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## Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass

### Abstract

**Objective** The effects of food tolerance (if any) on diet quality several years post-surgery remain unclear. Our study aimed to assess food tolerance and diet quality after three bariatric procedures; adjustable gastric banding (AGB), sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP), 2–4 years post-surgery. **Methods** This prospective, cross-sectional study assessed weight loss, food tolerance and diet quality in 130 subjects (14 obese pre-surgical controls, 13 AGB, 62 SG and 41 RYGBP). Inclusion criteria selected patients who underwent bariatric surgery between 1 January 2007 and 31 December 2008, at a single bariatric clinic. Non-parametric tests (Kruskal–Wallis and Mann–Whitney) along with Spearman's correlation coefficient analysis were used. **Results** Superior food tolerance was reported by the control (24.5), SG (24.0) and RYGBP (22.0) groups, compared with the AGB group (15.5;  $P < 0.001$ ). The control and AGB groups consumed significantly more high-calorie extra foods (9.2 and 7.7 daily serves respectively) compared with the SG (3.4 serves) and RYGBP (4.0 serves) groups. There were several significant correlations between food tolerance and dietary intake including breads and cereals and meat and meat alternatives. **Conclusion** The control and AGB groups consumed significantly more high-calorie extra foods, a result that was paralleled by poor weight loss and food tolerance outcomes for the AGB group. A significant positive relationship between food tolerance and diet quality was established. Poor food tolerance and thus compromised diet quality need to be considered as post-surgical complications of the AGB procedure.

### Keywords

Gastric banding, Bypass surgery, Gastric sleeve, Morbid obesity, Nutrition

### Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

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# Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass

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## **Abstract**

*Objective:* The effects of food tolerance (if any) on diet quality several years post-surgery, remains unclear. Our study aimed to assess food tolerance and diet quality after three bariatric procedures; Adjustable Gastric Banding (AGB), Sleeve Gastrectomy (SG) and Roux-en-Y Gastric Bypass (RYGBP), two to four years post-surgery.

*Methods:* This prospective, cross-sectional study assessed weight loss, food tolerance and diet quality in 130 subjects (14 obese pre-surgical controls, 13 AGB, 62 SG and 41 RYGBP). Inclusion criteria selected patients who underwent bariatric surgery between 1 January 2007 and 31 December 2008, at a single bariatric clinic. Non-parametric tests (Kruskal-Wallis and Mann-Whitney) along with Spearman's correlation coefficient analysis were used.

*Results:* Superior food tolerance was reported by the control (24.5), SG (24.0) and RYGBP (22.0) groups, compared with the AGB group (15.5;  $P < 0.001$ ). The control and AGB groups consumed significantly more high-calorie extra foods (9.2 and 7.7 daily serves respectively) compared with the SG (3.4 serves) and RYGBP (4.0 serves) groups. There were several significant correlations between food tolerance and dietary intake including breads and cereals and meat and meat alternatives.

*Conclusion:* The control and AGB groups consumed significantly more high-calorie extra foods, a result that was paralleled by poor weight loss and food tolerance outcomes for the AGB group. A significant positive relationship between food tolerance and diet quality was established. Poor food tolerance and thus compromised diet quality need to be considered as post-surgical complications of the AGB procedure.

**Keywords:** gastric banding, bypass surgery, gastric sleeve, morbid obesity, nutrition.

## **Introduction**

Bariatric surgery is an effective tool for weight loss in morbidly obese patients [1, 2].

Adjustable gastric banding (AGB), sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP) differ in technique, anatomical configuration and their mode of action [1]. AGB procedure involves an adjustable band placed high on the stomach, distal to the cardio esophageal junction, creating a virtual pouch [3, 4]. Considered a restrictive procedure, AGB has also been illustrated to induce satiety as a mechanism for weight loss [5]. The SG is a restrictive procedure with resection of approximately 80% of the greater curvature of the stomach resulting in a 'sleeve' shaped stomach with reduced gastric volume. Furthermore hormonal changes including reduced ghrelin secretion following the fundectomy, and an increase in hindgut satiety hormones (PYY and GLP-1) secondary to the increased rate of gastric emptying [6], are also suggested mechanisms for action. The mechanisms for weight loss in RYGBP is a reduced stomach capacity restricting food intake and gastrointestinal hormonal changes similar to the SG, which have been documented to reduce appetite [7].

