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RESEARCH ARTICLE

Hunger Control and Regular Physical Activity Facilitate Weight Loss After Laparoscopic Adjustable Gastric Banding

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Abstract
Background Bariatric surgery facilitates substantial and durable weight loss; however, outcomes vary. In addition to physiological and technical factors, weight loss efficacy is dependent on modification of behavior to maintain a long-term change in energy balance. This study aimed to assess the extent and nature of change in energy intake and physical activity and identify factors associated with percentage weight loss (%WL) 12 months after laparoscopic adjustable gastric banding (LAGB).
Methods 129 bariatric surgery candidates (26 men/103 women, mean age 45.2±11.5, mean body mass index [BMI] 44.3±6.8, range 31.9 to 66.7) completed the study. Data were collected at baseline and 12 months. Validated questionnaires included the Cancer Council Victoria Food Frequency Questionnaire, Three Factor Eating Questionnaire, Short Form-36, Baecke Physical Activity Questionnaire, and Beck Depression Inventory. Symptoms of "non-hungry eating," "emotional eating," and "grazing" were assessed.
Results Mean %WL was 20.8±8.5%, and excess weight loss was 50.0±20.7 ($p<0.001$). Mean total energy intake reduced from 9,991±3,986 kj to 4,077±1,493 kj ($p<0.001$). Average leisure time and sport-related physical activity scores increased (both $p<0.001$). Regression analysis identified baseline BMI ($\beta=0.241$; $p=0.002$), subjective hunger ($\beta=-0.275$; $p=0.001$), physical function ($\beta=0.309$; $p<0.001$), and leisure time physical activity ($\beta=0.213$; $p=0.010$) as independent predictors of %WL, total R^2 0.34%. "Non-hungry eating" and symptoms of depression were also related to poorer %WL.
Conclusion LAGB affects marked behavior change and facilitates substantial weight loss in the first 12 months. However, variations in adopted behaviors can affect energy balance and weight loss success. Achievement and maintenance of favorable behaviors should be an important consideration during on-going postsurgical review and counseling. Management should include adequate band adjustment to control physical hunger, optimization of physical function and activity, and reinforcement of strategies to reduce energy intake.

Keywords Obesity surgery · Eating behavior · Physical activity · Exercise · Predictor

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Introduction

The utilization of laparoscopic adjustable gastric banding (LAGB) is increasing throughout the world in response to escalating rates of classes II and III obesity. LAGB facilitates substantial and durable weight loss; however, outcomes vary [1, 2]. Presurgical factors predicting poorer weight reduction include increasing age, higher baseline body mass index (BMI), insulin resistance, and low self-reported physical ability [3]. Mechanical factors such as port leakage have predicted weight regain after LAGB [1]. In addition to physiological and technical factors, the efficacy of bariatric surgery is dependent on modification of behavior to bring about a long-term change in energy balance [4].

Gastric restrictive surgery facilitates a reliable reduction in energy intake within the first postoperative year [5, 6]. Yet, the excessive consumption of high energy liquids and soft foods after vertical banded gastroplasty has been associated with inferior weight outcomes [7, 8].

An increase in liquid calories and decrease in solid foods have been observed after LAGB [5], but the association with weight outcome is unexplored. A preference for sweets does not result in inferior weight loss [9]. Poorer 12-month weight outcomes have, however, been associated with greater subjective hunger and dietary disinhibition [10]. High levels of depression [11] and eating in response to emotional cues [12] are also found among bariatric surgery candidates. Although preoperative depression has not predicted poorer weight loss at 1 year [3], the association between postsurgical mood, eating behavior, and weight outcome is unknown. A "grazing" pattern of eating has also been observed after surgery [13], but the prevalence and significance of this eating behavior require elucidation. After surgery, physical activity levels appear to increase [14, 15] and contribute positively to lean tissue mass [16]. Yet, objective measures of the change in physical activity have not been undertaken, and the nature of any association with other postsurgical behaviors is unexplored.

