



Original Article

## Laparoscopic sleeve gastrectomy for weight loss and treatment of type 2 diabetes mellitus



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### المخلص

**أهداف البحث:** فقدان الوزن هو عنصر أساسي في علاج النوع الثاني من السكري. يمكن تحقيق هذه النتيجة عن طريق تكميم المعدة بالمنظار. تهدف هذه الدراسة لتحديد فاعلية تكميم المعدة بالمنظار لإنقاص الوزن، وتقييم تأثيرها للتحكم على النوع الثاني من السكري عن طريق قياس السكر التراكمي ومؤشر كتلة الجسم قبل الجراحة وخلال العام الأول بعد تكميم المعدة بالمنظار.

**طرق البحث:** أجريت هذه الدراسة بأثر رجعي على ٣٤٠ مريضاً أعمارهم  $\geq 15$  عاماً، مصابون بالنوع الثاني من السكري ومؤشر كتلة الجسم  $\geq 35$  كجم/م<sup>٢</sup>. خضع هؤلاء المرضى لعملية تكميم المعدة بالمنظار في مستشفى الملك فهد بالمدينة المنورة بالمملكة العربية السعودية بين ١ يناير ٢٠١٥ و ٣١ يوليو ٢٠١٩. تم قياس السكر التراكمي ومؤشر كتلة الجسم قبل الجراحة وبعدها في أقل من شهر واحد، ١-٣، ٤-٦، ٧-٩، ١٠-١٢ شهراً وبعدها عام واحد.

**النتائج:** انخفض المتوسط لمؤشر كتلة الجسم بشكل مستمر من ٤٩.٢٧ كجم/م<sup>٢</sup> قبل العملية إلى ٣٢.٧٢ كجم/م<sup>٢</sup> بعد ١٠-١٢ شهراً من تكميم المعدة بالمنظار. كان هناك انخفاض ملحوظ في متوسط السكر التراكمي من ٨.٣٨٪ إلى ٦.٤٣٪ في عام واحد. وصل ٧٥٪ من المرضى إلى المستوى المطلوب للسكر التراكمي ٦.٥٪ أو أقل في عام واحد. أظهر ٢٥٪ المتبقين من المرضى تحسناً في السكر التراكمي ولكن أقل من المستوى المطلوب.

**الاستنتاجات:** تدعم هذه الدراسة النتيجة الإيجابية لعملية تكميم المعدة بالمنظار على كلاً من فقدان الوزن وحالة السكري. هناك انخفاض كبير في كلاً من مؤشر كتلة الجسم (حتى العام الأول) ومستويات السكر التراكمي بعد الجراحة.

**الكلمات المفتاحية:** جراحات السمنة؛ تكميم المعدة بالمنظار؛ السمنة؛ النوع الثاني من السكري؛ فقدان الوزن

### Abstract

**Objectives:** Weight loss is a key component in the management of type 2 diabetes mellitus (T2DM). This outcome can be potentially achieved by laparoscopic sleeve gastrectomy (LSG). This study aims to determine the efficacy of LSG in reducing weight and to evaluate its impact on controlling T2DM by measuring HbA1c and body mass index (BMI) preoperatively and during the first year following the procedure.

**Methods:** This retrospective study was carried out on 340 patients aged  $\geq 15$  years who had T2DM and a BMI of  $\geq 35$  kg/m<sup>2</sup>. These patients had LSG at King Fahad Hospital Almadinah Almunawwarah KSA between January 2015 and July 2019. Their HbA1c and BMI were measured preoperatively and then postoperatively at less than one month, 1–3, 4–6, 7–9, and 10–12 months as well as after one year.

**Results:** Average BMI dropped consistently from a pre-operative BMI of 49.27 kg/m<sup>2</sup> to 32.72 kg/m<sup>2</sup> at 10–12 months following LSG. A reduction in HbA1c from 8.38% to 6.43% was observed over one year ( $p = 0.0001$ ). Seventy-five percent of the patients achieved the HbA1c target of 6.5% or less within one year. The remaining

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25% of the patients showed improvement in their HbA1c but did not reach the target level.

**Conclusion:** This study endorses a positive impact of LSG on both weight loss and diabetic status. There was a significant reduction of both BMI (up to the first year) and HbA1c levels postoperatively.