Percentage excess weight loss (%EWL) is commonly used for reporting weight loss after bariatric surgery. Other frequently used success markers include co-morbidity improvement and quality of life outcomes. While these are important parameters to consider, food tolerance and diet quality are also particularly important to assess as their outcomes may influence co-morbidities and quality of life. Suter et al [8] suggest good food tolerance is the ability to consume a variety of foods without difficulty, and with minimal regurgitation/vomiting. Several studies have examined food tolerance following bariatric surgery [8-11], including an article by Overs et al [12] which reports on the food tolerance experienced in the same population sample as the current study. These studies show that food

tolerance outcomes differ with surgical type and time since surgery [8, 9]. The literature to date reveals the AGB procedure results in a significantly lower total food tolerance score compared with other bariatric procedures [8, 9, 13].

Poor food tolerance is expected early after surgery, however if persistent, may lead to food avoidance or maladaptive eating behaviours [14, 15]. This may result in eating habits that affect overall diet quality, increasing a patient's risk for nutritional deficiencies and compromise weight loss. Previous research has identified dietary and nutrition issues in post-surgical patients [16]. However to the authors knowledge, no studies to date have reported on the effect food tolerance (if any) exhibits on the consumption of the core food groups and overall quality of diet, after bariatric surgery. The aim of this study was to assess food tolerance and diet quality in AGB, SG and RYGBP patients two to four years post-surgery, comparing findings with an obese control group. A secondary aim was to assess whether there is an association between food tolerance and diet quality in these patients.

## Methods

### Study Design

This study was conducted as part of a larger study investigating several outcomes at a time point of two to four years post-surgery [12]. Ethics were approved by the University of Wollongong/South Eastern Sydney & Illawarra Area Health Service Human Research Ethics Committee in August 2010.

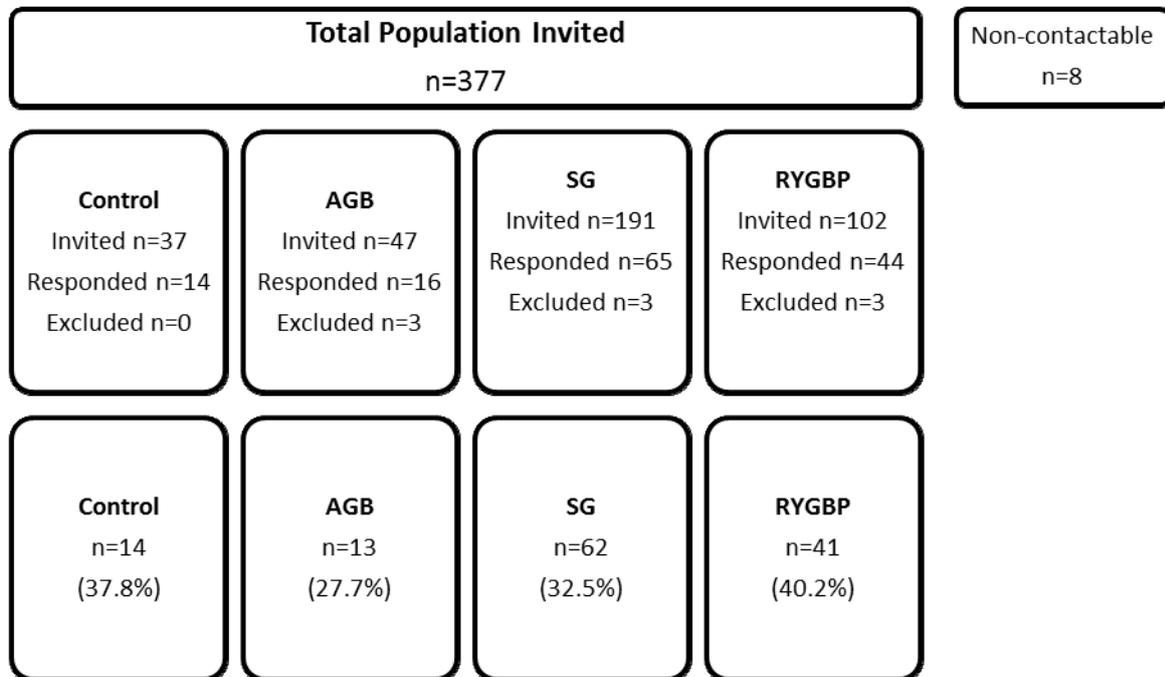
Recruitment took place from a single clinic in Sydney in August and September 2010. Invitation packages were mailed to all patients who had undergone bariatric surgery by a single surgeon between January 1st 2007 and December 31st 2008 ( $n=340$ ). The timeframe selected for this study was chosen to assess outcomes at a time point of two to four years post-surgery. Patients who underwent bariatric surgery during this period were deemed suitable for surgery as per National Institute of Health Consensus criteria [17]. Random assignment was not used in this study. Alternatively patients underwent the most suitable surgery (performed by the surgeon) for their individual needs. This was assessed during a pre-surgical consultation with the surgeon and support team (Dietitian and Nurse). Surgical procedures were standardized and have previously been described for this study population in detail by Overs et al. [12]. Researchers recruited the obese control group during the recruitment phase from the pre-surgical assessment appointments ( $n=37$ ) conducted at the clinic.

