9	−59.1 ± 74.0
Glucose (mg/dl)	91.4 ± 18.5	84.2 ± 8.9	−7.2 ± 16.4
Insulin (uU/ml)	27.1 ± 25.3	8.6 ± 5.2	−18.5 ± 25.1
HOMA-IR	6.2 ± 5.7	1.9 ± 1.3	−4.3 ± 5.5
BMI (kg/m2)	37.3 ± 4.9	26.1 ± 3.6	−11.2 ± 4.2

Variables are presented as mean (SD).
Δ (Delta): Value at 12 months - Baseline value.
*A paired Student's t-test was performed, obtaining a p-value <0.001 for all cases.
HDL: high-density lipoprotein, LDL: low-density lipoprotein, VLDL: very-low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance, BMI: body mass index.

Table 2
Correlation between %EBMIL and change (Δ) in cardiometabolic risk markers.

	Total cholesterol (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	VLDL (mg/dl)	Triglycerides (mg/dl)	Glucose (mg/dl)	Insulin (uU/ml)	HOMA-IR
%EBMIL								
r	−0.351	0.119	−0.384	−0.056	−0.197	0.134	0.088	0.165
p-value	<0.001	0.216	<0.001	0.561	0.039	0.163	0.363	0.085

%EBMIL: Percentage of Excess Body Mass Index Lost.
r: Pearson's r coefficient.
HDL: high-density lipoprotein, LDL: low-density lipoprotein, VLDL: very-low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance.

Table 3
Association between %EBMIL with change (Δ) in cardiometabolic risk markers.

Exposure: %EBMIL[a]	Crude model			Adjusted model		
	cβ	95% CI	p	aβ	95% CI	p
Outcome:						
Δ Cardiometabolic risk variable						
Total cholesterol (mg/dl)	−9.36	−14.69 a −4.04	<0.001	−10.36	−15.82 a −4.91	<0.001
HDL (mg/dl)	1.31	−0.77 a 3.39	0.216	1.52	−0.88 a 3.93	0.212
LDL (mg/dl)	−8.46	−13.22 a −3.69	<0.001	−7.98	−12.43 a −3.53	0.001
VLDL (mg/dl)	−0.43	−1.90 a 1.04	0.561	−0.75	−2.27 a 0.76	0.326
Triglycerides (mg/dl)	−11.10	−21.62 a −0.57	0.039	−13.35	−25.59 a −1.10	0.033
Glucose (mg/dl)	1.67	−1.00 a 4.33	0.217	2.52	−0.22 a 5.26	0.071
Insulin (uU/ml)	1.67	−1.96 a 5.30	0.363	−3.63	−7.07 a −0.18	0.040
HOMA-IR	0.69	−0.30 a 1.07	<0.001	−0.41	−1.17 a 0.35	0.287

HDL: high-density lipoprotein, LDL: low-density lipoprotein, VLDL: very-low-density lipoprotein, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance.
*Adjusted for sex, age and baseline BMI.
[a] The %EBMIL was scaled every 25%.

4. Discussion

4.1. Main findings

%EBMIL was associated with a decrease in insulin values and some lipid profile laboratory values 12 months after a sleeve gastrectomy. To the best of our knowledge, this is the first study conducted on a Peruvian population and one of the first ones conducted on a Latin American population to assess the effect of the results of this anthropometric method on cardiometabolic risk variables in bariatric patients.

4.2. Comparison with other studies

Nora M et al. (2014) conducted a study on patients with BMI of >35 kg/m^2 who underwent RYGB in a Portuguese hospital and who complied with the "Harmonizing" criteria for metabolic syndrome. In their study, a suitable %EBMIL performance (areas under the curve [AUC], 0.75–0.85) was evidenced as a predictor of metabolic syndrome remission after six months and 1, 2, and 3 years (Nora et al., 2014). Similarly, Rossi M et al. (2009) conducted a study on patients with morbid obesity who underwent RYGB in a Brazilian clinic. Authors described the %EBMIL performance as suitable (AUC: 0.846, 95% CI: 0.78–0.90) to classify patients with metabolic syndrome remission (defined pursuant to the International Diabetes Federation criterion). Therefore, considering a 64.55% cut-off point, 100% and 61.3% sensitivity and specificity were obtained, respectively (Rossi et al., 2009).

Notably, even though none of the two abovementioned studies followed our study approach, i.e., assessing the association between %EBMIL and change in different cardiometabolic risk markers, their findings suggest a potential use of %EBMIL as a tool to predict metabolic syndrome resolution. However, we should consider that the population in both studies consisted of adults with a BMI of ≥35 kg/m^2 who had undergone RYGB, whereas our study included subjects with BMI above 30 kg/m^2 who underwent LSG.

Despite the fact that some studies suggest that LSG and RYGB are similar in terms of weight loss 1-year after surgery (Peterli et al., 2018; Otto et al., 2016), after adjusting by baseline BMI, it has been reported that patients subject to RYGB with a higher weight before surgery experience a lower %EBMIL than patients who were initially "lighter." Furthermore, this accounts for the fact that %EBMIL has a higher variation coefficient than other anthropometric indicators (Sczepaniak et al., 2015). Additionally, even though bariatric surgery is considered a safe procedure, RYGB usually has a relatively higher rate of complications than LSG (Osland et al., 2016), which may confound the effect of %EBMIL on the different outcomes.