The identification of behavioral factors associated positively and negatively with postsurgical weight loss may help us modify current lifestyle guidelines and identify patients who need more intensive interventional therapy. This study aimed to explore the nature and extent of change in (1) patterns of dietary intake, (2) patterns of physical activity 12 months after LAGB, and associations with surgical outcome. Assessment of dietary patterns included prospective measurement of energy and macronutrient intake and food consistency and eating behavior. Habitual physical activity and functioning before and after surgery were assessed by two self-report questionnaires and pedometer step-counts. Factors most closely associated with the percentage of weight lost were of primary interest.

Methods and Materials

Subjects

Consecutive, eligible subjects were recruited upon acceptance into the bariatric surgery program at The Avenue Hospital, Melbourne, Australia, before Lap-Band® System (Allergan Health, Irvine, CA, USA) placement. Eligible individuals were men or women aged between 18 to 65 years, with no previous history of bariatric surgery. All subjects provided written informed consent before taking part in the study, which was approved by the Monash University Standing Committee on Ethics in Research involving Humans.

During pre- and postsurgical appointments, subjects were provided with standard advice regarding recommended postoperative eating behaviors and exercise patterns. The topics of education and discussion that were covered extensively and repeatedly included: (1) eat three small meals per day, (2) eat only good, solid food, (3) eat slowly, stop when comfortable, (4) avoid eating between meals, (5) take no liquids with the meal, (6) consume only liquids that contain zero calories, (7) exercise for at least 30 min per day, (8) be active throughout the day, (9) aim for 10,000 (pedometer-recorded) steps per day, (10) take a daily multivitamin and mineral supplement.

Study Design

The study was of a prospective, observational design. Baseline and follow-up data at 4 and 12 postsurgical months were primarily obtained via validated self-report questionnaire.

Anthropometry

Weight was recorded at baseline, 4 and 12 months to the nearest 0.1 kg using the electronic Tanita Wedderburn TBF-305 (Lake Worth, FL 33467, USA) in light clothing without shoes. Height was determined at baseline to the nearest millimeter using a wall-mounted stadiometer. The main outcome measure was the percentage of weight lost at 12 months after LAGB placement (percentage weight loss [%WL]). The percentage of excess weight loss (%EWL) has also been reported. The %EWL was calculated by dividing weight loss in kilograms by excess weight (the initial weight minus weight at BMI 25), and multiplying this figure by 100.

Assessment of Eating Behavior

The Cancer Council Victoria Food Frequency Questionnaire (CCVFFQ) [17] was used to record subject's usual dietary intake at baseline, 4 and 12 months. The CCVFFQ is an optically scannable, semi-quantitative assessment tool that lists 74 foods with 10 frequency options. To control for extreme values, the top and bottom 2% of usual energy intakes for the baseline, 4- and 12-month questionnaires were excluded from all statistical analyses. To compare different consistencies, foods were divided according to "solid", "soft," and "liquid" textures. Based on the definition of Busetto et al. [5], solid food was defined as "all food requiring chewing before swallowing," soft food as "all solid foods and viscous liquids not requiring mastication before swallowing," and liquid food as "all caloried liquids."

The Three Factor Eating Questionnaire (TFEQ) [18] assessed dietary restraint, disinhibition, and hunger at baseline and 12 months. A self-made questionnaire collected additional data on eating behavior. At baseline, 4- and 12-month subjects were asked how many times a day they ate, considering all meals and snacks as a separate “eating episode.” At 12 months, a series of questions also obtained information on subjective feelings of fullness, the return of “old eating habits,” and situations or emotions considered by the subject to stimulate eating or overeating.

Assessment of Depression

The Beck Depression Inventory (BDI) [19] assessed symptoms of depressive illness at baseline and 12 months. Within a possible score range of 0 and 63, a score of 0–9 was considered ‘Normal’; 10–16 ‘Mild depression’; 17–29 ‘Moderate depression’; and 30–63 ‘Severe depression’ [20].

Assessment of Physical Activity

The Physical Component Summary (PCS) score of the Medical Outcomes Trust Short Form-36 (SF-36) [21] was used as a measure of well-being related to physical function. This health summary scale was adjusted to achieve a community mean value of 50 with a standard deviation of 10. The Baecke Physical Activity Questionnaire assessed habitual physical activity over the previous year at baseline and 12 months [22]. Separate work, sport and leisure index scores were calculated, plus a total score. A self-made questionnaire also assessed the presence of 11 possible barriers to regular physical activity. Participants were encouraged to record pedometer step counts (Sportline 330, Manufactured by Sportline, Inc., Hazleton, PA 18202, USA) at baseline and 12 months in a 7-day pedometer diary. Maintenance of a pedometer diary was not mandatory.

