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REVIEW ARTICLE

Weight Regain Following Sleeve Gastrectomy—a Systematic Review

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Abstract Sleeve gastrectomy (SG) is a commonly performed bariatric procedure. Weight regain following SG is a significant issue. Yet the defining, reporting and understanding of this phenomenon remains largely neglected. Systematic review was performed to locate articles reporting the definition, rate and/or cause of weight regain in patients at least 2 years post-SG. A range of definitions employed to describe weight regain were identified in the literature. Rates of regain ranged from 5.7 % at 2 years to 75.6 % at 6 years. Proposed causes of weight regain included initial sleeve size, sleeve dilation, increased ghrelin levels, inadequate follow-up support and maladaptive lifestyle behaviours. Bariatric literature would benefit from standardising definitions used to report weight regain and its rate in clinical series. Larger prospective studies are required to further understand mechanisms of weight regain following SG.

Keywords Bariatric surgery · Sleeve gastrectomy · Weight regain

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Introduction

Weight regain, also referred to as secondary weight gain or recidivism, is a complication of bariatric surgery evidenced by a gradual decline in the percentage of weight change observed in longitudinal studies [1, 2]. It is associated with the recurrence of obesity-related comorbidities including type 2 diabetes [3, 4] and is likely to have a significant economic burden [5].

Sleeve gastrectomy (SG) has become one of the most commonly performed bariatric procedures and has become so without a large knowledge base of long-term outcomes. A recent systematic review of longer-term series suggests that weight loss following SG is durable with sustained loss of over 50 % of excess weight (EWL) after 5 years [6]. Now that long-term data are being reported, it is evident that weight regain following SG is significant [7–11]. Yet the defining, reporting and understanding of this phenomenon remains largely neglected.

With an increasing number of SGs performed, the significant issue of weight regain is becoming more prevalent. Consensus statements and reporting guidelines seldom mention this phenomenon, and the true incidence of weight regain, and what constitutes significance, is not well defined [12–14]. Accordingly, we undertook a systematic review to determine the current definitions of weight regain employed in the literature, as well as the rate and cause of weight regain specifically following SG.

Methods

This systematic review was performed according to the PRISMA statement where appropriate [15]. A series of

electronic searches were conducted in Medline, Embase, PubMed and the Cochrane Library in November 2015. The strategies combined search terms for SG and weight regain (Table 1). There were no limits for study design or language. Results were filtered for human-only studies and limited to 2007 onwards. Search results were downloaded and managed with Endnote X7.4 citation management software (Thomson Reuters, USA).

Abstracts were screened and full-text papers obtained to identify primary research studies reporting definitions, rates and causes of weight regain following SG. Papers were excluded if no definition, rate or proposed mechanism of weight regain was recorded. Other exclusion criteria were papers reporting non-primary SG, follow-up less than 2 years, and papers not reporting primary research (e.g. review papers).

Abstracts were initially screened for inclusion by authors ML and MK. Screening of full text articles was performed independently by the same two authors. Any uncertainties about inclusion were discussed with the senior author, who made the final decision. Data extraction for weight regain definition, rate and cause was performed independently by authors ML and MK, who both screened the bibliographies of full-text papers to identify further references for possible inclusion.

Results

After abstract screening, the review yielded 132 full-text papers, of which 21 met the inclusion criteria (Fig. 1). Of these 21 papers, 12 reported a weight regain definition, nine reported the rate of weight regain in a clinical series and 12 proposed mechanisms that may be responsible for weight regain following SG.

Table 1 Search strategy used in Ovid MEDLINE® In-Process & Other Non-Indexed Citations

Sleeve gastrectomy	Weight regain
1.sleeve gastrectomy.mp	1.weight regain.mp
2.vertical gastrectomy.mp	2.exp Weight Gain
3.gastrectomy.mp	3.weight recidivism
4.exp Gastrectomy	
5.bariatric surgery.mp	
6.exp Bariatric Surgery	

Strategy was modified as needed to use with other databases. Terms for 'sleeve gastrectomy' and 'weight regain' combined. Search limited to human studies published from 2007 onwards. For MeSH terms, all subheadings were selected

exp exploded MeSH term, *mp* key word

Definition of Weight Regain

Twelve papers from nine research groups were identified that specifically defined weight regain following SG. These are reported in Table 2.