As mentioned before, our results cannot be fully comparable with those obtained in the two abovementioned studies. Moreover, the external validity of those two studies is already limited itself when compared with our study since LSG is the bariatric surgery most commonly performed in Peru (The International Federation for the, 2019). However, this could be considered a positive point since our study would be supplementing the evidence currently available.

4.3. Result interpretation

Several mechanisms have been proposed thus far that could account for the effect of bariatric surgery on the remission of some metabolic disorders. Some of these mechanisms include BMI decrease, dietary improvements, visceral fat reduction, and improvements in the endothelial function, fatty acid metabolism, and general inflammatory response (Lupoli et al., 2016; Walle et al., 2017; Sinclair et al., 2018; Ji et al., 2021).

Not only BMI reduction is a bariatric surgery effect, but it can positively affect metabolism alone. A clinical trial conducted on obese adults showed that a 5% weight loss improved insulin sensitivity of the fat tissue, muscle, and liver, and improved β cell function. In addition, a 16% or higher weight loss was shown to decrease free fatty acid and C reactive protein concentrations, along with an increase in plasma adiponectin levels (Magkos et al., 2016). Higher weight loss may have a closer relationship with the potential additional effect of bariatric surgery since this procedure results in a higher BMI decrease as opposed to other therapies (Maciejewski et al., 2016; Gloy et al., 2013). Moreover, adiponectin levels are negatively correlated with insulin resistance (Sinclair et al., 2018), which could also account for the potential effect of the decrease in BMI based on these values.

However, weight loss has been associated with variations in the fatty acid composition in fat tissue (Kunešová et al., 2012). This is closely related to its direct effect on lipid profile, regardless of the patients' baseline BMI (Kiriyama et al., 2021). As a consequence, it has been reported that weight losses of around 3 kg result in 15 mg/dL decrease in triglyceride levels, and weight losses of 5–8 kg may result in 5 mg/dL in LDL cholesterol and a 2–3 mg/dL increase in HDL cholesterol (Uranga and Keller, 2019).

Finally, a BMI decrease has proven to reduce the size of fat cells (Ye et al., 2022). In turn, this decrease is closely correlated with improved insulin sensitivity (Andersson et al., 2014), which is why this mechanism adds up to the one described in previous paragraphs, further supporting the effect of %EBMIL on insulin level changes following bariatric surgery.

4.4. Relevance to clinical-surgical practice

Bariatric surgery has proven to be an effective and safe, as well as a long-term maintenance procedure for weight reduction in patients with obesity (Wolfe et al., 2016; Rasera et al., 2017). In addition, it is regarded as the best treatment for associated metabolic comorbidities (Wolfe et al., 2016; Schroeder et al., 2016). In this sense, bariatric surgery success goes beyond weight loss; it should also result in comorbidity remission.

The findings in our study, as well as the evidence currently available, provide a favorable scenario for the potential use of %EBMIL as a predictor of positive cardiometabolic evolution in bariatric patients. It should also be noted that timely identification of metabolic complications is one of the fundamental pillars in the processes currently recommended for the follow-up optimization after bariatric surgery (Mingrone et al., 2018).

4.5. Limitations

Our study has some limitations. First, it included a relatively short follow-up period (12 months). Patient assessment and evolution should be completed with medium and long-term data. Second, the medical history record reported in the study corresponds to the report given by the patient. In some cases, the diagnosis was made during the patient's preoperative evaluations; however, this information could not be obtained from the database. For this reason, the real frequency of comorbidities may be underestimated. Third, for patients with diabetes, some hypoglycemic drugs may also have had effects on weight; however, this could not be assessed in the present study. Fourth, some metabolic parameters that could have been of interest, such as HbA1c, could not be considered due to the lack of information at one year after surgery. Fifth, there may be many possible reasons why follow-up could not be completed in some patients. As we used a secondary database, we could not complete that follow-up, resulting in a possible selection bias. Sixth, complications were not considered as they were not the primary objective of the study. However, there is an actual possibility that complications may affect patients' weight loss and, as a consequence, their %EBMIL, so there is a possible unmeasured confounding bias.

4.6. Recommendations

Future research should conduct a prospective evaluation covering a more extended period to determine if the effect reported by this study remains in the medium and long term. Moreover, a cut-off points for %EBMIL should be determined for complex long-term outcomes, such as diabetes and metabolic syndrome remission. These studies should consider different confounding factors, such as complications emerging during patient follow-up. Finally, the potential utility of this or other anthropometric markers should be explored in prognostic validation studies as part of models used to predict the remission of different cardiometabolic disorders.

5. Conclusion

In our study population, %EBMIL was associated with a decrease in total cholesterol, LDL cholesterol, triglyceride, and insulin levels, which could suggest a favorable cardiometabolic evolution during the first 12 months following sleeve gastrectomy.

Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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