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INVITED REVIEW

A systematic review of dietary intake after laparoscopic adjustable gastric banding

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dietary intake, gastric banding, obesity surgery, systematic review.

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Abstract

Background: Laparoscopic adjustable gastric banding (LAGB) is currently one of the most popular surgical obesity treatments worldwide. Although dietary modification is recognised as a key factor in determining weight loss and health outcomes post surgery, existing evidence regarding changes in dietary intake after LAGB has not been systematically evaluated. This is essential for developing best-practice dietetic guidelines for the management of LAGB patients. The aim of this systematic review was to evaluate the current evidence base regarding changes in dietary intake after LAGB.
Methods: A literature search of Medline, EMBASE, Scopus, Cinahl and the Cochrane Library from 1990 to February 2010 was conducted to identify original studies that assessed dietary intake in adults who have undergone LAGB.
Results: Only 11 articles (10 separate studies) met inclusion criteria. Although the strength of the evidence base is limited by the small number of studies, observational study designs and methodological weaknesses, the results indicate that short-term positive changes occur post surgery, including reduced caloric intake, contributed to by reductions in fat, carbohydrate and protein intake. Issues including optimal macronutrient intake, diet quality and longer-term sustainability of reduced food intake remain largely unexplored. Because no dietary intervention studies were identified, evidence-based dietary strategies that may help optimise weight loss outcomes and other health outcomes remain unknown.
Conclusions: There is a paucity of high-quality evidence regarding changes in dietary intake after LAGB. Further well-designed, dietary-based intervention research will be beneficial to better establish dietetic management guidelines for optimising outcomes for individuals who have LAGB.

Introduction

Bariatric surgery is increasingly gaining recognition as the most efficacious treatment strategy for obesity compared to traditional lifestyle and pharmacological approaches (Colquitt *et al.*, 2009). Laparoscopic adjustable gastric banding (LAGB) is currently the most popular form of obesity surgery in the UK, Europe and Australia (Buchwald & Williams, 2004), and is the second most popular procedure in the USA (Farrell *et al.*, 2009). LAGB is a purely restrictive procedure, facilitating weight loss by acting as a tool to reduce food intake rather than altering digestive and/or absorptive processes (Colquitt *et al.*, 2009).

Average weight loss following LAGB is 20–30% of initial body weight by 2 years post surgery (Gasteyger *et al.*, 2006, Sjostrom *et al.*, 2007), with longer-term weight loss maintained at approximately 14% of initial weight (Sjostrom *et al.*, 2007). Although LAGB generally achieves smaller weight losses compared to more invasive procedures such as roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (Colquitt *et al.*, 2009), this is offset by its favourable risk profile and complete reversibility, with integrity of the gastrointestinal tract maintained (O'Brien *et al.*, 2005). As such, LAGB is likely to remain as a preferred surgical option for obesity in the foreseeable future, despite criticism that it may lead to inadequate weight loss and/or weight regain over the longer term (Suter *et al.*, 2006; Tolonen *et al.*, 2008).

Given the intrinsic link between an individuals ability to modify food intake behaviours and weight loss following LAGB, compliance with dietary advice and ongoing dietary follow-up are often cited as key factors in determining weight loss and health outcomes post surgery (Dixon & O'Brien, 2002; Sauerland *et al.*, 2005; Pontiroli *et al.*, 2007). Despite this, there has been limited evaluation of the evidence regarding post-operative dietary intake in the context of weight loss and health optimisation after LAGB. Previous reviews and practice guidelines have generally focused on clinical nutritional deficiencies (Bloomberg *et al.*, 2005; Malinowski, 2006; Shah *et al.*, 2006; Davies *et al.*, 2007; Aills *et al.*, 2008; Mechanick *et al.*, 2008), where it is generally accepted that prophylactic supplementation with a multivitamin post surgery is sufficient to prevent overt deficiencies from occurring (Gasteyger *et al.*, 2006; Aills *et al.*, 2008).

Evaluation of the current evidence base is an important step for identifying dietary strategies that may help optimise weight loss and health outcomes for individuals who have had LAGB. This will assist in the development of best practice dietetic guidelines for the management of LAGB in the context of weight loss and health optimisation post surgery. Therefore, the present study aims to systematically review the current evidence regarding changes in dietary intake following LAGB, with a view to inform further development of dietetic management guidelines in the future.

Materials and methods

This present study reports on dietary intake outcomes identified as part of a broader systematic review of dietary intake and eating behaviours after LAGB. Results of the eating behaviour component of the review will be published separately.

Review inclusion criteria

Any original published study that reported dietary intake outcomes for adults (aged >18 years) who had undergone LAGB was considered for inclusion. Children/adolescent studies were not included given that LAGB is traditionally performed in adults, and children/adolescents represent a distinct needs group that is not directly comparable with the adult population. Studies were not limited to randomised control trials (RCTs) because based on preliminary literature searches, the authors anticipated a scarcity of RCTs in the area. Cross-sectional studies were considered only if they included a post-operative LAGB group and a preoperative comparison group. Because it was anticipated that there would be a paucity of studies available for inclusion in the review, the minimum length of follow-up post surgery was not set as an inclusion criterion.

The following types of articles were excluded: narrative reviews, conference abstracts, case reports, editorials, letters, comments and any other articles that were not original research papers. Studies that did not clearly specify the surgical procedure undertaken or that combined results of LAGB with other surgical procedures were also excluded. Studies that only reported preoperative dietary variables or that did not report specific results for which data could be extracted were also deemed ineligible for inclusion.

Search strategy

To identify relevant articles, the following electronic databases were searched: Medline (Ovid SP), EMBASE, Scopus, Cinahl and the Cochrane Library. Combinations of the following search terms were used: 'gastric banding' OR 'LAGB' OR 'gastroplasty' AND 'dietary' OR 'nutrition' OR 'food' OR 'eating' OR 'feeding' OR 'calori*'. The search strategy was modified for each database as required, with limits set for humans, English language, adult population and publication date after 1990. A publication date limit was set given that LAGB was not an established procedure prior to this time. Reference lists of all retrieved papers were also manually searched to identify any additional articles not identified by the electronic search. The search included articles published up to February 2010. Unpublished studies were not included in the search strategy.

