Harbury, Cathy M.; Verbruggen, Elisabeth E.; Callister, Robin & Collins, Clare E. "What do individuals with morbid obesity report as a usual dietary intake? A narrative review of available evidence" Published in *Clinical Nutrition ESPEN*, Vol. 13, Issue June, p. e15-e22, (2016).

Available from: http://dx.doi.org/10.1016/j.clnesp.2016.02.001

What do morbidly obese individuals report as a usual dietary intake? A narrative review of available evidence

Abstract

Background

In several developed countries, as obesity prevalence doubles it has quadrupled for morbid obesity (BMI ≥ 40 kgm^{-2}). As more individuals with morbid obesity present for weight loss treatment there is a greater need to understand their dietary habits. No reviews were found in the literature, therefore this systematic review aims to identify and describe the existing evidence on the usual dietary intake of individuals with morbid obesity including those from a general population and those seeking treatment such as weight loss surgery.

Methods

A literature search of ten databases from 1980 to June 2014 was conducted to identify original research of adults with morbid obesity (aged 18-60 years) that reported a usual dietary intake.

Results

Ten studies met all inclusion criteria and reported energy intake, most reported macronutrient composition, two assessed micronutrient intake, and one reported food-based outcomes. Other dietary outcomes were related to surgical intervention. The most plausible energy intake data suggest high intakes, > 4000 Kcal/day for those weight stable at the highest levels of morbid obesity (up to BMI 97 kgm^{-2}). Fat intakes are also high, around 40% of energy intake and up to 57% for some individuals. Suboptimal intakes of iron and calcium are reported.

Conclusion

This review draws attention to a limited evidence base, offers preliminary insight suggesting individuals with morbid obesity are prone to consuming poor quality diets similar to those reported for obese populations, and highlights challenges for future research.

Keywords

Morbid obesity, dietary intake, adult, systematic review, bariatric surgery.

Introduction

In several developed countries, as obesity prevalence doubles morbid obesity (defined as a body mass index ≥ 40 kgm^{-2}) has quadrupled [1, 2], resulting in more individuals with morbid obesity presenting for weight loss treatment [3]. The morbidity associated with carrying excessive adiposity is recognized by treatment guidelines, as those individuals with a BMI ≥ 40 kgm^{-2} are eligible for invasive surgical intervention without co-existing medical problems, unlike those individuals with lower BMI's [4]. Treatment guidelines indicate that all modalities of weight loss intervention should include nutrition therapy and in less severe obesity research has focused on investigating lifestyle approaches [5] rather than the effectiveness of surgical intervention for clinically significant obesity (defined as a BMI ≥ 35 kgm^{-2} with obesity-related comorbid conditions) [6]. Consequently, the aims of nutrition research have differed for these two populations, and it appears that less has been published about the dietary intake of those with the highest level of obesity. This is despite a high prevalence of nutritional deficiencies identified in individuals with clinically significant obesity preparing for weight loss surgery [7-11], a propensity for nutrient deficiencies post-operatively [12-14] and recognition that poor dietary habits may be contributing to these deficiencies [11]. Furthermore it has been suggested that permanent change in eating behaviour is required to facilitate reductions in energy intake for long-term weight management [15]. It is reasonable to hypothesise that individuals with the poorest quality diet are those most vulnerable and at risk of remaining morbidly obese and with co-morbid health conditions, even after surgical interventions. Therefore treatment optimisation relies on understanding the usual dietary patterns of individuals with morbid obesity.

A preliminary search of the literature found no reviews that summarized the usual dietary intake of individuals with morbid obesity, either those that were seeking treatment or those within the general community. Therefore the aim of this research was to develop a review protocol and undertake the first systematic review to identify and describe the existing evidence on the usual dietary intake of the morbidly obese, including both individuals from a general population and those seeking treatment such as weight loss surgery. In a novel approach, this review collates pre-surgery dietary data to represent usual intake due to a lack of alternative evidence. The findings of this review will inform understanding

of the reported dietary intake of individuals with morbid obesity and identify knowledge gaps to guide future research to enhance current weight loss treatments and prevention strategies.