The invitation package mailed to all eligible patients contained: a participant information sheet; an invitation to participate; a consent form; the surgeons letter of support; a questionnaire (including a food tolerance questionnaire [8], a qualitative dietary assessment form and a 24 hour food recall template); along with a return, self-addressed, stamped envelope. All patients were contacted via telephone within two weeks of mail out. Written informed consent was received from all participants.

## Study Population

An overall response rate of 34% was obtained. The control group ( $n=14$ ) contained the pre-surgical candidates who presented to the clinic for initial appointments with the bariatric surgeon during the recruitment period. This population group was selected as the control group in order to capture a population with similar weight problems, physiology and to a degree, pre-surgical eating behaviours, as the surgical population. The post-surgical study population totalled 116 participants (AGB  $n=13$ , RYGBP  $n=41$ , SG  $n=62$ ), see figure 1. Exclusions ( $n=9$ ) were conducted for known confounding factors such as pregnancy or diagnosis and/or treatment for cancer at time of recruitment; and having a subsequent bariatric procedure or procedure reversal since 31st December 2008. Participants who had undergone multiple bariatric procedures were only excluded from the study if their subsequent procedure was performed after December 31<sup>st</sup> 2008. These participants ( $n=33$ ) were placed in the surgical group according to the surgical procedure performed between January 1st 2007 and December 31st 2008. Incomplete data sets were excluded from analysis

resulting in one hundred and twenty nine food tolerance questionnaires being retained (control  $n=14$ , AGB  $n=12$ , RYGBP  $n=41$ , SG  $n=62$ ) and one hundred and twenty eight dietary assessment forms (control  $n=14$ , AGB  $n=13$ , RYGBP  $n=41$ , SG  $n=60$ ).



**Figure 1** Recruitment response rate by surgical group

## Food Tolerance

Food tolerance was compared across the three surgical groups as well as a control group using a Quality of Alimentation questionnaire, a recognised tool for assessing food tolerance in bariatric patients [8]. The questionnaire is divided into three sections. Section one assesses satisfaction with current ability to consume food, with a score range from 1 (very poor) up to 5 (excellent). Section two, specific food tolerance, describes how well eight listed foods are tolerated (red meat, white meat, salad, vegetables, bread, rice, pasta, fish). A score of 2 indicates no difficulty with consumption, 1 indicates some difficulty with consumption, and 0

indicates food item is not at all tolerated. Section three quantifies vomiting/regurgitation frequency with the score ranging from 0 to 6, where: 0 indicates 'daily', 2 indicates 'often' (greater than twice per week); 4 indicates 'rarely' (up to twice per week); and 6 indicates 'never'. Cumulatively the three sections provide an overall score range of 0-27, with a maximum possible score of 27 indicating superior food tolerance.