Data Analyses

All continuous variables were normally distributed except the BDI score at baseline and 12 months and the TFEQ hunger score at 12 months, which required log transformation. Descriptive statistics were used to express the mean ±SD for continuous variables and median (interquartile range [IQR]) for categorical variables and data not normally distributed. Paired Student’s *t*-tests compared continuous variables between baseline, 4 and 12 months as appropriate. Independent samples *t*-tests compared continuous variables divided into respondents and nonrespondents, quartiles and eating categories. The chi square test assessed for differences between categorical variables. Simple bivariate correlations assessed the strength of the association between two continuous behavioral variables. Mann–Whitney *U* tests assessed for differences between categorical and ordinal data. Linear regression, using forward and backward modeling, assessed for predictors of %WL. Factors were grouped into (1) age, gender, baseline BMI, and insulin resistance (controlling variables), (2) energy and macronutrient intake, (3) eating behavior, (4) psychopathology, and (5) physical activity-related variables. SPSS version 12.0.1 was used for statistical analysis. A p value of less than 0.05 was considered statistically significant. A p value of greater than 0.05 and less than 0.10 was considered a statistical trend.

Results

Subject Characteristics

Of 180 baseline respondents, 6 subjects did not undergo LAGB, and 1 subject with a past history of heart disease died of a related cardiac illness 3 months after surgery. At 12 months, 129 surveys from a possible 173 subjects were returned, a response rate of 75%. Nonrespondents had achieved a lower %WL, 16.0±8.9% versus 20.8±8.5% (p= 0.002) and had attended less clinic appointments during their first postoperative year; median (IQR) 10 (8–12) versus 12 (9–14) (p=0.015). Gender and age distribution did not differ. The median (IQR) number of band adjustments was also similar at 7(5–9) in nonrespondents and 7(5–10) in study participants. In the combined group of respondents and nonrespondents (n=173), there was a positive correlation between the annual number of clinic visits and %WL, r=0.16, p=0.045. The number of band adjustments was strongly associated with clinic visits, r=0.76, p<0.001, but did not correlate with %WL. In the first year after surgery, 85.5% of the original cohort (n=148 of 173) achieved greater than a 10%WL.

In the final group of 129, anterior prolapse of the band occurred in two subjects (1.6%) and port-related problems in three subjects (2.4%) during the first year. Once diagnosed, all fluid was removed from the Lap-band system. Fluid removal commonly results in increased hunger, and some weight regain can be expected before reoperation. Revisional surgery was undertaken in all cases.

Tables 1 and 2 list a range of demographic, anthropometric, and behavioral characteristics at baseline and 12 months after LAGB. Body weight reduced significantly between baseline and 4 months, and 4- and 12-month follow-up. This corresponded to a mean reduction in BMI of 6.0±2.8 and 9.3±4.5 kg/m^2, respectively. Marked change across a range of eating- and exercise-related variables was also evident.

Change in Energy, Macronutrient Intake, Food Consistency and Associated Factors

Average energy and macronutrient intakes as measured by the CCVFFQ are listed in Table 1. Mean total energy intake decreased significantly from 9,991 kj at baseline to 4,104 kj

Table 1 Demographic, anthropometric, and eating-related traits at baseline, 4, and 12 months