Study selection

To identify studies that met review criteria, two reviewers independently assessed information provided in the title, abstract and keywords aiming to make a decision about the article's suitability for inclusion. In the case that there was insufficient information in the title and abstract to determine suitability for inclusion, the full paper was retrieved and reviewed so that a determination could be made.

Critical appraisal

Methodological quality of included studies was assessed independently by two reviewers using the Quality Assessment Tool for Quantitative Studies (Effective Public Health Practice Project). This tool has established content and construct validity (Thomas *et al.*, 2004) and has been deemed appropriate for assessing study quality in systematic reviews, with the advantage of covering multiple types of study design including controlled and uncontrolled studies (Deeks *et al.*, 2003). The tool was modified to include an additional question for assessment of confounders relevant to observational study designs, as adapted from the American Dietetic Association Evidence Analysis Library: Quality Criteria Checklist for Primary Research (ADAEAL: QCCPR) (American Dietetic Association, 2010). A copy of the modified tool is provided in the Appendix.

Detailed instructions as provided by the Quality Assessment Tool for Quantitative Studies developers were used as a basis to determine the overall quality rating for each study (Effective Public Health Practice Project, 1998a). In summary, this involved rating each component within the tool as 'strong', 'moderate' or weak', based on question-specific criteria provided in the guidelines (Effective Public Health Practice Project, 1998a). A global rating was then assigned using the following criteria: strong (at least four strong component ratings with no weak ratings); moderate (less than four strong ratings and one weak rating); and weak (two or more weak ratings) (Effective Public Health Practice Project, 1998b). Because the quality checklist tool did not include an assessment of potential funding bias, this was assessed using a question from the ADAEAL: QCCPR, 'Is bias due to study's funding or sponsorship unlikely?', determined by the sub-questions: 'Were sources of funding and investigators' affiliations described?' and 'was there no apparent conflict of interest'? The overall response options were: Yes/No/Unclear or N/A, with critical reasoning skills required to make an overall determination (American Dietetic Association, 2010).

Studies were also graded according to Australia's National Health and Medical Research Council (NHMRC) level of evidence guidelines to further assess the degree to which bias has been eliminated by study design (National Health and Medical Research Council, 2000). Level I reflects the highest level evidence (systematic reviews of RCTS) and level IV reflects the lowest (case series and cross-sectional studies) (National Health and Medical Research Council, 2009).

Data extraction and synthesis

Data relating to study characteristics, study design, methodology and dietary intake outcomes were extracted by the first reviewer using standardised, self-developed data extraction forms. Specific data extracted included: length of follow-up, number of participants, retention rate, study setting, subject characteristics (gender, age, preoperative weight, body mass index), mean weight loss post surgery, dietary intake assessment methodology and all dietary intake results for which post-operative data were reported. These dietary intake results included: preoperative and post-operative energy, nutrient and food group intakes (including changes in intake); dietary-related comparisons between non-operative controls and/or subjects with different types of gastric band; relationships between dietary intake variables; and relationships between dietary intake variables and weight loss outcomes where available.

In the case that a study compared LAGB with another surgical procedure/weight loss intervention, only data relevant to the LAGB arm of the study were extracted because it was not an aim of the present review to compare outcomes of LAGB with other procedures. Data extraction was verified by the second reviewer. Results for dietary intake outcomes were tabulated and described using narrative summary. A meta-analysis was not attempted as a result of variability in the outcomes assessed and methodological differences between studies.

Results

Description and critical appraisal of included studies

Of the 815 articles identified from the search strategy, 85 articles were retrieved with 11 articles (10 separate studies) identified for inclusion in the dietary intake component of the review (Fig. 1). All studies were observational with respect to dietary intake outcomes, with one study classified as level III-2 evidence (Sjostrom *et al.*, 2004), one as level III-3 (Busetto *et al.*, 1997) and eight studies (nine articles) as level IV evidence (Busetto *et al.*, 1996; Larsen *et al.*, 2004; Guida *et al.*, 2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Colles *et al.*, 2008a,b; Coupaye *et al.*, 2009; Ernst *et al.*, 2009) according to NHMRC guidelines.

Although all studies were classified as observational, most did include some reference to post-operative dietary advice provided (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Colles *et al.*, 2008a,b; Coupaye *et al.*, 2009; Ernst *et al.*, 2009). Details regarding the nature and frequency of this follow-up care were variable, however, and no study directly evaluated the impact that this advice may have had on dietary intake outcomes.

The follow-up period of included studies was in the range 3 months to 10 years; however, the majority of studies were in the range 6 months and 2 years. Sample size was in the range 20–946 subjects, although most studies (n = 7) had <100 participants. Females predominated in every study, although six studies did include a small proportion of males. Average baseline body mass index of participants was generally >40 kg m^{-2} and