Rates of Weight Regain

Nine papers were identified that reported weight regain rates for a series of SGs of which six reported the definition used to calculate these rates. Table 3 presents the rates of weight regain and demonstrates that included studies were small with significant heterogeneity and attrition rates.

Causes of Weight Regain Following SG

Twelve papers proposed a cause for weight regain following SG based on their findings and are summarised in Table 4.

Initial Sleeve Size/Technical Factors

Weiner et al. (2007) were among the first to perform the SG as a single-stage procedure in super obese patients [30]. They initially formed gastric sleeves with no calibration aiming to resect two-thirds of the stomach to leave a residual volume of 150–200 ml. This was succeeded by sleeve calibration using a 44-Fr and later a 32-Fr bougie. Both sleeve volume and the capacity of the excised stomach were measured. They reported that a removed gastric volume of less than 500 cc appeared to be a predictor of treatment failure or early weight regain, though the latter was not defined. This was not a randomised trial, though the baseline demographics of each group were similar, and the weight regain rate is not clear.

Himpens et al. (2010) introduced the concept of a 'neofundus' caused by leaving too much fundus at the time of operation to avoid fistulas and gave examples of two cases of weight regain in a series of 53 who benefited from a re-sleeve to correct an oversized fundus demonstrated by a barium upper gastrointestinal series [7]. Weiner et al. (2011) report back 4 years later having performed over 900 SGs and deciding on a 42-Fr bougie as the 32 Fr was associated with an increase in staple-line leaks [31]. They described performing 88 secondary procedures for insufficient weight loss (<50 % EWL) and weight regain (not defined) in which more than 50 % had anatomically incorrect sleeves. In their discussion, they further describe that approximately 50 % of primary treatment failure (poor weight loss from the beginning) is due to a technical issue such as an incompletely resected fundus. In cases with successful weight loss complicated by weight regain, they observed a dilated antrum acting as a new reservoir within 2 to 4 years when the stomach was divided 4–6 cm from the pylorus.

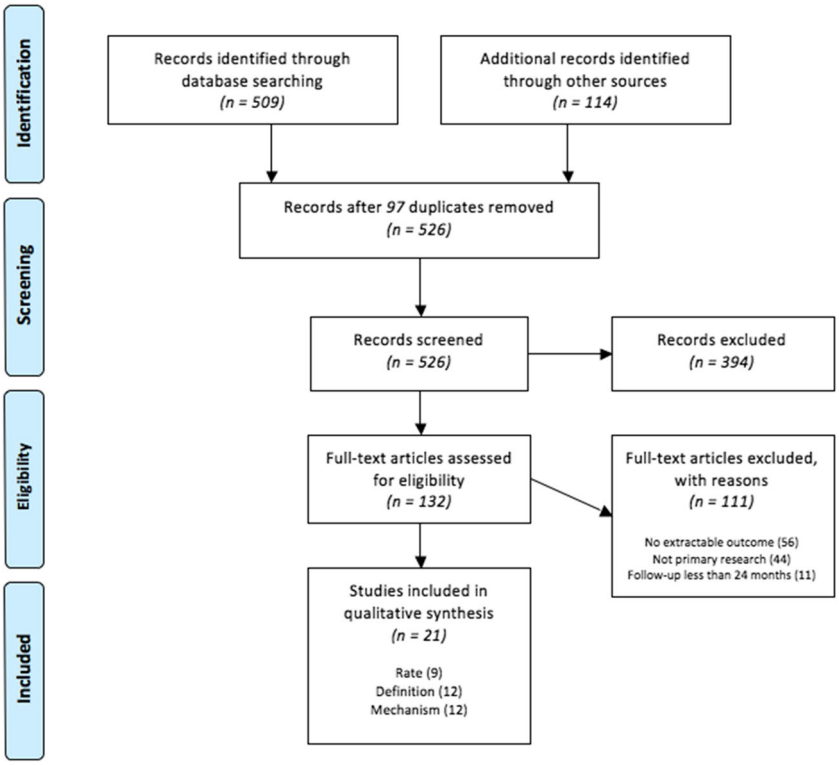

Fig. 1 Preferred reporting items for systematic reviews and meta-analysis (PRISMA) systematic review flow diagram