**Keywords:** Bariatric surgery; Laparoscopic sleeve gastrectomy; Obesity; Type 2 diabetes mellitus; Weight loss

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## Introduction

The prevalence of overweight and obesity has increased dramatically worldwide within the last three decades.<sup>1</sup> KSA is no exception; it is now among the countries with the highest prevalence of obesity, estimated at 36% in females and 23% in males over the age of 15 years.<sup>2,3</sup> There are multiple factors that lead to obesity, primarily diet pattern and eating habits, genetic factors, marital status, and lack of physical activity.<sup>4,5</sup> The major consequences of obesity are diabetes,<sup>6</sup> hypertension,<sup>7</sup> coronary artery disease,<sup>8</sup> and stroke.<sup>9</sup> According to the WHO, KSA has the second highest rate of diabetes in the Middle East and the seventh highest in the world, with an estimated population of seven million diagnosed with diabetes and more than three million with pre-diabetes.<sup>10,11</sup> Ninety percent of patients with T2DM are overweight or obese.<sup>12</sup> Despite significant advances in the pharmacological treatment of diabetes, only 50% of patients achieve the recommended level of HbA1c.<sup>13</sup> Weight loss is a key component of diabetes management.<sup>14</sup> Different strategies have been used to address obesity, including prevention, dietary and lifestyle modification, and behavioural and pharmacological therapy, but these current therapies are usually ineffective in maintaining sustained weight loss.<sup>15</sup> Both physical activity and diet can achieve long-lasting weight loss. However, it is difficult for patients to maintain long-term commitment, and weight reduction from a low-calorie diet tends to rebound within 2–5 years.<sup>16</sup>

Bariatric surgery is a surgical treatment option for weight loss and the most effective method for achieving long-term weight loss.<sup>17</sup> Bariatric surgical operations lead to weight loss by decreasing the amount of food intake and/or adjusting the physiological changes that cause weight regain.<sup>18</sup> Different studies have shown that bariatric surgeries have a sustainable and adequate effect on weight loss. A meta-analysis of 4742 patients showed that over both a short- and a long-term period, Laparoscopic Roux-En-Y Gastric Bypass (LRYGB) has a significantly better % TWL outcomes, while laparoscopic sleeve gastrectomy (LSG) shows higher Percentage total weight loss (%TWL) in the mid-term.<sup>19</sup> In addition, a significantly better Percentage

Excess Weight Loss (%EWL) is reported over the long term as a result of LRYGB than as a result of LSG.<sup>19</sup> Furthermore, LSG is easier to perform with a shorter operative time and low complication incidence, such as dumping syndrome, internal hernia, marginal ulcer, and vitamin deficiency.<sup>20</sup> It is thus preferable to other bariatric procedures and is the most commonly performed such procedure in KSA.

Post-surgical weight loss can improve all comorbidities associated with obesity, which will, in turn, improve quality of life and decrease the overall mortality rate.<sup>21</sup> However, there a limited number of studies have been conducted in KSA to determine the effectiveness of LSG as one of the treatment options for obese patients with T2DM.

The objective of this study is to confirm the efficacy of LSG on reducing weight and determine its effect on controlling T2DM by measuring HbA1c and BMI before and after one year following surgery.

## Materials and Methods

Bariatric surgery can be classified as restrictive, mal-absorptive, or a combination of the two.<sup>22</sup> Restrictive operations aim to decrease the size of the stomach, which decreases the amount of food consumption and thus leads to weight loss.<sup>22</sup> Malabsorptive procedures decrease absorption by reducing the time during which digestive enzymes interact with food, which also results in weight loss.<sup>23</sup> As seen in [Figure 1](#), LSG is a simple operation, which results in forming a 15-20%-sized tubular stomach along the lesser curve.<sup>24</sup> Resection of the fundus and antrum produce an alteration of gut hormones and major endocrine changes.<sup>25</sup> These changes are primarily responsible for the mechanism of weight loss and remission of T2DM following LSG.