Methods

This systematic review protocol was registered in Prospero in May 2013. The protocol can be accessed at http://www.crd.york.ac.uk/PROSPERO using registration number CRD42013004526. Research ethics approval was not required for this review.

Selection criteria

Inclusion criteria for studies were original research in human adults aged between 18-60 years, with a body mass index ≥ 40 kgm^{-2}, that reported at least one measure of habitual dietary intake as an outcome (i.e., energy, macro- and/or micronutrient intakes, grams of food groups/items, frequency of meals/snacks). In studies where not all participants had a BMI ≥ 40 kgm^{-2}, an arbitrary cut-off was set to exclude studies where < 80% of the total participants had a BMI ≥ 40 kgm^{-2}. Other criteria for exclusion included reporting only eating behaviours or dietary intakes during or following an intervention (e.g., post bariatric surgery). Corresponding authors were contacted in cases where eligibility criteria, such as age range and the percentage of subjects with a BMI ≥ 40 kgm^{-2}, were not reported explicitly, and studies excluded if the eligibility criteria were not met or the corresponding author was unable to provide the required detail. For studies published more than 15 years previous, only those authors that could be identified by an Internet search were contacted.

Search strategy

The search strategy identified published studies in the English language from 1980 to June 2014. Search strategy keywords were identified by an initial limited search. Individual searches were conducted for all the identified keywords for BMI ≥ 40 kgm^{-2} and habitual intake, prior to combining these searches. This second search was undertaken across 10 databases: The Cochrane library, MEDLINE, EMBASE, CINAHL, Informit Health Collection, Web of Science, Scopus, PsycINFO, Trove, and Dissertation & Abstracts. An example of the full search strategy, including keywords, is provided in Table 1.

Selection strategy and procedures

Two reviewers independently reviewed all studies. Titles and abstracts were used to determine relevance. Full articles were retrieved for those studies that met the inclusion criteria or where it was unclear, and relevance checked. A final decision was sought from a third reviewer when eligibility remained uncertain.

Critical appraisal

The methodological quality of all included studies was independently assessed by two reviewers using three procedures. The National Health and Medical Research Council (NHMRC) levels of evidence guidelines were used to grade each study design [16]. Methodological quality of included studies was assessed using the American Dietetic Association critical appraisal tool to assign an overall rating to each study [17]. In the case of disagreement consensus was achieved by joint review. The quality of dietary intake methods and reporting within each study was graded using a tool adapted from Burrows et al (2012) [18].

Data extraction and analysis

Data extraction was completed by one investigator and checked for accuracy by a second. Standardised tables were used to collate data relating to study characteristics, design and quality, dietary methodology, intake outcomes and reporting quality.

Results

General description of included studies

Of 3249 studies identified full texts were retrieved for 344 papers, with 11 papers (10 studies) meeting all inclusion criteria (Figure 1). Of the 10 studies, seven were observational [10, 19-22], including one retrospective study [23] and one case report of a single subject [24], and three studies were experimental randomized control trials (RCT)[25-28]. Due to the low number of eligible studies, no studies were

excluded based on methodological quality. Table 2 provides a summary of study characteristics including study design grade, study quality rating, and dietary reporting quality.

Of the 10 included studies, none included a general population representative sample of morbidly obese individuals. All studies recruited 'treatment seeking' individuals from outpatient clinics, with bariatric surgery the main treatment modality (n=8 studies). Only four studies [10, 21, 24, 28] had 100% of participants with a BMI ≥ 40kgm^{-2}, including Arnoff et al (1994) who studied one participant over three study conditions. The number of participants ranged from one up to 231; only one study had > 100 participants (n=231)[10], and three studies had < 20 participants [20, 23, 24]. Six studies reported a BMI range [19-23, 28]; these spanned a minimum of 13 BMI units (BMI 38-51 kgm^{-2}) [20] to a maximum of 56 BMI units (BMI 41-97 kgm^{-2}) [21]. The highest BMI's reported were 90 kgm^{-2} [22] and 97 kgm^{-2} [21]. No study categorised BMI into quantiles.