Table 2 Reported definitions for weight regain following sleeve gastrectomy

Definition origin	Year	Definition
Abdallah et al. [16] Egypt	2014	An increase of body weight of more than 10 kg from the nadir
Bohdjalian et al. [17] Austria	2010	More than 10 kg from the nadir
Braghetto et al. [18] Chile	2012	Greater than 10 kg
Brethauer et al. [3] United States	2013	An increase in BMI of 5 kg/m^2 or more above the weight loss nadir
Carmeli et al. [19] Israel	2015	Regaining weight after successful loss to achieve a BMI greater than 35 kg/m^2
Casella et al. [20] Italy	2016	Weight increase greater than 10 kg from weight loss nadir
de Hollanda et al. [21] Spain	2015	The difference between weight at last follow-up and nadir weight expressed in kilograms or as percent of maximum weight loss
Homan et al. [22] Netherlands	2015	Greater than 25 % EWL regain with respect to the minimal weight after LSG or when a patient met the criteria for bariatric surgery again as established by the International Federation for the Surgery of Obesity
Jimenez et al. [4] Spain	2012	Any weight regain after T2DM remission
Langer et al. [17, 23] Austria	2010	An increase of body weight of more than 10 kg from the nadir
Liu et al. [24] Hong Kong	2015	When the percentage of rebound in excess weight loss (%REWL) is greater than 25 % where %REWL is the difference between the best post-operative %EWL and the current measured %EWL.
Obeidat et al. [25] Jordan	2015	An increase in body weight of more than 10 kg from the nadir.

Table 3 Reported rates of weight regain following sleeve gastrectomy

Author and country	Number of patients	Patient selection	Mean pre-op BMI (kg/m^2 (*n*))	Bougie size (Fr)	Distance of division from antrum (cm)	Follow-up period (years)	Follow-up schedule	Mean post-op BMI (kg/m^2 (*n*))	Mean %EWL (% (*n*))	Regain rate (% (*n*))	Definition used
Abdallah et al. (2014) Egypt [16]	105	Morbidly obese patients aged between 18 and 60 years	51.7 (105)	38	2 or 6	2	2 weeks then 3, 6, 12 and 24 months	NR	66.5 (105)	5.7 % (6)	More than 10 kg from nadir
Nocca et al. (2008) [26] France	163	BMI >40 with high-volume eating disorder BMI >35 high-volume eating disorder and severe comorbidities BMI >50 Sweet-eating disorders were a contra-indication.	45.9 (163)	36	Where the calibration tube makes contact with the greater curve.	2	1, 6, 12, 18 and 24 months	31.6 (98)	61.5 (98)	10.2 % (10)	NR
Obeidat et al. (2015) [25] Jordan	125	Patients selected according to the 1991 NIH guidelines with all patients having a BMI of >40 or >35 with a major comorbidity	46.1 (110)	38Fr	2 or 6	2	1 week then 1, 3, 6, 12 and 24 months	NR	73.2 (110)	12.7 (14)	An increase in body weight of more than 10 kg from the nadir.
Braghetto et al. (2009) [27] Chile	15	NR	39.7 (15)	32	2–3	2–3	NR	NR	NR	20.0 % (3)	NR
Bohdjalian et al. (2010) [17] Austria	26	NR	48.2 (26)	48	Division described as starting opposite the nerve of Latarjet [28]	5	3, 6, 9, 12, 18 and 24 months then annually	NR	55.0 (22)[a]	19.2 % (5)	More than 10 kg from nadir
Liu et al. (2015) [24] Hong Kong	140	Asia-Pacific Bariatric Surgery Group consensus guidelines 2005 initially then the International Federation for the Surgery of Obesity and Metabolic Disorders–Asia Pacific Chapter consensus	41.0 (140)	58.6 % with a bougie less than 40Fr and 41.4 % with a bougie of 40Fr or above	6	5	1, 6, 12, 18 and 24 months then annually	33.7 (52)	57.2 (52)	29.5 % (NR)	Rebound in excess weight loss greater than 25 %

Table 3 (continued)