This is an analytical retrospective study performed by reviewing the files of all patients undergoing LSG between the 1st of January, 2015, and the 31st of July, 2019 (a total of 340 patients) at King Fahad Hospital in Almadinah Almunawwarah, KSA. One hundred and seventy-six of these patients (both genders) met the inclusion criteria; age  $\geq 15$  years, BMI  $\geq 35$  kg/m<sup>2</sup>, and diagnosed with T2DM. All 176 of the patient had T2DM preoperatively, and of these, only 41 patients had full HbA1c readings at the end of the study period. These 41 patients were the subjects of this study. [Figure 2](#) shows the method of patient selection. The study was approved by both the Institutional Review Board of King Fahad Hospital Research Center- Almadinah Almunawwarah, KSA and the Scientific Research Ethics Committee (CM-REC) at Taibah University - Almadinah Almunawwarah, KSA. The data for this study were collected from electronic medical records between the 8th of March and the 24th of July, 2019. These data were saved in a password-secured Excel 2010 program file accessible only by the study team to ensure patient privacy and confidentiality. No identifier data were disclosed; therefore, the patients' consent was not required.

The measurement tools were based on patients' age, gender, and preoperative and postoperative HbA1c readings in percent as well as their BMI in kg/m<sup>2</sup> at less than one month, 1–3, 4–6, 7–9, and 10–12 months, and one year

following the surgery. For the purpose of the study, 6.5% was considered the delineation between a normal and an abnormal HbA1c. In cases in which multiple readings were recorded in the same study interval, the average of the readings was taken. Diabetic medications taken by patients preoperatively as well as any other chronic diseases were also

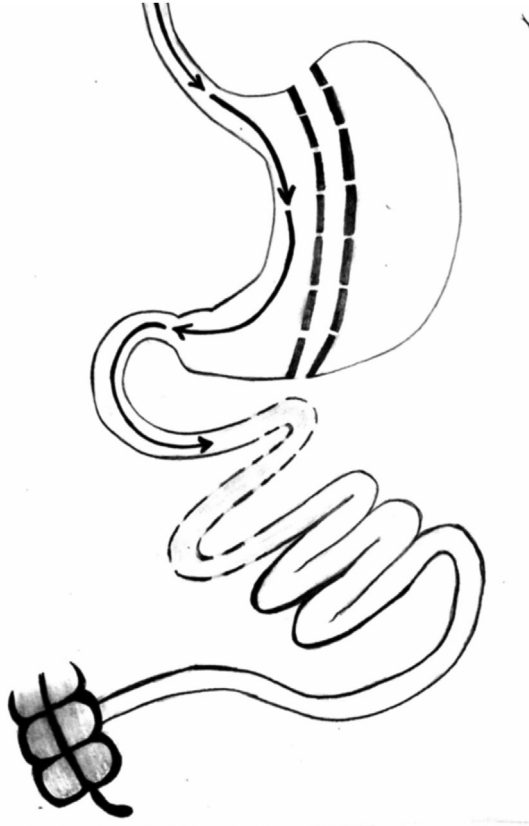
recorded. The Statistical Package for the Social Sciences (SPSS) version 21 was used for data analysis, while the Wilcoxon signed ranks test was used for quantitative data analysis. A p-value of less than 0.05 was considered statistically significant in the final models.

## Results

Since our objective was to confirm the efficacy of LSG on reducing weight and to determine its effect on controlling T2DM, our results were aimed at measuring both HbA1c and BMI in our selected study population, before and throughout one year following the surgery.

### Study population

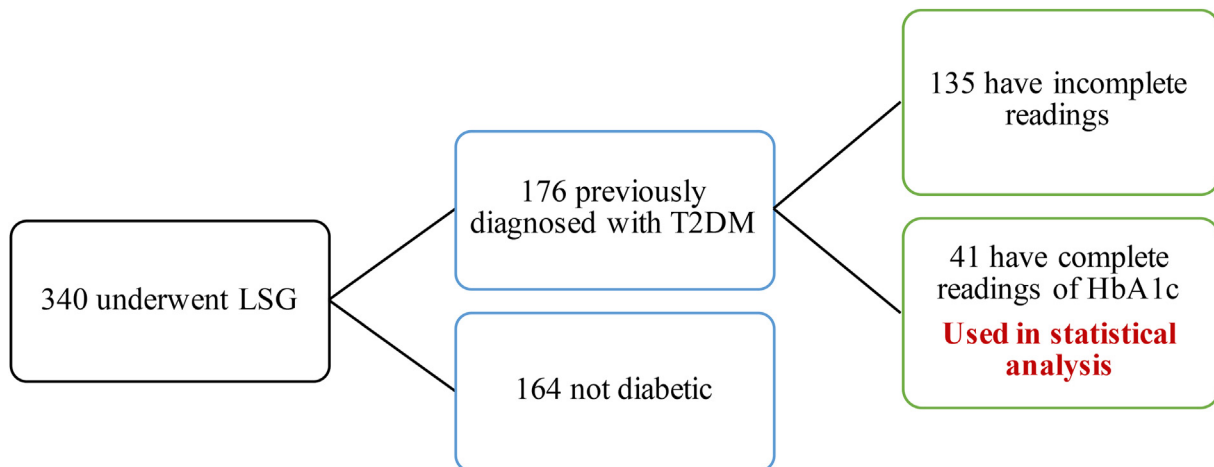
The study population included all of the 340 obese patients who underwent LSG between the 1st of January, 2015, and the 31st of July, 2019. These patients were subjected to further sub-selection as shown in Figure 2, with only 41 patients remaining who fulfilled the criteria and had a complete set of tests. As shown in Table 1 and 32 of these 41 patients (78%) were female, and 9 (22%) were male. The mean of the preoperative BMI (baseline) was 49.29 kg/m<sup>2</sup> with a median of 48.44 kg/m<sup>2</sup>, and the mean preoperative HbA1c (baseline) was 8.38% with a median of 8.3%. Most of the patients (95%) had poor glycaemic