Dietary assessment: outcomes, methods and reporting

The main dietary outcome measures reported by all studies were energy intake, followed by macronutrient intakes (n=6) [10, 19-21, 28](Table 3). Only two studies evaluated micronutrient intake: iron [25]; zinc [26]; and calcium, phosphorus, magnesium and iron [10]. Other dietary outcomes were specifically related to bariatric surgery, such as the number of occasions of eating, food consistency (liquid, soft, solid) as a percentage of total energy intake [19], daily liquid volume (defined as all nutritive and non-nutritive fluids) as percentage of total energy intake [20], and intake of sweets (not defined) as percentage of total daily energy [27]. Only Strain et al (1992) reported intake by food groups [22], and only Aronoff et al (1994) evaluated night time food intake [24]. Table 3 summarizes the reported energy and macronutrient intakes by dietary method. Table 4 summarizes all other dietary outcomes.

Although all studies reported mean energy intakes, only two reported these data by sex, with both reporting higher energy intakes for males, with mean (±SD) intakes of 10,811 kJ/day (SD not reported) [10] and 18,723 ± 2,159 kJ/day [22]. The latter was the highest mean energy intake reported in any

study with these participants observed to have a preference for energy-dense, nutrient-poor foods, with extremely limited intakes of low energy dense, nutrient rich foods such as fruit and low starch vegetables, and those who weighed more also consumed more [22]. The study with the most obese participant (BMI 97 kgm^{-2}) reported the highest absolute energy intake of 20,364 kJ/day. The lowest mean energy intake was 7,008 ± 2,674 kJ/day [25, 26]; all other studies reported intakes above 8,000 kJ/day [23, 24, 27, 28] and often approaching 12,000 kJ/day [19-21, 28].

Across the studies the reports for mean macronutrient intakes were more consistent, with dietary fat around 40% of energy, carbohydrate between 40-45% of energy and protein mostly between 15-20% of energy [10, 19-21, 28]. Moize et al. (2011) assessed the type of lipids consumed by their Spanish population, identifying 55% of total fat intake as monounsaturated fatty acids. No other study reported the lipid profiles of consumed fats. The highest reports for both dietary fat and protein intakes were 57 and 84% of energy respectively [21]. In one study sweets contributed between 15 to 20% of total energy [27]. In two studies up to 20% of ingested energy was from liquids [19, 20] and another reported the number of occasions of eating as 4.3 ±1.0 (times per day) [19]. Moize et al (2011) reported men consumed more dietary iron (mean 16.2 mg/day) than women (mean 13 mg/day) and calcium intakes were comparable between sexes, with both consuming above 900 mg/day [10]. In contrast to these results, Ruz et al (2009 & 2011) reported lower mean intakes of iron (pooled sex data, 9.4 ± 4.8 mg/day) [25], and similar levels for zinc (9.1 ± 3.5 mg/day) [26].

The most common method for assessing dietary intake was self-reported food records (n=8) [22, 23] usually over three or four days (n=5)[10, 20, 23, 25, 28] but up to 3 months (n=1)[24] in duration. No objective measurement of intake (weighed or household measures) was reported. The other main method was by 24-hour recall (n=4) (Table 2). Two studies employed both a food record and 24-hour recall [10, 23]. One study used a validated food frequency questionnaire, the Block 98 [27]. In a novel approach, Strain et al (1992) admitted one group of 11 morbidly obese individuals to a metabolic ward for a week with weight kept stable during admission and dietary intakes observed and recorded [22]. Observation methodology was not described.