Author and country	Number of patients	Patient selection	Mean pre-op BMI (kg/m^2 (*n*))	Bougie size (Fr)	Distance of division from antrum (cm)	Follow-up period (years)	Follow-up schedule	Mean post-op BMI (kg/m^2 (*n*))	Mean %EWL (% (*n*))	Regain rate (% (*n*))	Definition used
		statement. BMI >35 or >30 with inadequately controlled T2DM or metabolic syndrome.									
Braghetto et al. (2012) [18] Chile	560	NR	38.4 (560)	32 or 40 [29]	2–3 [29]	5+	NR	29.9 (60)	57.3 (60)	39.5 % (NR)	Greater than 10 kg
Himpens et al. (2010) [7]	53	Patients selected according to the 1991 NIH guidelines and were volume eaters but not diabetics nor subject to significant reflux disease	39.5 (41)	34	6	6	On a regular basis until 3 years	31.1 (30)[b]	53.3 (30)[b]	75.6 % (31)[c]	NR
Belgium								30.1 (41)	57.3 (41)		
Casella et al. (2016) [20] Italy	182[d]	NR	45.9 (182)	48	4–6	6	3, 6, 9, 12, 18 and 24 months then annually	30.2 (148)[e]	67.3 (148)	26.3 % (39)[f]	Weight increase greater than 10 kg from weight loss nadir

BMI body mass index, *%EWL* percent of excess weight lost, *NR* not reported

[a] Excludes the four patients converted to gastric bypass—three for weight regain and one for reflux

[b] Excludes the 11 patients who had a duodenal switch between 3 and 6 years but includes two resleeve procedures

[c] Of the 53 consecutive patients, 12 patients were unable to be followed-up

[d] In eight of these cases, the sleeve was a revision procedure (six following gastric banding and two following vertical banded gastroplasty)

[e] 32 patients excluded for not attending follow-up and a further four excluded as they underwent biliopancreatic diversion with duodenal switch for insufficient weight loss within 18 months

[f] Amount of weight regained was between 11 and 20 kg for 27 patients, 21 and 30 kg for nine patients and >30 kg for three patients

Table 4 Proposed mechanisms for weight regain following sleeve gastrectomy

Proposed mechanism for weight regain following sleeve gastrectomy
Technical factors contributing to initial sleeve size
Bougie size [30]
Leaving fundal remnant [7, 31]
Size of antral remnant [16, 25, 31]
Sleeve dilatation [18, 27]
Ghrelin levels [17]
Follow-up support [7, 8, 32]
Lifestyle behaviours [33, 34]

Two recent papers have reported that creating a larger antral remnant at the time of SG is associated with higher rates of weight regain [16, 25]. Abdallah et al. (2014) performed a randomised trial comparing 52 patients with a remnant antrum of 2 cm and 53 patients with a remnant antrum of 6 cm. At 24 months following SG, only one patient (1.9 %) with a 2-cm remnant antrum had regained weight (defined as at least 10 kg from nadir weight) compared with five patients (9.4 %) with 6-cm antral remnants. Although this difference did not reach statistical significance ($p = 0.09$), the findings have been corroborated. Obeidat et al. (2015) performed a retrospective review of prospectively collected data of 125 consecutive patients who underwent SG [25]. Of the 110 patients with available data, 54 had the antrum divided 6 cm from the pylorus and 56 patients at 2 cm. At 2 years following surgery, 12 patients (22 %) with a 6-cm remnant antrum had regained weight (again defined as at least 10 kg from nadir weight) compared with only two patients (4 %) with a 2-cm antral remnant ($p = 0.003$).

Sleeve Dilatation

Braghetto et al. (2009) demonstrated a doubling in gastric sleeve size 2 to 3 years post-operatively [27]. Their capacity calculations should be reliable given that two different techniques achieved similar results for gastric capacity. While they postulate that this increase in sleeve size may be a cause of weight regain, this did not correlate with patient outcome in this small series with follow-up at 2 years. Similarly, when patients were followed up at 5 years, only 17/108 (15.7 %) patients demonstrated weight regain associated with more than quadrupling of the sleeve capacity [18].

Ghrelin Levels

Bohdjalian et al. (2010) demonstrated halving of pre-operative ghrelin levels that persisted up to 5 years post-operatively in a small series of 12 patients of whom three had regained at least 10 kg from the nadir weight [17]. They observed slightly higher plasma ghrelin levels in patients with weight regain throughout the observation period, but this was not statistically significant due to high variability and small patient numbers.

Follow-Up Support

Sarela et al. (2012) proposed that the lifelong follow-up provided by the National Health Service in the UK is responsible for less weight regain in the long term [8]. They reported a series of 20 patients with a median pre-operative BMI of 45.8 kg/m^2 who underwent SG with a 32-Fr bougie and report a median excess weight loss of 68 % at 8 or 9 years in the 16 patients that they were able to follow-up which included three patients who went on to have a duodenal switch or bypass. They attribute their excellent result for %EWL in the long term to the comprehensive support care pathway involving continuous dietary support, patient support group meetings and standard follow-up visits to the outpatient clinic every 3 months for the first year, every 6 months for the second year and annually thereafter.