**Figure 1:** LSG including resection of the greater curvature and fundus of the stomach.

**Table 1: The age and gender of the 41 patients.**

Variable			
Age (years)	Mean ± Std.D	47.54 ± 10.791	
Gender		Frequency	Percent
	Male	9	22.0
	Female	32	78.0
	Total	41	100.0



**Figure 2:** Method of patient selection for the study.

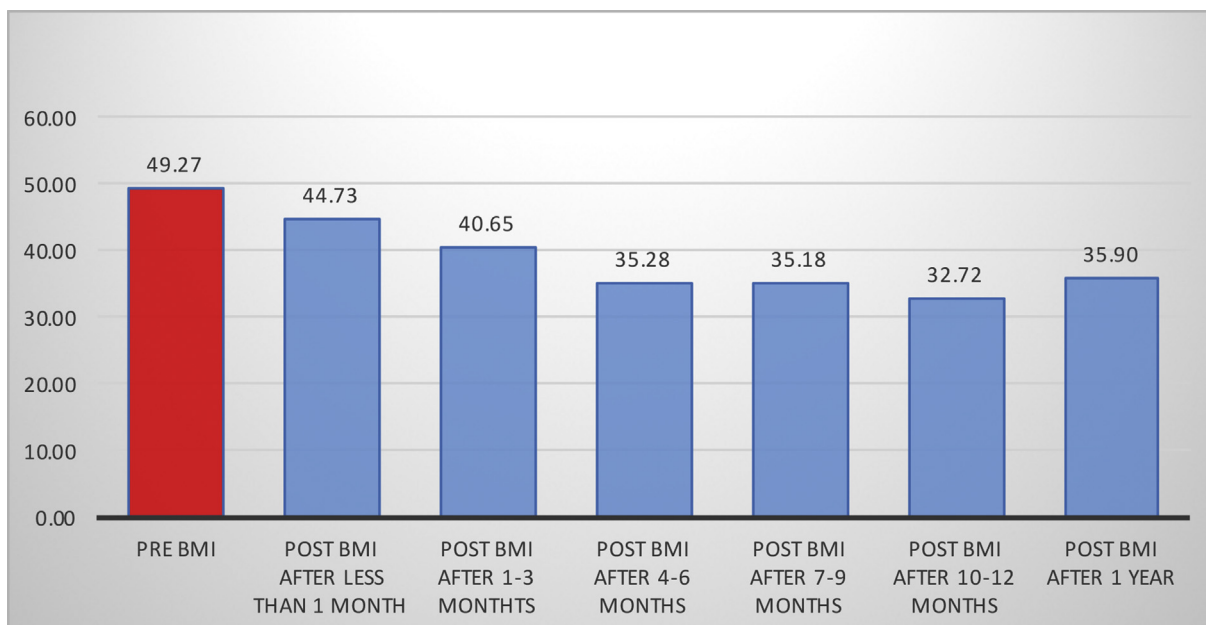


Figure 3: Changes in the average BMI throughout the study period.

Table 2: The Wilcoxon signed ranks test results for the differences in BMI before and throughout one year following surgery.