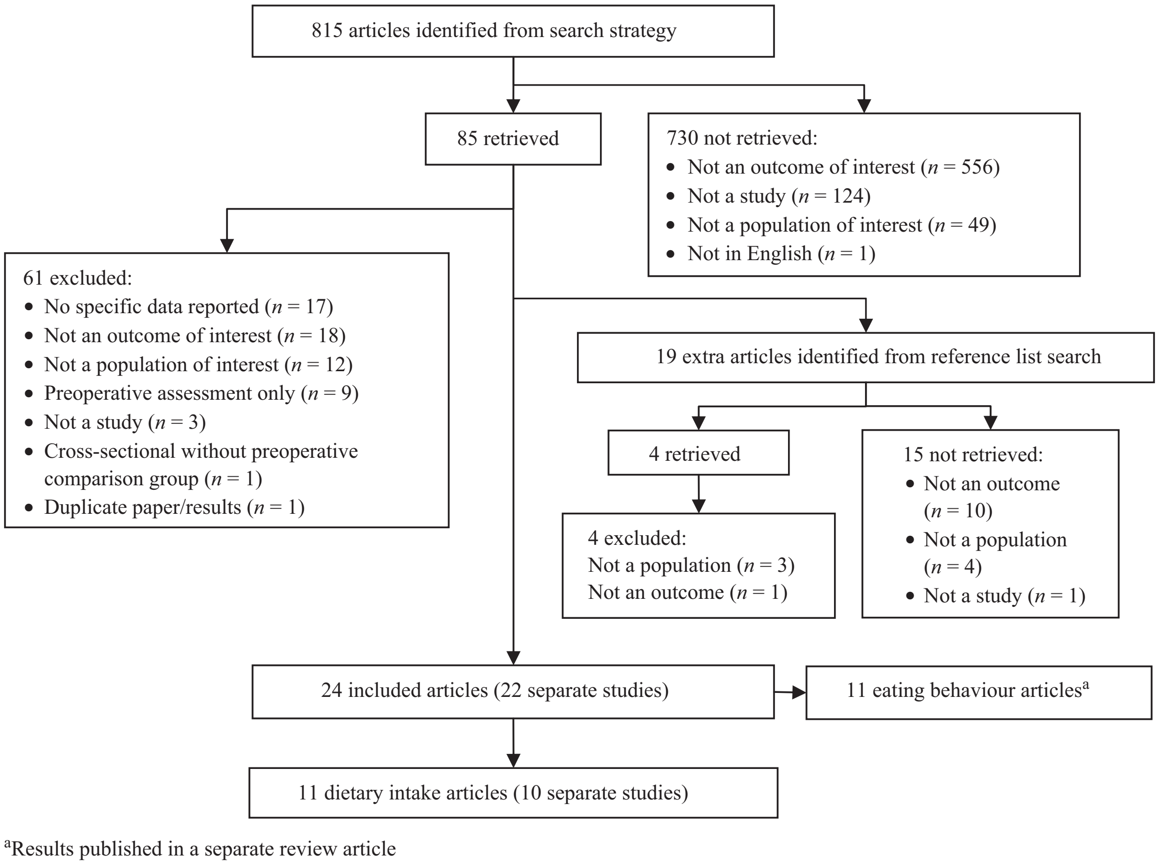

Figure 1 Flow diagram of included and excluded studies for review.

all studies were from Europe or Australia. Summary characteristics of included studies are provided in Table 1.

No articles met the criteria for a strong quality study. Eight articles were classified as moderate quality (Busetto *et al.*, 1996, 1997; Larsen *et al.*, 2004; Sjostrom *et al.*, 2004; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008a,b) and three articles were classified as weak (Wahlroos *et al.*, 2007; Coupaye *et al.*, 2009; Ernst *et al.*, 2009). Key limitations included: a nonrandomised study design (all studies), potential for selection bias (Guida *et al.*, 2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Ernst *et al.*, 2009), poor or unknown validity and reliability of data collection methods (Wahlroos *et al.*, 2007; Colles *et al.*, 2008a; Coupaye *et al.*, 2009; Ernst *et al.*, 2009), and limited consideration of confounding factors (Wahlroos *et al.*, 2007; Coupaye *et al.*, 2009; Ernst *et al.*, 2009). Only three studies reported the funding source (Sjostrom *et al.*, 2004; Wahlroos *et al.*, 2007; Ernst *et al.*, 2009), for which potential funding bias was deemed as unlikely. Potential funding bias for the remaining eight studies was deemed as unclear. Based on author affiliations, however, there were no apparent conflicts of interest for any of the included studies.

Changes in dietary intake after LAGB

Detailed findings for the ten studies that assessed dietary intake outcomes are presented in Table 2. The method of dietary assessment was variable; however, all but one study (Wahlroos *et al.*, 2007) used a retrospective approach. This included different food frequency questionnaires (Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008a,b; Ernst *et al.*, 2009), specifically developed dietary intake questionnaires (Sjostrom *et al.*, 2004), dietitian administered 24-h recalls (Busetto *et al.*, 1996, 1997) and nonspecified dietitian assessment (Coupaye *et al.*, 2009). Additionally, one study used the Dutch Fat Consumption Questionnaire to assess the level of fat intake only (Larsen *et al.*, 2004).

Despite methodological variability, eight studies reported outcomes for energy intake (Busetto *et al.*, 1996, 1997; Sjostrom *et al.*, 2004; Guida *et al.*, 2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Colles *et al.*, 2008b; Coupaye *et al.*, 2009). Significant reductions in energy intake were consistently reported for the immediate 3–6 months post surgery, with energy intake reductions in the range 45–73% (Busetto *et al.*, 1996; Guida *et al.*,