In their series, Himpens et al. (2010) noticed that weight regain coincided with discharge from follow-up at 3 years [7]. Exactly what their regular office visits entailed prior to discharge was not described. Their excess weight loss results in a series of 53 patients with an initial BMI of 39.5 kg/m^2 who underwent SG with a 34-Fr bougie were less impressive at 57.3 % at 6 years than that of Sarela et al. These results include an attrition rate of 23 % (similar to Sarela et al) and 11 cases that were converted to a duodenal switch and a further two re-sleeve procedures.

Lombardo et al. (2015) performed the only study that specifically aimed to investigate whether or not more frequent follow-up visits prevent weight regain [32]. In their series of 71 patients that included 43 patients who had undergone SG with a baseline BMI of 49.8 kg/m^2, they compared a group of patients who had follow-up visits at 9, 12, 15, 18, 24, 30 and 36 months with a group that had follow-up at only 12, 18, 24 and 36 months. They concluded that more follow-up visits may help reduce weight regain based on significant differences between the groups for change in body weight, change in BMI and change in %EWL. However, no definition or rate was reported pertaining to weight regain in this retrospective non-randomised study.

Lifestyle Behaviours

In a retrospective analysis of prospectively collected data, Kehagias et al. (2013) reported a series of 208 patients with an initial BMI of 34.3 kg/m^2 who underwent SG as a sole procedure with a 32-Fr bougie to have a 78 % excess weight lost at 2 years but only 58 % at 5 years [33]. Patients attended outpatient clinics at 1, 3, 6 and 12 months post-operatively

then annually thereafter. There was an attrition rate of 22 % in the 27 patients who were 5 years post-procedure. Regardless, this gradual decline in %EWL was attributed to maladaptive eating and lack of exercise based on data obtained from annual dietary questionnaires.

Keren et al. (2014) corroborated these findings when they reported a series of 115 patients with an initial BMI of 44.1 kg/m^2 who underwent SG calibrated with a 39-Fr bougie [34]. The post-operative support provided to patients was described as '24/7'—in web forums, internet support groups, telephone and mail support and regular clinic visits. Five patients were excluded as they went on to bilio-pancreatic diversion, with the remainder showing a gradual decrease in excess weight lost from 66.5 % at 2 years to 45.3 % at 5 years. They developed a lifestyle modification score based on two questions from the Bariatric Analysis and Reporting Outcome System and found that it correlated well with sufficient weight loss (%EWL >50) at 5 years [35, 36]. Specifically, over 80 % of patients with sufficient weight loss had a lifestyle modification score of ≥0.5 compared with none of the patients with insufficient weight loss.

Discussion

This systematic review brings together relevant literature pertaining to the increasingly recognised issue of weight regain following SG and highlights the lack of standardised clinical terms, understanding and reporting in this area. This review is an important first step in properly defining this issue.

A number of different definitions have been employed in the literature to define weight regain following SG. The most common of these, an increase of at least 10 kg from nadir weight, does little to define the significance of the amount of weight regained in the affected individual. For example, a 10-kg weight gain is, by far, more significant in a 60-kg person than a 100-kg person. Nor does it allow for comparability between individuals or research studies. As such, a relative measure such as a BMI or total body weight change may be more clinically meaningful and useful.

While conducting this review, it became apparent that the phenomena of weight regain, insufficient weight loss and SG failure are often confusingly combined as indications for revision procedures following SG [31, 37, 38]. Weight regain is a medium- to late-term complication occurring after the weight loss nadir, insufficient weight loss is often defined as never achieving more than 50 % EWL which appears to be based on the historic Reinhold criteria, and procedure failure is variably defined and interpreted [39, 40]. Importantly, weight regain and insufficient weight loss are likely to have different causative mechanisms, and thus, management may differ [31, 41].

Weight regain following a variety of bariatric procedures is well recognised but poorly reported [13, 42]. Rates of regain specifically following SG are reported in nine heterogeneous studies as 5.7 % at 2 years to 75.6 % at 6 years [7, 16–18, 20, 24–27]. Nothing further can be extrapolated from this data as studies were small, consisted of different populations, had different (if any) definitions for weight regain and reported rates in a variable manner. The number of studies that even attempted to report a regain rate is small compared to the number of published clinical series. This is unsurprising given the lack of prominence that this subject has in the literature and expert statements.