Comparison	Rank Type	Mean Rank	Sum of Ranks	Z	p-value
Post BMI after less than 1 month – Pre BMI	Negative Ranks	10.50	210.0	3.920	<b>.000*</b>
	Positive Ranks	0.00	0.00		
Post BMI after 1–3 months - Pre BMI	Negative Ranks	11.33	238.00	3.620	<b>.000*</b>
	Positive Ranks	15.00	15.00		
Post BMI after 4–6 months - Pre BMI	Negative Ranks	13.95	349.00	4.407	<b>.000*</b>
	Positive Ranks	2.00	2.00		
Post BMI after 7–9 months - Pre BMI	Negative Ranks	8.50	136.00	3.516	<b>.000*</b>
	Positive Ranks	.00	.00		
Post BMI after 10–12 months - Pre BMI	Negative Ranks	5.50	55.00	2.803	<b>.005*</b>
	Positive Ranks	.00	.00		
Post BMI after 1 year - Pre BMI	Negative Ranks	7.50	105.00	3.296	<b>.001*</b>
	Positive Ranks	.00	.00		

Wilcoxon signed ranks test: \*Differences found; p-value less than 0.05 (statistically significant) are indicated in bold.

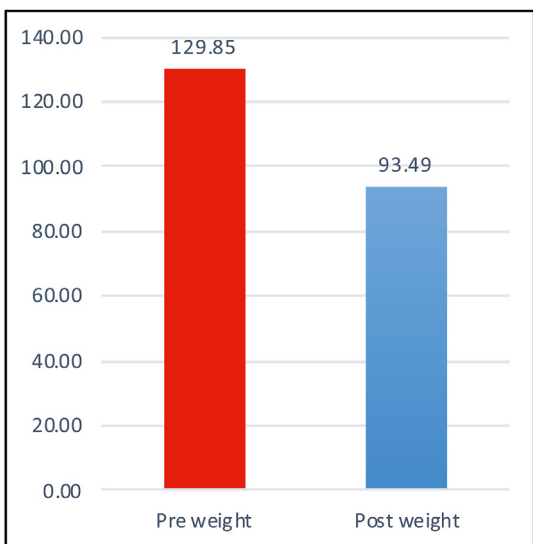


Figure 4: Mean weight loss throughout the study period.

control (HbA1c above 6.5%) preoperatively. Forty-three percent of the patients were on a combination of insulin and metformin, while 26.82% were only on oral hypoglycaemic medications for their T2DM. In those patients with comorbidities diagnosed preoperatively, the most common was hypertension (31.7%), followed by bronchial asthma (19.51%), hypothyroidism (17.07%), and anaemia (4.87%). The remaining 26.82% represented a variety of other comorbidities.

Table 3: The Wilcoxon signed ranks test results testing for the differences in weight before and after the surgery.

Comparison	Rank Type	Mean Rank	Sum of Ranks	Z	p-value
Post weight - Pre weight	Negative Ranks	20.45	777.00	5.401	<b>.000*</b>
	Positive Ranks	3.00	3.00		

Wilcoxon signed ranks test: \*Differences found; p-value less than 0.05 (statistically significant) are indicated in bold.