Table 1 Summary of characteristics of included studies

Study	Study design	Level of evidence*	Follow-up	*n*	Retention†	Setting	Female : Male	Age (SD)‡ (years)	Weight (SD) (kg)	BMI (SD)‡ (kg m^{-2})	Mean weight loss
Busetto *et al.* (1996)	Prospective case series	IV	1 year	80	100% (80/80)	Italy	57 : 23	36.0 (11.0)	133.4 (26.7)	48.0 (7.5)	34.4 (14.9) kg
Busetto *et al.* (1997)	Comparative case series with historical control ASGB (matched controls from (Busetto *et al.*, 1996) (a) versus Lap-band (b)	III-3	1 year	60 (a/b) 30/30	100% (60/60)	Italy	60 : 0	(a) 34.1 (10.1) (b) 37.4 (10.6)	(a) 117.4 (10.8) (b) 111.2 (13.7)	(a) 44.2 (3.3) (b) 43.1 (5.1)	(a) 30.0 (11.4) kg (b) 25.4 (9.7) kg
Colles *et al.* (2008a,b)	Prospective case series	IV	1 year	129	75% (129/173)	Australia	103 : 26	45.2 (11.5)	122.2 (20.5)	44.3 (6.8)	4 m: 16.5 kg 12 m: 25.7 kg
Coupaye *et al.* (2009)	Comparative case series (LAGB versus RYBG)	IV	1 year	21	Unclear	France	18 : 3	35 (10)	116 (12)	43 (3)	16 (8) kg
Ernst *et al.* (2009)	Cross-sectional comparison (LAGB, RYGB and non-obese and obese controls)	IV	Time since LAGB: 78.9 (3.2) months	73	NR	Switzerland	59 : 14	44.0 (1.2)	NR	44.6 (0.5	Mean % EWL: 48.1 (2.6)
Guida *et al.* (2005)	Prospective case series	IV	2 years	20	100% (20/20)	Italy	20 : 0	36 (6)	120.2 (16.4)	46.1 (6.8)	6 m: 18.5 (5.9) kg 2 y: 34 kg
Larsen *et al.* (2004)	Cross-sectional comparison [3 groups: PS (a), 8–24 m PO (b), 25–68 m PO (c)]	IV	Time since LAGB (months): (a) NA (b) 16 (8–24) (c) 42 (25–68)	(a) 89 (b) 48 (c) 109	(a) 75.6% (b/c) 81.6%	Netherlands	(a) 77 : 16 (b) 42 : 6 (c) 102 : 7	(a) 39 (22–59) (b) 40 (24–61) (c) 41 (22–55)	NR	(a) 46.5 (37–67) (b) 45.5 (37–72) (c) 45.4 (36–63)	NR
Savastano *et al.* (2005)	Prospective case series	IV	2 years	30	100% (30/30)	Italy	30 : 0	36.7 (6.4)	126.3 (17.3)	48.4 (7.1)	Mean % WL: 12 m: 25.1 (5.2) (~33 kg) 24 m: 27.7 (6.4) (~36 kg)
Sjostrom *et al.* (2004)	Prospective cohort with matched controls [Surgical group: LAGB, VBG, RYBG (a) versus nonsurgical controls]	III-2	10 years	(a) 641 (LAGB: 156)	Unclear: Overall for (a) 75.3%	Sweden	Unclear: Overall for (a) 445 : 196	Unclear: Overall for (a) 47.0 (5.6)	Unclear: Overall for (a) 120.0 (16.4)	Unclear: Overall for (a) 41.9 (4.2)	Mean % WL (LAGB) 1 y: 21 (1010) y: 13.2 (13)
Wahlroos *et al.* (2007)	Pre–post comparative study (LAGB versus VLCD)	IV	3 months	25	NR	Australia	25 : 0	20–62	104.5 (12.2)	38 (5)	Mean % WL: 9.0 (4.3)

SD, standard deviation; BMI, body mass index; ASGB, adjustable silicone gastric banding; m, months; LAGB, laparoscopic adjustable gastric banding; RYGB, roux en Y gastric bypass; NR, not reported; EWL, excess weight loss; y, years; NA, not applicable; PS, presurgery; PO, post-operative WL, weight loss; VBG, vertical banded gastroplasty; VLCD, very low calorie diet.
*Source: NHMRC levels of evidence and grades for recommendations for developers of guidelines (National Health and Medical Research Council, 2009).
†For cross-sectional studies response rate is reported.
‡Data reported as the mean (SD) for all studies except Larsen *et al.* (2004), which is reported as the mean (range).

Table 2 Summary of dietary intake findings

Study	Assessment method	Variable(s)	Result[†]						Significance
Busetto *et al.* (1996)	Dietitian administered 24-h recall	*Time point*	PS	3 months	6 months	12 months			
		Energy intake (MJ per day)	11.9 (6)	3.2 (1.2)*	3.6 (1.6)	4.2 (1.8)			*$P < 0.001$ versus PS[‡]
		Macronutrient intakes as % daily energy intake							
		Fat	36 (10)	38 (10)	39 (10)	38 (11)			*$P < 0.001$ versus PS[‡]
		Carbohydrate	45 (11)	40 (11)	41 (11)	43 (12)			
		Protein	17 (5)	22 (7)*	20 (7)	19 (5)			
		Food consistency as % daily energy intake							
		Liquid foods	15 (13)	27 (22)*	27 (24)	28 (22)			*$P < 0.001$ versus PS[‡]
		Soft foods	13 (12)	18 (22)	17 (18)	23 (22)			
		Solid foods	72 (15)	56 (26)*	56 (27)	50 (25)			
		Number of food contacts (meals and snacks) per day	4.3 (1)	3.4 (0.5)*	3.7 (0.9)	3.6 (0.8)			*$P < 0.001$ versus PS[‡]
		Correlation between energy intake and WL	NA	$r = -0.28$	$r = -0.32$	$r = -0.22$			$P < 0.05$ for all
Busetto *et al.* (1997)	Dietitian administered 24-h recall		*(a) ASGB (controls)*			*(b) LAP-BAND patients*			
		Time point	3 months	6 months	12 months	3 months	6 months	12 months	
		Energy intake (MJ per day)	3.2 (9.1)	3.5 (1.3)	4.2 (1.3)	3.4 (1.0)	3.8 (1.2)	4.3 (1.5)	NSD: (a) versus (b)[§]
		Macronutrient intake as % daily energy intake							
		Fat	37 (11)	39 (13)	40 (11)	36 (10)	40 (7)	41 (11)	NSD: (a) versus (b)[§]
		Carbohydrate	42 (13)	42 (13)	42 (12)	41 (11)	40 (9)	40 (9)	
		Protein	21 (6)	19 (8)	18 (5)	23 (7)	20 (6)	19 (5)	
		Food consistency as a % daily energy intake							
		Liquid foods	29 (20)	32 (23)	27 (20)	13 (8)*	12 (12)*	13 (13)**	*$P < 0.001$: (a) versus (b)[§]
		Soft foods	18 (21)	16 (16)	26 (23)	15 (21)	15 (17)	17 (21)	
		Solid foods	53 (24)	52 (27)	48 (26)	72 (24)**	74 (20)**	70 (22)*	**$P < 0.01$: (a) versus (b)[§]
Colles *et al.* (2008a)/Colles *et al.* (2008b)	74 item validated FFQ	*Time point*	PS		4 months		12 months		
		Energy intake (MJ per day)	10.0 (4.0)		4.0 (1.5)*		4.1 (1.5		*$P < 0.001$ versus PS[¶]
		Macronutrient intake as a % daily energy intake							
		Fat	37 (5)		30 (6)*		31 (7)		*$P < 0.001$ versus PS[¶]
		Carbohydrate	38 (6)		40 (7)**		39 (7)		**$P < 0.05$ versus PS[¶]
		Protein	20 (3)		23 (4)*		22 (4)		
		Fat intake (g per day)	98.5 (42.6)		34.1 (15.9)*		34.6 (16.1)		*$P < 0.001$ versus PS[¶]