	Baseline (n=129)	4 months after LAGB [n=93 (72%)]	12 months after LAGB (n=129)
Mean age (years)	45.2±11.5	–	–
Male/female	26/103	8/85	26/103
Mean weight (kg)	122.2±20.5	105.7±17.1***	96.5±18.2***
Mean BMI (kg/m^2)	44.3±6.8	38.3±5.9***	35.0±6.0***
Mean %WL	–	13.3±5.1%	20.8±8.5%***
Mean %EWL	–	32.2±13.0	50.0±20.7***
Total energy (kj)[a]	9991±3986	4104±1504***	4077±1493
Total fat (m)	98.5±42.6	34.1±15.9***	34.6±16.1
Total protein (g)	113.8±40.6	54.0±19.7***	52.2±18.7
Total CHO (g)	233.0±93.4	100.4±39.4***	98.5±40.6
% Energy from fat	36.6±5.3	30.1±6.2***	30.8±6.8
% Energy from protein	20.1±3.4	22.7±3.9***	22.1±4.3
% Energy from CHO	37.9±5.6	39.6±7.1*	38.8±7.3
% Solid foods	56.7±11.6	44.6±11.8***	39.7±13.8**
% Soft foods	12.5±5.9	12.7±7.0	13.0±7.9
% Liquid foods	30.9±13.2	42.7±14.0***	47.3±16.1**
No. of eating episodes	5.0±3.0	4.0±3.0***	4.0±3.0
TFEQ restraint	8.3±3.9	–	13.0±4.2***
TFEQ disinhibition	11.5±3.4	–	6.2±3.9***
TFEQ hunger[b]	9 (6–12)	–	2 (1–5)***
BDI depression score[b]	15 (10–21)	–	7 (4–11)***

Continuous variables presented as mean±SD except where indicated.
Dietary comparisons based on 85 subjects who completed a questionnaire at baseline, 4, and 12 months.
Student's t-tests assessed for differences between baseline and 4 months, 4 months and 12 months, and baseline and 12 months as appropriate.
Wilcoxin Signed Ranks test assessed for differences between categorical data at baseline and 4 months, and 4 and 12 months.
BMI Body mass index; *%WL* percentage weight loss; *%EWL* percentage excess weight loss; *CHO* carbohydrate; *TFEQ* Three Factor Eating Questionnaire; *BDI* Beck Depression Inventory.
[a] The highest and lowest 2% of total reported energy intake have been excluded from analysis.
[b] Data log transformed for analysis and presented as median (quartile range).
*p<0.05
**p<0.01
***p<0.001

at 4 months. At 12 months, the average energy intake of 4,077 kj did not differ from the 4-month value. By four postsurgical months, the percentage of energy derived from fat had reduced significantly, and the proportion of energy from protein and carbohydrate (CHO) increased. Total energy intake at 12 months was positively associated with the percentage of energy derived from fat, r=0.19, p=0.035, and negatively associated with the percentage of energy derived from protein, r=−0.25, p=0.006. Total energy intake was not associated with the proportion of dietary CHO, r=−0.08, p=0.37.

Food choice also altered after surgery. The proportion of total energy derived from solid foods reduced significantly between baseline and 4 months and reduced further by 12 months (Table 1). Equally, the proportion of total energy intake derived from liquid foods increased between baseline and 4 months and continued to increase to 12 months. The mean percentage of soft foods did not change. A higher proportion of protein (p=0.002) and CHO (p=0.048) was consumed by those in the highest quartile of solid food intake compared to the lowest.

At 12 months, total energy intake was positively correlated with the hunger score, r=0.029, p=0.001, disinhibition score, r=.229, p=0.011, and symptoms of depression, r=0.27, p=0.003. Total energy intake was inversely associated with dietary restraint, r=−0.23, p=0.013, SF-36 PCS score, r=−0.17, p=0.05, and Baecke Leisure Index Score, r=−0.22, p=0.014. Eating in response to anxiety (p=0.050) and fatigue (p=0.028) was related to a higher energy intake, and those conscious of the frequent recurrence of "old eating patterns" (n=35) also consumed more energy than those who reported no difficulty maintaining behavioral change (p=0.009).

Change in Physical Activity Levels and Associated Factors

Throughout the study period, voluntary activity assessed by the Baecke Work Index remained constant, whereas Baecke

Leisure and Sport Index Scores increased, contributing to an improvement in Baecke Total Score (Table 2). At 12 months, the Baecke Leisure Index Score was positively correlated with %WL (see below) and dietary restraint, $r=0.20$, $p=0.022$, and negatively related to total energy intake, dietary disinhibition, $r=-0.28$, $p=0.002$, hunger, $r=-0.29$, $p=0.001$, and the number of perceived barriers to exercise, $r=-0.22$, $p=0.015$. Those reporting the return of "old eating habits" ($p=0.003$) and overeating because of stress ($p=0.05$) also reported a lower Leisure Index Score. A trend toward lower Leisure Index Scores was also noted in those who ate when depressed/upset ($p=0.072$) and anxious ($p=0.072$).