### Diet Quality

Diet quality was assessed using a non-validated assessment form, developed in line with the Australian Guide to Healthy Eating (AGHE) [18] specifically for this study. This tool specifies a list of food groupings and serving sizes as represented in the AGHE. Participants identified the quantity of food consumed on an *average* day using the food items and serving sizes specified in the tool to record intake. This data was cross referenced with information collected from the self-administered 24 hour food recall to determine each subject's *usual daily intake*.

### Statistical Analysis

Statistical analyses were performed using SPSS for Windows version 17.0 (SPSS, Inc., Chicago, IL, 2008) with statistical significance set at  $p < 0.05$ . Non-parametric tests (Kruskal-Wallis and Mann-Whitney) were used to compare groups with a post hoc comparison using Bonferroni correction as data were not normally distributed. Spearman's correlation

coefficient analysis was used to investigate the relationships between study population characteristics, food tolerance and diet quality.

## Results

### Study Population

The characteristics of the study population are presented in Table 1. A higher proportion of the study was made up by women (67.7%). The RYGBP patients were significantly older than both the control ( $P=0.007$ ) and the SG groups ( $P<0.001$ ). The median time since surgery differed significantly between the RYGBP and the SG groups (34.0 and 26.5 months respectively;  $P=0.003$ ).

There were no significant differences between the pre-surgical BMI's of the four study groups. The post-surgical BMI of the AGB group was significantly different from that of the RYGBP ( $P=0.001$ ) and the SG group ( $P=0.002$ ), however was not significantly different from the pre-surgical BMI of the control group ( $P=0.017$ ). The %EWL of the AGB group (38.2%) was significantly less than that achieved by the RYGBP (76.5%;  $P<0.001$ ) and the SG group (76.6%;  $P<0.001$ ).

**Table 1** Characteristics of population<sup>a</sup>

	CONTROL (n= 14)	AGB (n= 13)	RYGBP (n=41)	SG (n= 62)
Male/Female	4/10	4/9	20/21	14/48
Age (years)	47(28)	46(21)	58(15)*	50(18)
Months since surgery	-	30.0(12)	34.0(12)	26.5(10)**
Pre-surgical BMI (kg/m <sup>2</sup> )	43.2(15.9)	45.5(10.4)	42.4(9.1)	43.2(8.1)
Post-surgical BMI (kg/m <sup>2</sup> )	-	36.4(6.9)***	29.0(6.4)****	30.0(8.9)*****
EWL (%)	-	38.2(35.9)*****	76.5(27.6)	76.3(43.3)

<sup>a</sup> Data presented as median (interquartile range)

AGB, adjustable gastric banding; SG, sleeve gastrectomy; RYGBP, Roux-en-Y gastric bypass

%EWL = (Post-operative weight loss/(pre-operative weight – ideal body weight at BMI 25)) x 100