Table 2 (Continued)

Study	Assessment method	Variable(s)	Result†			Significance
		Carbohydrate intake (g per day)	233.0 (93.4)	100.4 (39.4)*	98.5 (40.6)	
		Protein intake (g per day)	113.8 (40.6)	54.0 (19.7)*	52.2 (18.7)	
		Food consistency as a % daily energy intake				
		Liquid foods	31 (13)	43 (14)*	47 (16)**	*$P < 0.001$ versus PS¶
		Soft foods	13 (6)	13 (7)	13 (8)	
		Solids	57 (12)	45 (12)*	40 (14)**	**$P < 0.01$ versus 4 m¶
		Number of eating episodes per day	5 (3)	4 (3)*	4 (3)	*$P < 0.001$ versus PS¶
		Correlations between dietary variables	12 m E intake and % E from fat		$r = 0.19$††	$P = 0.035$
			12 m E intake and % E from protein		$r = -0.25$††	$P = 0.006$
			12 m E intake and % E from carbohydrate		$r = -0.08$††	$P = 0.37$
		Relationship between dietary variables and WL	Total E intake and % WL		$r = -0.23$††	$P = 0.009$
			Magnitude of change in E and % WL		$r = -0.22$††	$P = 0.020$
			Consumption of soft foods and WL		$r = -0.16$††	$P = 0.075$
			Poorer weight loss in highest energy intake quartile [5.9 (1) MJ per day] versus lowest quartile [2.3 (0.3) MJ day^{-1}]††			$P = 0.041$
			Poorer weight loss in highest fat intake quartile (>41.1 g per day) versus lowest quartile (<22.9 g per day)††			$P = 0.029$
			Total energy intake independent predictor of % WL: $\beta = -0.182$; explaining 29.6% of variance‡‡,§§			$P = 0.075$
Coupaye *et al.* (2009)	Dietitian assessment (unspecified)	Energy intake (MJ per day)	PS: 9.6 (2.7)	12 m: 6.5 (1.8)		$P < 0.001$

Table 2 (Continued)

Study	Assessment method	Variable(s)	Result†				Significance
Ernst *et al.* (2009)	24 food category FFQ. Frequency categories: 1 = almost every day; 2 = several times weekly; 3 = once per week; 4 = several times monthly; 5 = once per month or less; 6 = never	Food item/group intake	Obese control group		LAGB group [78.9 (3.2) m PO]		
		Poultry	2.9 (0.1)		3.7 (0.2)		$P = 0.002$
		Fish	3.6 (0.1)		4.3 (0.2)		$P = 0.005$
		Pasta	2.9 (0.1)		2.5 (0.2)		$P = 0.032$
		Fresh fruit	2.5 (0.2)		2.0 (0.2)		$P = 0.042$
		White bread/toast	3.3 (0.2)		2.4 (0.2)		$P = 0.002$
		Sausage products/ham	2.7 (0.2)		3.2 (0.2)		$P = 0.06$
		Potatoes, cooked/raw vegetables, chocolate, cakes/biscuits, sweets, salted snacks, cereals, yogurt, cheese, eggs, milk, fruit juice/soft drinks, diet drinks between groups	No differences between groups (Figures NR)				NS
Guida *et al.* (2005)	130 item validated FFQ	*Time point*	PS	6 months	12 months	24 months	
		Energy intake (MJ per day)	12.1 (1.8)	5.7 (1.1)*	6.0 (1.0)*	6.5 (1.0)*	*$P < 0.05$ versus PS
		Macronutrient intake as % daily energy intake					
		Fat	35 (10)	27 (5)*	25 (8)*	26 (5)*	*$P < 0.05$ versus PS
		Carbohydrate	47 (11)	53 (9)	55 (10)	54 (10)	
		Protein	18 (5)	20 (7)	20 (6)	20 (7)	
Larsen *et al.* (2004)	Dutch Fat Consumption Questionnaire (validated)	Fat intake (higher score reflects higher intake)	*(a) PS group*		*(b) <2 y PO group*	*(c) >2 y PO group*	
			30.07 (7.28)		26.17 (5.15)*	26.91 (5.54)*	*$P = 0.00$ versus (a)
Savastano *et al.* (2005)	130 item validated FFQ	*Time point*	PS	6 months	12 months	24 months	
		Energy intake (MJ per day)	13.3 (1.9)	5.6 (0.9)*	5.7 (1.2)*	5.6 (1.2)*	*$P < 0.05$ versus PS
		Macronutrient intake as % daily energy intake					
		Fat	38 (8)	29 (3)*	25 (8)*	25 (6)*	*$P < 0.05$ versus PS
		Carbohydrate	46 (9)	55 (9)*	56 (8)*	55 (8)*	
		Protein	18 (2)	19 (4)	19 (4)	19 (3)	
Sjostrom *et al.* (2004)	Swedish Obese Subjects Dietary Questionnaire (validated)	*Time point*	PS		10 y)		
		Energy intake (MJ per day)	9.5 (LAGB and RYGB subjects)		19.7% reduction in intake (LAGB subjects)		NR