The mean SF-36 PCS score increased significantly in the first 12 months after LAGB (Table 2). The SF-36 PCS was positively associated with the Baecke Total Score, $r=0.23$, $p=0.008$ and Baecke Leisure Index Score, $r=0.20$, $p=0.024$. Inverse relationships were seen between the SF-36 PCS and dietary disinhibition, $r=-0.21$, $p=0.016$, hunger, $r=-0.20$, $p=0.026$, and BDI score, $r=-0.33$, $p\leq 0.001$.

Paired 7-day pedometer diaries were returned by 48 subjects (37.2%). In this group daily step-counts rose by 2,655 steps to an average of 8716 (Table 2). After surgery, walking further on a given day was positively associated with the Baecke Leisure Index Score, $r=0.34$, $p=0.016$. It is possible that those who failed to return the paired pedometer diaries were more likely to be walking less regularly or had not significantly changed their physical activity patterns from baseline. However, the correlation between poorer %WL and lower daily step counts still suggests that regular walking is associated with better weight outcomes (see below).

Factors Associated with %WL

Five subjects (3.9%) required reoperation in the first year for either band prolapse or port-related problems. These subjects lost significantly less weight (10.1±5.7% versus 21.1±8.4%) than the remainder of the cohort ($p=0.010$).

At 12 months, total energy intake was inversely correlated with %WL, $r=-0.23$, $p=0.009$. Those in the highest quartile for total energy intake, consuming a reported 5,898±1,009 kj/day, achieved a significantly poorer %WL than those in lowest quartile, consuming a reported 2,334±304 kj/day ($p=0.005$). The highest quartile for total fat intake, consuming >41.1 gm/day, also lost a lower %WL than those in the lowest quartile, consuming <22.9 g/day ($p=0.029$). With regard to food consistency, a trend toward poorer weight loss was apparent only in those who consumed more soft foods, $r=-0.16$, $p=0.075$.

Not surprisingly, there was a high overlap between behaviors influencing %WL and total energy intake. The %WL was positively associated with dietary restraint, $r=0.22$, $p=0.014$, SF-36 PCS, $r=0.38$, $p<0.001$, and Baecke Leisure Index Score, $r=0.32$, $p<0.001$. Inverse associations were noted for disinhibition, $r=-0.39$, $p<0.001$, hunger scores, $r=-0.43$, $p<0.001$, eating in response to anxiety ($p=0.006$), the frequent recurrence of "old eating patterns" ($p<0.001$), and symptoms of depression ($p=0.005$). The magnitude of change in total energy intake, $r=-0.22$, $p=0.020$, TFEQ hunger, $r=-0.30$, $p<0.001$, disinhibition, $r=-0.36$, $p<0.001$, and dietary restraint, $r=0.20$, $p=0.025$, SF-36 PCS, $r=-0.33$, $p<0.001$, Baecke Leisure Index Score, $r=0.33$, $p<0.001$, Baecke Total Score, $r=0.21$, $p=0.020$, and BDI score, $r=-0.22$, $p=0.016$, was also related to %WL. Less weight loss was also recorded in

Table 2 Changes in physical function and activity levels during the first postoperative year

	Baseline	12 months after LAGB
SF-36 PCS Score	37.2±10.0	49.2±9.8***
Pedometer step-count[a]	6061±2740	8716±5348**
Highest day's step-count[a]	8571±3511	11312±4438***
Lowest day's step-count[a]	3926±2246	5148±2772**
Baecke Work Index Score	2.49±0.64	2.46±0.57
Baecke Sport Index Score	1.69±0.50	2.11±0.61***
Baecke Leisure Index Score	2.11±0.60	2.74±0.66***
Beacke Total Score	6.30±1.17	7.32±1.27***
Total barriers to exercise	3.44±1.75	2.27±0.64***

Continuous variables presented as mean±SD.
Student's *t*-tests assessed for differences between scores at baseline and 12 months.
$n=129$ except where indicated
PCS Physical component summary
[a] $n=48$
** $p<0.01$
*** $p<0.001$

those who admitted eating despite feeling full (61%) (p=0.018) and eating when depressed/upset (p=0.008) and in those who recorded a lower minimum pedometer step-count, r=0.30, p=0.032, and higher number of barriers to physical activity, r=−0.20, p=0.021. Subjects who ate four or more times per day (n=43) lost a similar amount of weight to those who ate one to three times/day (n=86). There was no statistically significant correlation between the %WL and band fill volume for either the 10-cm or VG Lap-Band® system.