\*P=0.007 vs. control group and P<0.001 vs. SG

\*\*P= 0.003 vs. RYGBP

\*\*\*P=0.001 and P=0.002 vs. RYGBP and SG respectively

\*\*\*\*P<0.001 vs. control groups pre-surgical BMI

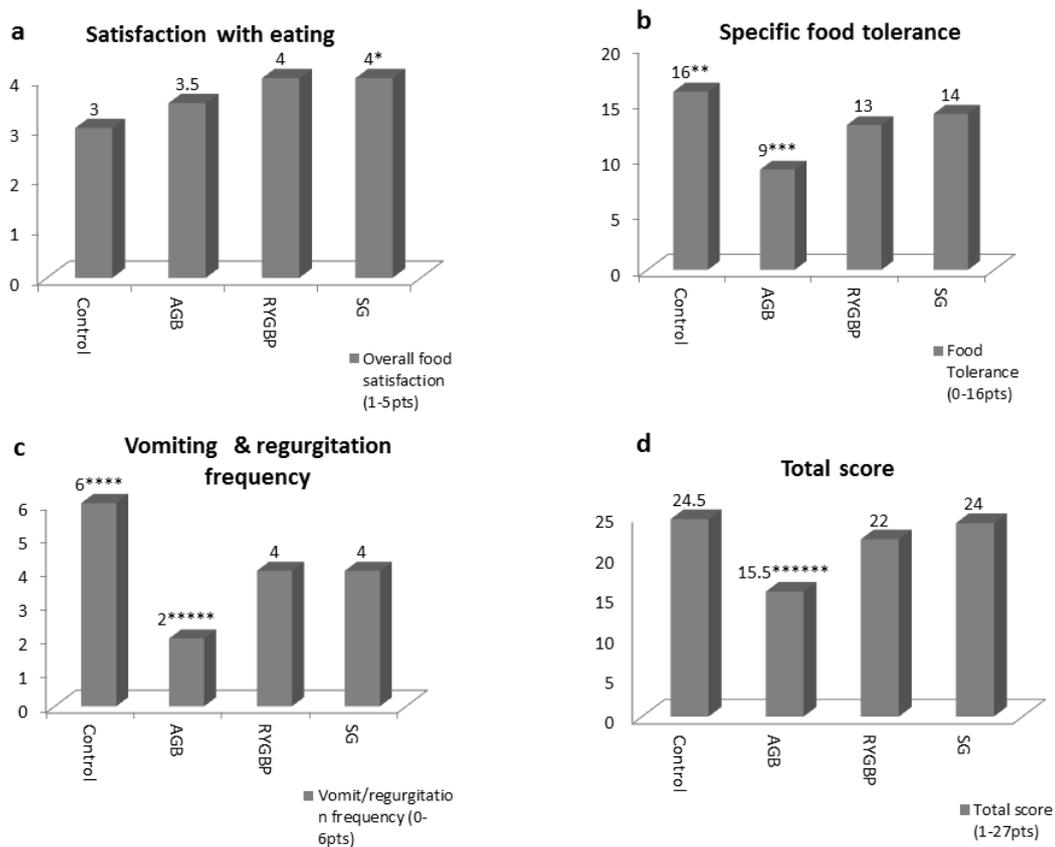
\*\*\*\*\*P<0.001 vs. control groups pre-surgical BMI

\*\*\*\*\*P<0.001 vs. RYGBP and SG

## Food Tolerance

Overall, the AGB group reported the poorest food tolerance with a median *total score* of 15.5 out of 27. This was significantly less than the RYGBP, SG and control groups, which were 22.0, 24.0 and 24.5, respectively (P<0.001) (Figure 2d). *Satisfaction with eating* was similar

for the SG and RYGBP, with both groups achieving a median score of 4.0 out of 5.0. Only the SG group was found to be significantly higher than the control and the AGB groups ( $P=0.003$ ;  $P=0.002$  respectively) (Figure 2a). The median *specific food tolerance* score of the control group was significantly higher than that achieved by the RYGBP and AGB groups ( $P<0.001$ ), though not the SG group (Figure 2b). Both the SG and RYGBP groups achieved a *specific food tolerance* score significantly higher than the AGB group ( $P<0.001$ ). The AGB group reported a higher frequency of *vomiting/regurgitation*, thus achieving a median score that was significantly lower than all other groups ( $P<0.001$ ) (Figure 2c).



**Figure 2** Food tolerance questionnaire results by domain

## Diet Quality

Diet quality analyses highlighted significant differences in daily consumption patterns between groups for the breads & cereals and the extras food groups (Table 2). The SG group reported a median daily consumption of two serves of breads & cereals, a figure significantly less than that consumed by the control group. Median consumption were similar across all four groups for fruit, vegetables, meat & meat alternatives and dairy.