Table 2 (Continued)

Study	Assessment method	Variable(s)	Result†		Significance
Wahlroos *et al.* (2007)	4-day weighed food diary ('informal diet analysis') (*n* = 17)	*Time point*	PS	3 months	
		Energy intake (MJ per day)	11.8 (4.7)	6.5 (1.7)*	*$P < 0.01$ versus PS
		% Energy from fat	39 (4)	36 (7)	
		Total fat intake (g)	123 (58)	61 (20)*	
		Saturated fat intake (g)	50 (20)	23 (8)*	
		Carbohydrate intake (g)	279 (101)	145 (40)*	
		Protein intake (g)	126 (65)	80 (29)*	
		Alcohol intake (g)	8 (9)	11 (13)	

PS, pre surgery; m, months; MJ, mega joules; WL, weight loss; ASGB, adjustable silicone gastric banding; NSD, no significant difference; E, energy; FFQ, food frequency questionnaire; PO, post-operative; NR, not reported; y, years; RYGB, roux-en-Y gastric bypass.

*/**Asterisks indicate significant time points for longitudinal results, and correspond with *P* values in the significance column for each variable.

†Results are presented as the mean (SD) unless otherwise specified.

‡Statistics not reported for 6 and 12 months versus presurgery (PS).

§Longitudinal changes NR.

¶Statistics not reported for 12 month versus presurgery.

††From Colles *et al.* (2008b).

‡‡From Colles *et al.* (2008a).

§§Other significant variables in model: Higher appearance dissatisfaction, $\beta = -0.278$, subjective hunger, $\beta = -0.254$, post-surgical grazing, $\beta = -0.186$, baseline BMI, $\beta = 0.194$.

2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Colles *et al.*, 2008b). Studies with longitudinal measures suggest this reduction was generally maintained over the first 1–2 post-operative years (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008b); however, there was a nonstatistically significant trend for energy intake to increase gradually over time in three of these studies (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005).

The reduction in energy intake reported by Coupaye *et al.* (2009) who only measured energy intake at baseline and 1 year, was more modest than other studies, equating to a reduction of approximately 30%. The one longer-term study by Sjostrom *et al.* (2004) (Swedish Obese Subjects cohort) reported energy intakes of approximately 7.7 MJ (approximately 1840 kcal) at 10 years after LAGB. In their study, the lowest energy intakes occurred at 6 months post surgery, with gradual increases recorded between this point and 4 years, before a relative plateau occurring between 4 and 10 years post surgery (Sjostrom *et al.*, 2004).

Five studies assessed overall macronutrient composition of the diet (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008b). Little change in overall macronutrient composition was observed in the studies of Busetto *et al.* (1996, 1997); however, modest reductions in percentage energy from fat and concurrent increases in percentage energy from carbohydrate were found by Colles *et al.* (2008b), Guida *et al.* (2005) and Savastano *et al.* (2005). The level of protein intake as a percentage of energy remained comparable with preoperative levels (Busetto *et al.*, 1996; Guida *et al.*, 2005; Savastano *et al.*, 2005) or slightly higher than (Colles *et al.*, 2008b) preoperative levels.

Only Colles *et al.* (2008b) and Wahlroos *et al.* (2007) reported an intake of macronutrients in absolute terms (g day^{-1}), with fat, carbohydrate and protein intake all significantly reduced at 3–4 months post surgery. Colles *et al.* (2008b) reported these reduced intakes were maintained at 1 year post surgery, and a similar pattern of reduced macronutrient intakes can also be calculated from the studies that reported overall macronutrient composition of the diet (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005). Based on this, protein intake was in the range 40–80 g day^{-1} at 3–6 months (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Wahlroos *et al.*, 2007; Colles *et al.*, 2008b) and 47–75 g day^{-1} at 12 months post surgery (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008b).

Two studies reported on changes in eating frequency, with both reporting decreased eating frequency in the first 12 months post surgery (Busetto *et al.*, 1996; Colles *et al.*, 2008b). Neither study reported specific results for a relationship between eating episodes and weight loss; however, Colles *et al.* (2008b) stated that weight loss was 'similar' between subjects who reported eating one to three times per day versus those who reported eating four or more time times per day.

Changes in the consistency of foods consumed were also assessed in the studies of Busetto *et al.* (1996, 1997) and Colles *et al.* (2008a,b). Both reported significant increases in intake of fluids as a percentage of daily energy intake, with a concomitant decrease in solids post surgery. When Busetto *et al.* (1997) compared patients who had undergone higher volume band adjustments sooner post surgery with patients who received smaller, more gradual fills, the latter group was found to have a significantly higher intake of solid foods as a percentage of daily energy intake, with significantly less calories contributed from liquids. There were no differences in weight loss according to adjustment protocol however.

Only one cross-sectional study reported dietary intake according to intake of different food groups (Ernst *et al.*, 2009). In comparison with the obese presurgical control group, LAGB subjects reported more frequent intake of poultry, fish, sausage and ham products and less frequent intake of pasta, bread/toast and fresh fruit.

Discussion

This systematic review comprehensively assesses the evidence base for dietary intake after LAGB, providing a basis for further research and development of best practice management guidelines for LAGB patients. It is the first systematic review to exclusively assess LAGB dietary intake outcomes, thereby eliminating the potential confounding influence of data derived from other restrictive procedures such as vertical banded gastroplasty (VBG).

The review highlights that there is a paucity of high-quality evidence for changes in dietary intake after LAGB. The existing evidence base is limited by vulnerability to bias, reflected by level III and IV study designs and weak to moderate quality ratings of included studies. Most studies involved small, selected population samples and there was a concentration of output from certain single research centres (Busetto *et al.*, 1996, 1997; Colles *et al.*, 2008a,b). This potentially limits the generalisability of findings to the wider LAGB population. Furthermore, there is a scarcity of studies assessing longer-term dietary intake and eating behaviours. Thus, the current evidence base provides limited insight into the sustainability of changes over the longer term.