Behavioral Predictors of %WL 12 Months After LAGB

A linear regression model identified four independent predictors of greater %WL 12 months after LAGB. Higher baseline BMI, β=0.241, p=0.002, lower 12-month hunger score, β=−0.275, p=0.001, higher 12 month SF-36 PCS, β=0.309, p<0.001 and higher 12 month Baecke Leisure Index Score, β=0.213, p=0.010, predicted 33.7% of total variance in %WL.

Discussion

This study measured a range of eating- and exercise-related behaviors before and 12 months after LAGB. The nature and extent of behavioral change and the association with weight loss were the main focus. Over the study period, mean BMI reduced significantly. This marked change in weight was accompanied by a sizable reduction in energy intake, comparable to that observed by Busetto et al. [5] using 24-h recall. Significant increases in physical functioning and activity levels were also reported, suggesting a favorable change in energy balance via reduced intake and increased expenditure. Significant improvements in a number of eating-related behaviors and a mood-related measure were also evident. However, across all variables, a range of outcomes occurred. Factors most strongly predicting greater 12 month %WL included a higher baseline BMI, lower 12 month subjective hunger, higher 12 month QoL related to physical function and higher 12 month leisure time activity.

Consistent with our findings, others have reported superior weight loss associated with marked reductions in subjective hunger at 12 [10] and 24 [23] after gastric restrictive surgery. The results of this study support that lower subjective ratings of hunger are directly associated with a reduction in total energy intake, which is in turn associated with greater weight loss. We have previously found an optimally adjusted Lap-band produced significantly higher ratings of satiety in the fasting state compared to unrestricted bands and obese non-banded controls [25]. A physiological response to restriction at the gastro-esophageal junction [5, 25, 26] that overrides the characteristic hormonal response to weight loss [27, 28] is one possible mechanism.

Appropriate band-fill volumes are clearly critical to achieve and maintain an increased sense of satiety and reduced hunger. Excessive energy intake may in part reflect inadequate band adjustment. However, higher subjective hunger measured by the TFEQ was also related to symptoms of "non-hungry eating" and depression. The TFEQ measures elements of "emotional" hunger and food craving. Eating in response to negative emotional states and continuing to eat despite feeling full are forms of non-hungry eating related to higher reports of hunger and poorer weight outcomes. Others have observed eating in response to emotions among bariatric patients [12, 29] and, in nonsurgical populations, an increased propensity for fatty and sweet foods [30, 31]. It has been suggested that "emotional eaters" have difficulty articulating negative emotions. Eating may provide a transient shelter to avoid confronting difficult feelings [29]. Recognition and management of those who engage in non-hungry eating appears important to optimize weight loss outcomes and psychological well-being.

After surgery, poorer QoL related to physical function and a lower physical activity level, particularly during leisure time, were clearly related to less weight loss. Although both physical activity measures increased markedly, lower 12-month scores and lesser improvements over the year were associated with poorer weight loss. Instruction to walk regularly, which is the most common and practical form of leisure time activity among overweight and obese persons, appears important. Pedometers can be useful self-monitoring and motivational tools [32], especially if participants are keeping records and working toward set goals [33]. Barriers to physical activity and inactive pursuits such as watching television should be minimized. Moreover, improvements in physical activity appeared to cluster with favorable eating behaviors. This relationship has been observed during a behavioral weight loss program and may highlight a more motivated group [34]. Regular physical activity is also considered one of the strongest predictors of long-term weight loss maintenance [35].

In this study, features of depression and several eating-related behaviors were inversely associated with physical functioning and leisure time physical activity. Physical activity is beneficial in the primary and secondary prevention of depression [36, 37], whereas a low mood can lead to isolation and immobilization. Regular exercise may also help manage negative emotions, rather than turning to food.