The SG and RYGBP groups reported consuming the least number of extra foods, with a daily median consumption of 3.4 and 4.0 respectively. This intake was significantly less than the control and the AGB groups. The control group reported the highest daily intake of extras. There was no significant difference between the extras consumption of the control and AGB groups (9.2 and 7.7 serves/day respectively).

**Table 2** Diet Quality: Median number of serves consumed daily according to surgical grouping<sup>a</sup> (serving sizes as specified in the AGHE)

	CONTROL	AGB	RYGBP	SG
	n = 14	n = 13	n = 41	n = 60
Breads & cereals	3.5(3.6)	2.0(2.0)	2.5(1.3)	2.0(2.0)*
Fruit	2.5(2.3)	2.0(2.8)	2.0(1.5)	2.0(2.0)
Vegetables	3.8(2.0)	4.0(3.3)	4.0(2.5)	3.0(2.5)
Meat & meat alternatives	2.3(1.8)	2.5(1.9)	2.5(1.6)	2.0(1.5)
Dairy Foods	2.1(1.5)	2.5(1.8)	2.0(1.8)	2.0(1.0)
Extras	9.2(7.6)**	7.7(5.7)***	4.0(3.7)	3.4(3.0)

<sup>a</sup>Data presented as median (interquartile range).

\*P=0.002 vs. control group

\*\*P=0.001 and P<0.001 vs. RYGBP and SG respectively

\*\*\*P=0.005 and P=0.003 vs. RYGBP and SG respectively.

## Correlation Analysis

Table 3 shows the correlation analysis results. A strong, positive association was found between the AGB groups' daily consumption of the meat & meat alternatives food group and their reported tolerance of white meat. A positive association was found between the number of serves of breads & cereals consumed daily and the level of reported food tolerance of both bread and pasta. Likewise a positive association was seen between the type of bariatric surgery and the reported satisfaction of eating.

**Table 3** Spearman’s correlation coefficient analysis to determine association between characteristics, food tolerance and dietary quality data

<b>Variables</b>	<b>r</b>	<b>P-value</b>
AGB Meat & meat alt. consumption (AGB white meat tolerance)	0.721	0.008
Bread & cereal consumption (bread tolerance)	0.354	0.000
Satisfaction with eating (surgery type)	0.309	0.000
Bread & cereal consumption (pasta tolerance)	0.288	0.001

## Discussion

This study showed that the SG and RYGBP patients experienced significantly better food tolerance compared to the AGB group. These superior results for the SG and RYGBP patients were complemented by significantly greater %EWL and a diet that contained significantly less high-calorie extras, compared to both the AGB and the control groups. Our results indicate that the consumption of breads & cereals as well as meat & meat alternatives increases with improved tolerance two to four years post-surgery.

Limited studies have compared the food tolerance of different bariatric surgeries at varying time points. To the best of our knowledge this is the first study to demonstrate this outcome when comparing these three surgical groups and an obese control group at a medium time point of two to four years post-surgery. Our results emulate previous findings by Schweiger et al [9] and Suter et al [8] who have demonstrated inferior food tolerance outcomes for AGB patients ranging between three months to seven years post-operatively. The growing body of evidence to support inferior and declining food tolerance in AGB patients illustrates the importance of considering all possible long term complications prior to bariatric surgery. Overs et al [12], using the same sample population as this study, demonstrated that poor food tolerance is associated with a reduced Gastrointestinal Quality of Life Index (GIQLI). This illustrates gastrointestinal QOL, as another inferior post-surgical outcome for AGB patients compared to other bariatric surgeries two to four years post surgery.