Although most studies used a retrospective method of dietary assessment, the validity, reliability and comparability of the specific approaches used to assess dietary intake is also unclear. Accuracy of dietary intake data is problematic in all dietary research as a result of inherent difficulties in obtaining objective measurements, with key sources of potential error in retrospective approaches including recall bias of the subject, difficulties in estimating portion sizes, and interviewer skills if an interview approach is used (Hill & Davies, 2001). This may result in an under-reporting of intake, particularly in obese subject populations (Westerterp & Goris, 2002). To support potential confounding of under-reporting in the current LAGB evidence base, both Colles *et al.* (2008b) and Busetto *et al.* (1996) reported only weak correlations between post-surgery energy intakes and weight loss in their studies and, although Colles *et al.* (2008b) did find energy intake to be a significant independent predictor of weight loss, it remained a weak predictor only. Given that reduced food and energy intake is considered the primary weight loss mechanism of LAGB, this highlights the likely accuracy limitations in dietary intake data that form the current evidence base.

These limitations must be taken into account when interpreting and applying the findings of the review. As such, this review offers preliminary insight into dietary intake issues following LAGB, and primarily provides a basis for further research to establish stronger evidence for best-practice management guidelines in future.

Studies consistently reported significant reductions in energy intake in the first 1–2 years after LAGB, with most studies reporting 1–2 year energy intakes in the range of 4–6 MJ (approximately 960–1435 kcal) per day (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008a,b). This is generally consistent with weight loss outcomes over the same period (Busetto *et al.*, 1996, 1997; Guida *et al.*, 2005; Savastano *et al.*, 2005; Colles *et al.*, 2008a,b). The only long-term data is provided by Sjostrom *et al.* (2004). Although this study suggests intake remains reduced at 10 years post surgery, when compared with the shorter-term results of the other studies, energy intake is notably higher, equating to approximately 7.7 MJ (1840 kcal) per day (Sjostrom *et al.*, 2004). Although greater energy intakes may be required to facilitate weight maintenance rather than continued weight loss over the longer-term, the apparent trend for increasing energy intake over time also suggests that individuals have trouble maintaining longer-term caloric restriction. Notably, Sjostrom *et al.* (2004) concurrently reported less percentage weight loss at 10 years versus 1 year post-LAGB (13.2% versus 21%, respectively).

This parallels growing evidence that difficulties with sustained weight loss and weight regain are significant problems in the LAGB population (Suter *et al.*, 2006; Tolonen *et al.*, 2008). Although this has lead to suggestions for the abandonment of LAGB (Suter *et al.*, 2006), it must be remembered that LAGB consistently achieves greater and more clinically significant weight loss compared to conventional lifestyle interventions (Colquitt *et al.*, 2009), and the longer-term safety and efficacy of other procedures versus LAGB versus remains unclear (Colquitt *et al.*, 2009). As such, an opportunity exists to identify long-term dietary and behavioural strategies that may assist individuals to maintain reduced energy intakes over time. This will be valuable for maximising the effectiveness of LAGB until other treatment strategies that are clearly proven as both efficacious and acceptable are better determined.

Despite the finding that protein intake when expressed as a percentage of daily intake does not decrease significantly after LAGB, three of five studies (Busetto *et al.*, 1996, 1997; Colles *et al.*, 2008b) suggested post-surgical protein intakes less than the commonly recommended minimum of 60 g day^{-1} for bariatric surgery patients (Aills *et al.*, 2008). Despite the possible confounder of under-reporting, this may represent a sub-optimal dietary pattern, where there is evidence from nonsurgical interventions to suggest that increased protein intakes can positively influence weight loss, preserve lean mass and improve disease risk profile in overweight and obese individuals (Skov *et al.*, 1999; Layman *et al.*, 2003; Bopp *et al.*, 2008; Lasker *et al.*, 2008).

Although a level of optimal protein intake after bariatric surgery remains to be determined (Aills *et al.*, 2008), a recent meta-regression suggested that a protein intake >1.05 g kg^{-1} body weight is associated with greater preservation of fat free mass during weight loss compared to intakes of <1.05 g kg^{-1} (Krieger *et al.*, 2006). Theoretically, the protein intakes reported by studies in the current review are well below this level. For example, based on the average protein intake and weight at 12 months reported in Colles *et al.* (2008b), protein intake equates to approximately 0.5 g kg^{-1}. Even in studies suggesting higher protein intakes, such as that by Guida *et al.* (2005), protein intake at 12 months equates to approximately 0.8 g kg^{-1}. Given the potential for suboptimal protein intake in the early months post surgery, appropriate targets for protein intake and dietary strategies to achieve this need to be better established for the LAGB population.

Previous research in VBG populations has suggested a link between the consumption of energy-dense soft foods and fluids and lower weight loss (Yale & Weiler, 1991; Brolin *et al.*, 1994). The present review finds little evidence to support this for LAGB patients; however, only three studies included consistency of food intake as an outcome (Busetto *et al.*, 1996, 1997; Colles *et al.*, 2008b) and two of these studies did not directly assess the relationship between food consistency and weight loss

(Busetto *et al.*, 1996, 1997). Colles *et al.* (2008b) did find a weak, nonsignificant correlation between poorer weight loss in subjects reporting a higher consumption of soft foods; however, this was not identified as an independent predictor of weight loss in multivariate analysis.

Busetto *et al.* (1997) provides evidence to suggest that band adjustment protocol (timing and volume of fills) has a significant influence on food consistency, with a delayed and more gradual fill strategy promoting a more desirable pattern of intake (i.e. a greater intake of solids). There was no difference in 12-month excess weight loss between the groups receiving the two different adjustment protocols, however, despite the significant differences in the consistency of food intake. Further research examining the relationship between food consistency and weight loss outcomes will be valuable for better defining guidelines regarding optimal consistency of the LAGB diet. Beyond influence on weight loss, consistency of food may also have an important impact on diet quality, given that soft or liquid type foods can typically be nutrient-poor compared to solid, whole foods.