During the first postoperative year, the percentage of solid foods was reduced, liquid foods increased, and soft foods remained stable in a pattern similar to that reported previously [5]. Dietary consistencies were not related to energy intake or weight outcome; however, diets proportionately higher in soft foods were associated with higher fat intakes and a trend toward poorer weight loss. Likely explanations for modifications in food consistency are fear of aversive stimuli and failure to maintain advice recommending slow, thorough mastication of small bite-sized pieces of solid food. Noncompliance with these guidelines increases the risk of gastrointestinal symptoms [38]. Those in the lowest quartile for fat intake lost significantly more weight than the highest quartile. The intake of high-fat foods and cooking methods should be minimized. Diets containing a higher percentage of solid foods contained more protein and were lower in energy than diets higher in fat or CHO. After surgery, the percentage of energy derived from protein increased; however, the mean daily protein intake could still be considered less than the average recommendations [39, 40]. A recent systematic review of change in fat-free mass during various weight loss interventions [41], and comparison of change in protein metabolism following LAGB and a medical weight loss intervention [42] have both shown favourable results following LAGB. Nevertheless, particularly during active weight loss, adequate dietary protein is an important consideration. Dietary protein is a vital macronutrient that should be consumed in preference to CHO and fat.

On-going assessment, counseling, and guidance after surgery are clearly essential. In this study, subjects who attended a higher number of clinic visits lost a greater %WL. Regular clinic attendance enables adequate band adjustment to facilitate increased feelings of satiety and reduced hunger. Reinforcement and good understanding of behavioral advice and effective strategies to implement favorable behaviors should contribute to reduced energy intake and increased physical activity, which in turn influence weight loss and mood. Regular clinic contact also provides the opportunity to identify potentially detrimental factors and behaviors such as high "physical" or "emotional" hunger, non-hungry eating, poor physical ability/mobility, or low mood. Interventions and professional counseling can then be provided as appropriate.

Several factors must be considered in the interpretation of this study. Nonrespondents (25%) were distinguished by a poorer %WL and fewer clinic visits, supporting the observation that patients who do more poorly are less inclined to attend follow-up [13]. Biased weight outcomes in study participants affect the ability to generalize our results and suggests the prevalence of unfavorable behaviors and/or low mood may have been higher. Despite this limitation, participants displayed a range of weight loss outcomes. Numbers were ample to find robust associations between %WL and data collected by validated questionnaires. The assessment of habitual dietary intake using a FFQ may decrease under-reporting in obese individuals [43]; however, this method may have lacked the sensitivity to detect differences in 4- and 12-month energy intakes.

This study highlights a range of postoperative behaviors associated with variations in energy balance and weight outcomes 12 months after LAGB surgery. Table 3 provides a summary of behavioral recommendations based on study findings. Although these subjects had undergone LAGB, low physical function and activity, elevated hunger and non-hungry eating, symptoms of depression, and higher intakes of energy and fat are universal possibilities after any bariatric procedure. Identification of any or a combination of these characteristics can highlight persons who may need more intensive interventional therapy. Regular clinic contact and band volume adjustment are vital to optimize weight loss after LAGB. Controlled studies are required to define optimal management strategies by testing the impact of approaches, such as cognitive behavioral therapy and intensive exercise therapy after LAGB and other bariatric procedures.

Table 3 Eating and exercise-related behaviors that can facilitate weight loss after LAGB

Eating-related behaviors:
Manage physical hunger. Encourage regular clinic attendance for band volume reviews and adjustments
Assess for signs of "non-hungry eating." For example, a tendency to eat when upset, anxious or tired, or eating despite feeling full
Encourage appropriate "solid" foods that are high in protein, in preference to soft foods
Provide advice and encouragement to minimise total energy intake and the proportion of fat in the diet
Exercise-related behaviors:
Assess for signs of poor physical function or bodily pain. Where possible, assist patients to overcome these problems
Encourage regular participation in physical activity, such as walking during leisure time and as a form of transport
A pedometer may be a useful motivation tool
Minimize inactive pursuits such as watching television
Assess and work to overcome barriers to participation in regular physical activity

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