Interestingly in the current study the control group, along with the AGB group, consumed significantly more high-calorie extra foods than both the RYGBP and SG groups. This may indicate that a higher level of dissatisfaction was experienced as a result of an excessive consumption of such foods. *Satisfaction with eating* in the current study was found to correlate with surgery type. Notably the AGB group recorded the lowest median score for *satisfaction with eating*, of the surgical groups; however the question remains is this inferior score a reflection of their reported physical symptoms or their dissatisfaction with their excessive intake of high calorie extras?

It also needs to be considered that the poor food tolerance experienced by the AGB group may play a role in their excessive intake of extras and perhaps be a contributing factor to their poorer weight loss outcomes. The extras food group is typically made up of highly processed and refined foods such as biscuits, pastries, chocolate and ice-cream [18], foods that can contribute to excess caloric intake. Due to the refined and processed nature of these products, they may offer an easier consumption alternative for post-surgical patients experiencing poor food tolerance. Our study adds to the current body of evidence [8, 9] that demonstrates the AGB group has a significantly reduced and declining ability to tolerate a list of specific foods. In addition to this, the AGB patients in our study consumed a significantly higher number of extras, while losing significantly less weight, compared with the SG and RYGBP groups. While the mechanisms for weight loss differ between the AGB procedure and that of the RYGBP and SG procedures, our study highlights that the poorer food tolerance experienced by AGB patients may be impeding their ability maintain a healthy and varied diet. As a result this may increase their consumption of extras adding to caloric intake and thus inhibiting successful weight loss.

Previous research has demonstrated a post-surgical decline in the consumption of high calorie extra foods in RYGBP patients compared to AGB patients [19]. Miras and le Roux [20] offer an explanation for this by reporting an increase in the sweet taste acuity in RYGBP patients, which in turn leads to a decreased desire to consume such foods. Ochner et al [21] recently reported that RYGBP patients displayed a post-surgical reduction in mesolimbic neural responsivity to desire to eat and the liking of high calorie food cues compared with low calorie food cues. This may offer an explanation as to why the consumption of extras by the RYGBP group in the current study was significantly less than that reported by the AGB and control groups. However interesting to note is the comparable result achieved by the SG group. Himpens et al [22] previously reported a loss of craving for sweets following the SG procedure. However to the best of our knowledge, this is the first study to demonstrate a comparable consumption of high calorie extras in RYGBP and SG patients. The comparatively low consumption of extras by the SG group, compared to the AGB and control groups, indicates that surgical procedure may indeed influence more than gastrointestinal anatomy and stomach volume as indicated in a recent review [13]. This finding may provide further insight into the weight loss disparities currently seen between bariatric surgeries and assist patients and surgeons with selecting bariatric procedures specific to desired outcomes.

The current study demonstrates that the consumption of breads & cereals and meat & meat alternatives is associated with the reported tolerance of these foods. In the case of the AGB group, the poor tolerance of white meats (such as pork or chicken) was found to strongly correlate with reduced meat consumption. Of the twelve AGB participants, eight reported consumption difficulties with white meat while eleven people reported consuming red meat

with difficulty. Thus the AGB procedure may continue to influence a patients' ability to consume high biological value (HBV) protein up to four years after the initial procedure. Our study demonstrates that the AGB procedure influences the tolerance of meat and hence its consumption.

Quantifying protein intake fell beyond the aims of this study. Faria et al [23] suggested an inadequate intake of HBV protein may compromise weight loss and lean muscle mass in post-surgical patients, thus emphasising the importance of adequate protein intake. Moize et al [24] outlined recommended intakes in the form of a nutrition pyramid for patients following gastric by-pass surgery. These recommendations emphasise the importance of adequate protein intake after bariatric surgery, with consideration of micronutrient deficiency and post-surgical changes in body composition with weight loss. While these recommendations are specific to gastric by-pass surgery patients, they currently provide a guide to patients undergoing other bariatric procedures in absence of more specific and suitable guidelines.