It is commonly advised that individuals who have LAGB should strictly eat only three meals per day (Favretti *et al.*, 2002); however, there is little evidence available to support or refute this guideline, with only two studies assessing the number of eating occasions post surgery. Furthermore, only Colles *et al.* (2008b) assessed the relationship with weight loss, failing to find any statistically or clinically significant relationship between eating frequency and weight loss outcome. The broader lifestyle weight loss literature has also failed to show that eating frequency (e.g. consuming three larger meals or six small meals per day) impacts on weight loss (Palmer *et al.*, 2009). It is likely that overall caloric intake has a greater influence on weight loss rather than eating occasions *per se*; however, further research is required to determine more definite guidelines regarding optimal eating frequency after LAGB.

Diet quality is gaining increased recognition in the epidemiological literature as a potential determinant of chronic disease outcomes (Wirt & Collins, 2009), which highlights that diet quality issues extend beyond the traditional bariatric surgery interest of avoiding overt nutritional deficiencies. There has been some speculation that LAGB may promote poor diet quality as a result of the potential for the gastric band to obstruct passage of 'high-quality' foods, such as vegetables, fruit, bread, seafood and lean meat/poultry, as has been suggested in VBG studies (Brolin *et al.*, 1994; Kriwanek *et al.*, 2000; Shai *et al.*, 2002; Olbers *et al.*, 2006).

Research conducted in the LAGB population has largely neglected assessment of diet quality outcomes, however, with only one study reporting food group intakes as a reflection of diet quality (Ernst *et al.*, 2009). Unfortunately, Ernst and colleagues study is limited by its cross-sectional nature and the food frequency questionnaire used, which only captured consumption frequency of broad food groups without any detail regarding portion sizes. The results of Ernst *et al.* (2009) do suggest that some aspects of diet quality may be compromised after LAGB (e.g. fruit intake); however, the cross-sectional study design precludes any causal inferences being made. Further prospective research is required to better investigate diet quality issues and potential influence on health outcomes following LAGB.

Given the diversity of issues related to diet and nutrition in the bariatric surgery field, it was considered beyond the scope of the present review to include all issues of relevance. One ongoing area of interest not included in the review is a comparison of dietary intake and nutritional status of individuals who have LAGB versus other surgical procedures. Few studies were identified from the search strategy that compared these outcomes. Of note, two studies that compared LAGB with RYGB did show some suggestion that RYGB may be more beneficial in terms of achieving better reductions in energy intake at 1 year post surgery (Coupaye *et al.*, 2009) and the promotion of better diet quality according to intake of different food groups (Ernst *et al.*, 2009). Sjostrom *et al.* (2004), however, did not find a significant difference in longer-term energy intakes between LAGB and RYGB. Dietary outcomes are essential considerations when assessing the merit of obesity surgery options, and further review of the existing evidence base exclusively focused on a comparison of dietary and nutritional outcomes of different procedures may be warranted.

Additionally, food tolerance outcomes were not addressed in the present review because no papers that specifically assessed food tolerance outcomes met the review inclusion criteria. Furthermore, related issues such as vomiting and regurgitation were considered to be beyond the scope of the current research question, and thus were not included in the original search strategy. Given that food tolerance, vomiting and regurgitation have the potential to influence diet quality, quality of life and post-surgical complications such as pouch dilation (Burton *et al.*, 2010), further evaluation of these issues will contribute to the development of a more comprehensive evidence base concerning diet and LAGB in the future.

In conclusion, despite the importance of diet after LAGB, there is a paucity of evidence currently available to help inform best practice management guidelines for optimising outcomes after LAGB. Although the current evidence base is limited by its observational nature and widespread methodological weakness, it does suggest that LAGB is effective in reducing overall caloric intake, including intake of fat, carbohydrate and protein. Maintaining reduced food intake over the longer-term, however, may be problematic. Other issues that may require attention include the optimal level of protein intake and diet quality, with further research required in these areas. There is a need for high-quality dietary-focused studies to better assess the influence of diet on weight loss and health outcomes and, furthermore, to determine optimal dietary interventions for individuals who have LAGB.

Conflict of interests, source of funding and authorship

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AD was primarily responsible for conception, design, literature search, data extraction, analysis and interpretation of data and drafting the manuscript. SB assisted with conception of the article, data extraction and drafting of the manuscript. HW-F assisted with drafting of the manuscript. All authors participated in reviewing and revising the article for intellectual content and have approved the final version submitted for publication.

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Appendix

Quality assessment tool

Selection bias

- Are the individuals selected to participate in the study likely to be representative of the target population?
- What percentage of selected individuals agreed to participate?

Study design

- Indicate the study design.
- Was the study described as randomised?
- If yes, was the method of randomisation described?
- If yes, was the method appropriate?

Confounders

- Were there important differences between groups prior to the intervention?
- If yes, indicate the percentage of relevant confounders[a] that were controlled [either in the design (e.g. stratification, matching) or analysis]?
- For observational studies, were study settings, interventions and clinicians described in detail? Were confounding factors controlled for in analysis or considered in discussion?

Blinding

- Was/were the outcome assessor(s) aware of the intervention or exposure status of participants?
- Were the study participants aware of the research question?

Data collection methods

- Were data collection tools shown to be valid?
- Were data collection tools shown to be reliable?

Withdrawals and drop-outs

- Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?
- Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).

Source: Adapted from the Quality Assessment Tool for Quantitative Studies, Effective Public Health Practice Project (1998a).

[a]Potential confounders considered included: race, sex, body mass index, age, socioeconomic status, education and health status. Additional potential confounders that were considered as relevant to dietary intake after LAGB include: medications, band adjustments, post-operative follow-up and nutritional/dietary advice provided.