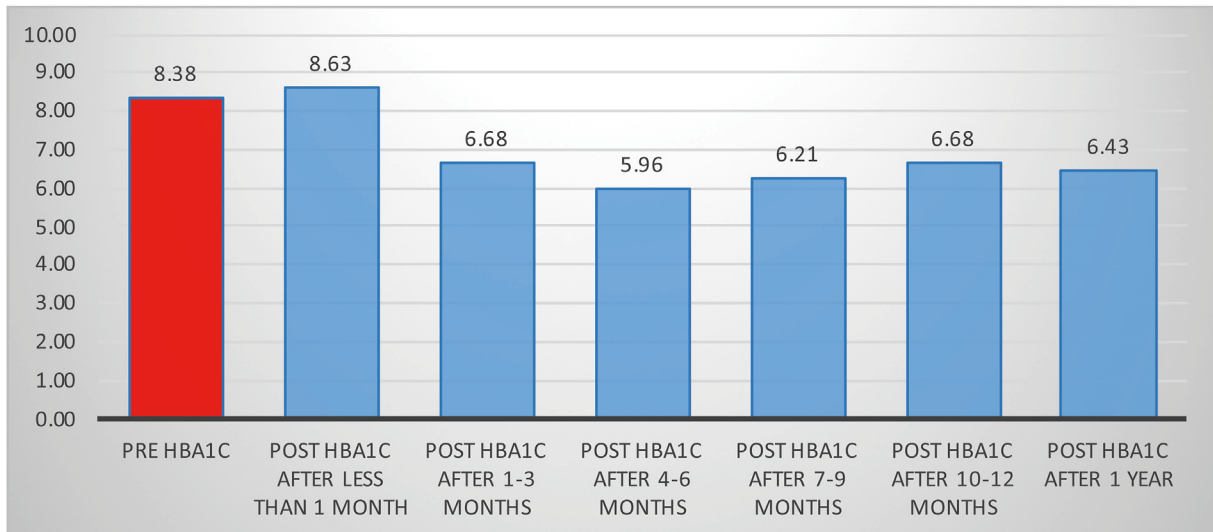


Figure 5: Changes in the average HbA1c throughout the study period.

Table 4: The Wilcoxon signed ranks test results for the differences in HbA1c before and throughout one year after surgery.

		Mean Rank	Sum of Ranks	Z	p-value
Post HbA1c after less than 1 month - Pre HbA1c	Negative Ranks	6.33	57.00	2.139	<b>.032*</b>
	Positive Ranks	4.50	9.00		
Post HbA1c after 1–3 months - Pre HbA1c	Negative Ranks	12.34	271.50	4.062	<b>.000*</b>
	Positive Ranks	4.50	4.50		
Post HbA1c after 4–6 months - Pre HbA1c	Negative Ranks	12.5	300.0	4.287	<b>.000*</b>
	Positive Ranks	0.0	0.00		
Post HbA1c after 7–9 months - Pre HbA1c	Negative Ranks	8.00	120.0	3.408	<b>.011*</b>
	Positive Ranks	0	.00		
Post HbA1c after 10–12 months - Pre HbA1c	Negative Ranks	8.95	98.50	2.888	<b>.004*</b>
	Positive Ranks	2.17	6.50		
Post HbA1c after 1 year - Pre HbA1c	Negative Ranks	11.00	209	3.884	<b>.000*</b>
	Positive Ranks	1.00	1.00		

Wilcoxon signed ranks test: \*Differences found; p-value less than 0.05 (statistically significant) are indicated in bold.

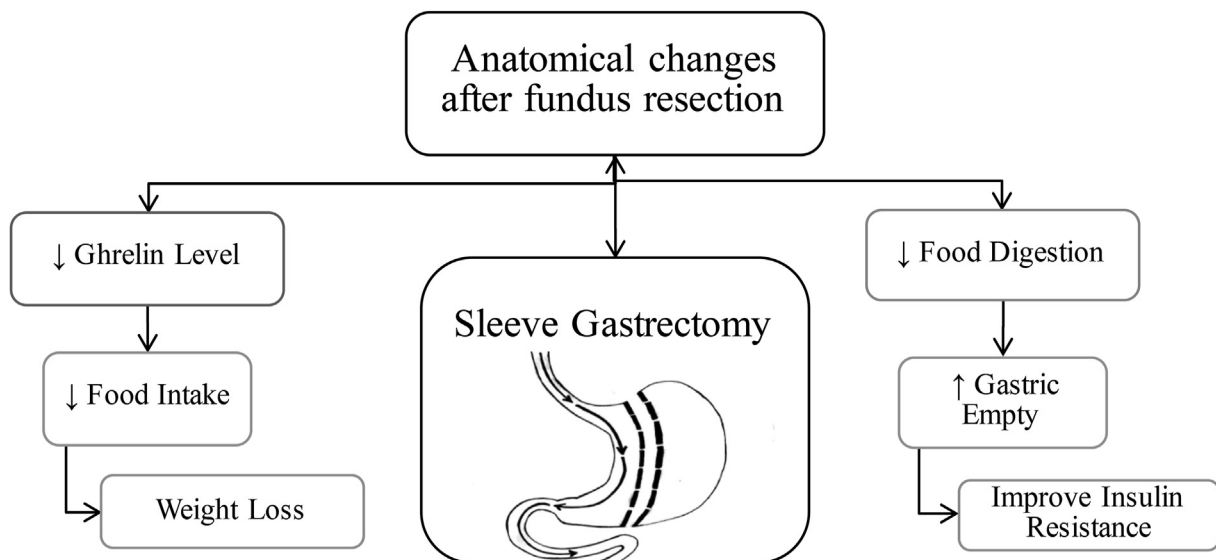


Figure 6: Major pathways of the beneficial effects of LSG on body weight and glucose homeostasis.