Liu et al. (2015) have been the only group to report weight regain rates yearly alongside other outcome data [24]. When they employed their definition of weight regain (an increase in %EWL of 25), they had regain rates of 0, 1.0, 11.6, 19.2 and 29.5 % at 1, 2, 3, 4 and 5 years post-operatively, respectively. This clearly demonstrates the increasing susceptibility to weight regain experienced by patients as time from surgery increases, a trend also illustrated in Table 3.

A systematic review of weight regain following bariatric surgery identified five principal aetiologies: nutritional non-compliance, hormonal/metabolic imbalance, mental health, physical inactivity and anatomical/surgical factors [42]. The current review of weight regain, specifically following SG in patients at least 2 years post-surgery, identified initial sleeve size, sleeve dilatation, increased ghrelin levels, inadequate follow-up support and maladaptive lifestyle behaviours as proposed mechanisms contributing to weight regain in the sleeve patient.

Sleeve anatomy is commonly proposed as a mechanism for weight regain following SG [18, 27, 38, 43]. It is difficult to understand how an initially 'large' sleeve, or primary dilation [38, 44], is a cause of weight regain rather than insufficient weight loss, but the answer may lie in the fact that this often results from an incompletely excised fundus, the most distensible part of the stomach, which may then increasingly distend and release larger amounts of ghrelin [45]. It does seem logical, however, that progressive sleeve dilatation, or secondary dilatation [38, 44], would contribute to weight regain. Deguines et al. (2013) have demonstrated a correlation between residual gastric volume and SG success as defined by %EWL >50 %, BAROS >3, BMI <35 kg/m^2 and/or the Biron criteria [46]. Yet, to date, the association between sleeve dilation and weight regain has not been convincing [18, 20, 27, 28].

Reduced ghrelin levels following SG reduce appetite and contribute to the restrictive effect in promoting weight loss [47]. Most previous work in this area has been in the short term, but Bohdjalian et al. demonstrated that ghrelin levels remained diminished up to 5 years post-operatively [17, 48, 49]. Furthermore, they observed slightly higher ghrelin levels in patients who regained weight, though this was not significant due to the small number of patients. This is an important finding that needs further investigation.

Five-year outcomes following SG at our institution were recently reported and demonstrated a trend towards weight regain commencing at 18 months which coincided with discharge from the bariatric service [9]. Himpens et al. noticed the same phenomenon at 3 years, and Sarela et al. attribute their superior %EWL results at 8 years to lifelong support [7, 8]. This is consistent with previous work that reported a significantly improved %EWL in patients who were 100 % compliant with clinic follow-up, compared to those who did not attend, at 30 months [50]. However, when those same patients were followed-up at 5 years, they found significant weight gain despite on-going annual follow-up visits [34]. This suggests a more complex interaction between weight regain and follow-up requiring further investigation and highlights the need for clinical series to adequately report the follow-up provided to their patients.

We identified two papers that specifically attributed weight regain to behaviours related to diet and/or exercise [33, 34]. Works investigating weight regain following gastric bypass report similar associations [51, 52]. Following SG, compliance to appropriate diet may be hindered by faster gastric emptying and the onset of an increased hunger sensation and craving for sweets at 3 years [53, 54]. While there are no sleeve-specific factors affecting exercise adherence, the recognised barriers include motivation, health-related problems and time constraints [55]. Screening tools to assess and manage behavioural risk in bariatric patients may prove beneficial in reducing weight regain rates if the tools themselves are shown to be effective [56].

Conclusion

Weight regain is a common phenomenon following SG. It is variably defined, described and reported in the literature. The bariatric literature would benefit from standardising the definitions used to report weight regain and its rate in clinical series. Authors should also be encouraged to refrain from grouping together patients with insufficient weight loss, procedure failure and weight regain. Larger prospective studies are required to further understand the underlying mechanisms of weight regain following SG. These studies will need to adequately report operative technique (bougie size and size of remnant antrum), residual sleeve size, ghrelin levels and post-operative follow-up care and assess patient behaviours in a longitudinal manner.

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Compliance with Ethical Standards

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of Interest This study was conducted whilst author ML held a Health Research Council of New Zealand Clinical Research Training Fellowship (15/008). The senior author has received fees from Covidien for a speaker honorarium. The remaining authors have nothing to declare.

Informed Consent Does not apply.

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