The consumption of breads & cereals and meat & meat alternatives in the current study was shown to be associated with tolerance. However other factors such as adherence with dietary counseling may have influenced this result and therefore cannot be dismissed. All surgical patients in this study cohort are required to attend pre and post-surgical dietary counseling with the clinic's dietitian. Patients are counseled to aim for a daily consumption of; two serves of protein, three to four serves each of dairy and vegetables, two serves of fruit, less than two serves of breads & cereals (or starchy foods) and a multivitamin supplement. This intake pattern enables patients to prioritise protein and micronutrient intake while limiting

overall energy consumption. This notion is also supported by Moize et al [24] who recently recommended limiting the consumption of breads & cereals to two serves daily for RYGBP patients in order to control total energy intake while optimising protein intake.

Given the surgical intervention and the restriction required to achieve weight loss, it is not appropriate to compare intake levels of this population group with that of general healthy population guidelines. The AGHE was used as a reference tool in the current study and was employed for its usefulness in ascertaining qualitative dietary intake results in this population group. The AGHE provides standard food groupings and serving sizes that are well established and can be utilised in diet quality analysis. They also provide recommendations on the restriction of high-calorie extra foods that may contribute to excess energy intake. Post-surgical dietary guidelines (specific to surgery type and considering problematic foods) would greatly benefit patients. Guidelines such as these would provide bench marks for acceptable long term consumption after surgery with the aim of decreasing the risk of nutritional deficiencies. They would assist stakeholders involved with on-going post-surgical care in identifying patients at nutrition risk and help identify food groups and nutrients of concern.

The current study had several limitations. The small sample number, the discrepancy in subject numbers among the groups and the overall response rate of 34% were the key limiting factors of our study. Results were reported as median and interquartile range due to small group numbers and required caution when comparing to the literature. Secondly this study was based on a questionnaire, relying on self-reported data including anthropometric measurements, and suffers all the limitations of self-reported data (including height, weight

and food consumed). The use of a non-validated tool to collect dietary data limits the strength of the results of the current study. The tool utilised was derived from the AGHE and relied on the ability of patients to accurately estimate the measurements that were specified on the dietary assessment form. Given this was a *diet quality* study specific nutrients and total energy intakes were not quantified. Finally, during the study it was identified that collecting data on maximum weight loss since surgery and weight re-gain may have provided further insight into weight loss outcomes. A recent study highlighted the importance of collecting such information, as weight regain is common in bariatric patients with the trend of weight regain increasing over time [16].

Further research might identify the underlying motivations for consumption patterns in this population group and the extent to which food tolerance influences adherence to diet. Establishing whether food consumption is largely determined by dietary counseling, individual preference or food tolerance would provide beneficial information for both pre and post-surgical counseling. Also, mechanical influences such as masticatory function and eating speed need to be excluded as confounders of food tolerance. A standardised tool to calculate energy and protein intake would be of benefit for future studies in this area.

## **Conclusion**

This study demonstrates the AGB procedure is inferior for weight loss and food tolerance outcomes. It also demonstrates that diet quality is associated with food tolerance. It illustrates that reduced food tolerance and poor diet quality need to be considered as possible complications of the AGB procedure.

## **Conflict of interest**

The authors declare that they have no conflict of interest.

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## Legends:

Figure 1: A control group was utilised to help identify statistically significant outcomes.

AGB, adjustable gastric banding; SG, sleeve gastrectomy; RYGBP, Roux-en-Y gastric bypass.

Figure 2: Adjustable gastric banding performed significantly poorer in three of the four domains.

AGB, adjustable gastric banding; SG, sleeve gastrectomy; RYGBP, Roux-en-Y gastric bypass.

\* $P=0.003$  and  $P=0.002$  vs. control and AGB groups respectively

\*\* $P<0.001$  vs. AGB and RYGBP

\*\*\* $P<0.001$  vs. control and RYGBP  $P=0.001$  vs. SG

\*\*\*\* $P=0.002$  vs. AGB

\*\*\*\*\* $P=0.001$  and  $P<0.001$  vs. RYGBP and SG respectively

\*\*\*\*\* $P<0.001$  vs. control, RYGBP and SG.