### Weight loss

Figure 3 shows that the average BMI dropped consistently from a preoperative BMI of 49.27 kg/m<sup>2</sup> to 32.72 kg/m<sup>2</sup> at 10–12 months following the surgery. It also shows that the average BMI rose to 35.90 kg/m<sup>2</sup> after one year following the surgery. Wilcoxon signed ranks test results (Table 2) shows that there is a difference in BMI before the surgery and within than one month, 1–3 months, 4–6 months, 7–9 months, 10–12 months, and one year following the surgery. The mean of weight loss decreased from 129.85 kg to 93.49 kg, as shown in Figure 4. Table 3 shows that the Wilcoxon signed ranks test result showed a difference in weight before and after the surgery.

### Glycaemic control

LSG resulted in an improvement in the HbA1c in all T2DM patients (100%). As summarised in Figure 5, the average HbA1c decreased from 8.38% to 6.43% after one year. The Wilcoxon signed ranks test (Table 4) shows a significant difference in HbA1c before the surgery and within one month, 1–3 months, 4–6 months, 7–9 months, 10–12 months, and after one year following surgery.

### Discussion

This study aimed to confirm the efficacy of LSG on reducing weight and determine its effect on controlling T2DM by repeatedly measuring BMI and HbA1c preoperatively and postoperatively throughout and following one year post-surgery. The data for this study were retrospectively collected and included all patients with T2DM with a BMI  $\geq$  35 kg/m<sup>2</sup> who underwent LSG at King Fahad Hospital in Almadinah Almunawwarah, KSA, between the 1st of January, 2015, and the 31st of July, 2019.

#### The effect on BMI

In our study, LSG resulted in an improvement in both BMI and HbA1c immediately after surgery and throughout a period of one year. The average BMI dropped from 49.27 kg/m<sup>2</sup> to 32.72 kg/m<sup>2</sup> at 10–12 months following the surgery. Table 2 shows that the *p*-value for the results within the first month was 0.000, which represents a significant reduction of BMI immediately after surgery. A study by Razak Hady et al. (2012) showed a statistically significant reduction of BMI from (52.15  $\pm$  8.5 kg/m<sup>2</sup>) to (45.81  $\pm$  7.71 kg/m<sup>2</sup>) observed one month after surgery.<sup>26</sup> According to 'Uptodate.com', LSG has a high success rate for excess body weight loss at two years postoperatively with an average loss of 60–65%.<sup>27</sup> This can be explained by the decrease of stomach volume, which restricts the volume of a meal (and thus the number of calories) that can be consumed.<sup>28,29</sup> Numerous studies have reported multiple changes that occur after LSG regarding gastrointestinal motility.<sup>30</sup> One of these changes includes volume resection, which increases intragastric pressure, thus leading to an increase in the rate of gastric emptying and an improvement in insulin resistance.<sup>29</sup> Another

pathway includes fundus resection, which decreases the ghrelin level (responsible for hunger sensation), thus decreasing food intake and leading to weight loss.<sup>29</sup> Figure 6 shows a summary of these changes.

Our results as shown in Figure 3 indicate that patients regain weight one year after LSG as evidenced by an increase in average BMI from 32.72 kg/m<sup>2</sup> to 35.90 kg/m<sup>2</sup> one year following the surgery. Shirley Liu et al. (2015) similarly reported weight regain with time as 0%, 1.0%, 11.6%, 19.2%, and 29.5% in each of the first five years of follow-up, respectively.<sup>31</sup> Their definition of weight regain was an increase in weight regain of >25%.<sup>31</sup> There are several explanations for regaining weight after LSG. First, weight regain may be attributed to the size of the initial sleeve.<sup>32</sup> Weiner et al. (2007) reported that treatment failure and early weight regain are associated with removing less than 500 cc of gastric volume.<sup>33</sup> Sleeve dilatation was reported by Braghetto et al. (2009), who found that after two to three years postoperatively, there was a doubling in gastric size.<sup>34</sup> In a later study by Weiner et al. (2011), the researchers reported that when the stomach was divided 4–6 cm from the pylorus, within two to four years, a dilated antrum acted as a new reservoir.<sup>35</sup> Weight regain is also influenced by lifestyle behaviours. Kehagias et al. (2013) reported that based on their outpatient follow up, there is an attrition rate of 22%, explained by maladaptive eating and lack of physical exercise.<sup>36</sup> Himpens et al. (2010) introduced the concept of a 'neofundus' caused by retaining too much fundus at the time of operation to prevent fistulas.<sup>37</sup> Ghrelin is a gastrointestinal peptide hormone secreted by the fundus of the stomach and acts on the hypothalamus. It is responsible for hunger sensation, stimulates appetite, and promotes fat storage.<sup>38</sup> A study by Bohdjalian et al. (2010) found a higher level of ghrelin levels postoperatively in patients who experienced weight regain compared to patients with appropriate weight loss or maintenance after LSG.<sup>39</sup>

#### The effect on HbA1c

LSG also resulted in a significant reduction in HbA1c (Figure 5). While all of our patients (100%) showed a reduction in their HbA1c levels in the first year following surgery, only 75% met the target HbA1c of 6.5%, while the remaining 25% failed to reach the target. A study by Silecchia et al. (2006) included 41 super-obese patients and showed that at the 18th month post-LSG, diabetes was cured in 76.9% and improved in 15.4% of participants.<sup>40</sup> Additionally, Vigneshwaran et al. (2016) reported an improvement of T2DM in all of their patients following LSG, with complete remission in 50% and 60% of patients at 12 and 24 months, respectively.<sup>41</sup> The Wilcoxon signed-rank test results shown in Table 4 indicate a significant effect of LSG in managing T2DM starting from before the end of the first month postoperatively (with a *p*-value of 0.032), which continued with significant *p*-values throughout the first year. This could be explained by the effect of LSG on the ghrelin level. Ghrelin is secreted when the stomach is empty, and secretion stops after a meal, when the stomach becomes stretched.<sup>42,43</sup> It also plays a

role in regulating glucose homeostasis by inhibiting insulin secretion.<sup>38</sup> LSG reduces the level of ghrelin, which, in turn, increases the secretion of insulin.<sup>41</sup> Bohdjalian et al. (2010) and Gagner et al. (2009) found that 90% of patients have permanently lower levels of ghrelin after LSG.<sup>39,44</sup> This is due to resection of the stomach fundus, where most of the ghrelin production occurs, and this reduction following LSG is even greater than the results observed after gastric bypass.<sup>45</sup>

The limitations of our study included a small sample size as well as the data being collected from a single facility. We attempted to overcome these limitations by expanding the number of years covered by the study. Another limitation was incomplete data due to poor patient follow up, and poor hospital documentation also resulted in a reduction of the number of patients with complete data. The short duration of the study limited us to choosing the retrospective study design, which relies on previously existing patient records. Despite these limitations, this study represents an optimistic outcome of LSG in terms of managing both obesity and diabetes in KSA.

## Conclusion

This study confirms the positive outcome of LSG on both BMI and diabetic status. The results show a significant difference in BMI and HbA1c before and less than one month to one year after surgery. Although there is evidence of weight regain following surgery, the extent of weight regain was not remarkably high.

## Recommendations

This article provides an indication of the effect of LSG on gut hormones that potentially leads to weight loss and remission of T2DM. However, further research is needed to explore the effect of LSG on other comorbidities, such as hypertension and coronary artery disease.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The study was approved by both the Institutional Review Board at King Fahad Hospital Research Center - Almadinah Almunawwarah, KSA and the Scientific Research Ethics Committee (CM-REC) at Taibah University - Almadinah Almunawwarah, KSA [PEP 4- F12, dated 13 January, 2019]. All study procedures were carried out in accordance with the 1975 Helsinki Declaration of Ethical Principles for medical research involving human subjects.

## Authors contributions

KRM formulated ideas and evolved research goals and aims, wrote and edited the article, and managed and coordinated responsibility for the research activity planning and execution. GHA provided supervision, research materials, and resources. FAA conducted research, collected and organised the data, and wrote the initial and final draft of the article. MMZ collected, analysed, and interpreted the data and wrote the final draft of the article. AAB conceived and designed the study, curated the data, and finalised and corrected the interpretation of the data. EHM collected the data and reviewed the final draft of the article. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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