Only two [10, 20] studies received the highest rating (good/excellent) for dietary assessment methodology and reporting. These two studies scored positively across all the reporting domains of dietary assessment method including reporting on; statistics to assess validity; who conducted data collection; the scoring methods including details regarding the nutrient database used; the use of multiple record days; and the use of prompts or aids in portion size estimation. One study achieved a "good" rating [24]. A further three studies were rated as "acceptable / reasonable" [23, 25, 26, 28]. The final four studies [19, 21, 22, 27] rated "poor" due to lack of validation of the dietary method and limited reporting for dietary methodology. Of these studies two included dietary data as secondary outcomes [19, 27].

Discussion

This systematic review is the first to collate the evidence on the dietary intake of individuals with morbid obesity. Unfortunately the current evidence base is limited. Although review offers preliminary insights, due to the small number of high quality studies eligible for inclusion, it is the first time the evidence has been systematically reviewed. This evidence gap and the need for more frequent assessment of dietary data in this population does not appear to be well recognized. Despite growing interest and an increase in the number of publications in populations with morbid obesity, few studies are dedicated to investigating dietary intake. Surprisingly, this review found that only one study has been published between 1980 and June 2014 with the primary aim of investigating their food choices [22]. This review finds that the bariatric surgery literature contributes almost all of the dietary data that exists, with no studies investigating the sub-group of individuals not seeking weight loss surgery, who are unwilling, ineligible or unable to access surgical intervention [29]. Reporting the existing evidence gives broader recognition of evidence gaps that could assist in increasing interest in an area that deserves attention.

Diet composition was not comprehensively evaluated in the review studies, yet the available data does suggest poor quality diets that are similar to those previously reported for obese populations, i.e. high in fat, low in fruit and vegetables, with a greater proportion of energy derived from sweets and cakes,

and frequent meals and snacking throughout the day [30, 31]. Likewise participants with morbid obesity were observed to consume diets that included negligible amounts of fruit and low starch vegetables [22]; some consumed a significant proportion of daily energy as non-nutritive liquids [19, 20] and sweets [27]; and suboptimal micronutrient intakes (iron and calcium) were observed among some individuals [10, 25] despite an energy intake within which nutrient intake targets could be met. Furthermore fat intake was consistently reported as approximately 40% of total energy intake [10, 19-21, 27, 28] and up to 57% [21], which is greater than national recommendations in many countries. However in the Spanish study which evaluated fat quality, a high proportion of the total fat was from monounsaturated fatty acids (55%), consistent with the Mediterranean diet as consumed in the general Spanish population [10]. The extent to which this dietary data deviates from the consumption patterns of those individuals with lower levels of obesity and the general community is unclear.

The lack of homogenous, high quality studies limit comparison of the reports to draw meaningful conclusions. The differences in methodology across the 10 studies to collect and report mean energy intake data highlight this point and may explain the considerable variation in reported energy intakes. This ranged from 7,008 ± 2,673 kJ/day for women self-reporting their intake over three days [25], up to the highest mean energy intakes of 18,723 ± 2,159 kJ/day (males) and 13,598 ± 2,347 kJ/day (females) for the only study that confirmed energy balance [22] and was one of the two studies that did attempt to validate self-reports of dietary intake [20, 22]. This highest mean energy intake concurs with later research that investigated total energy expenditure in a sample of morbidly obese women, using the gold standard method of doubly labelled water [32]. In this study, total energy expenditure was measured to be between 12,552 to 16,736 kJ/day in weight stable women (n=30, BMI 48.9 ± 1.7 kgm^{-2}), with absolute values for TEE and resting energy expenditure (REE) increasing with increasing total body mass [32]. Similarly, Gortz et al (1990) suspected under-reporting by at least 27% for reports of a mean energy intake of 11,715 ± 1,088 kJ/day [20]. In contrast, the other authors reported daily energy intakes between 8,368 to 12,552 kJ/day using either 24-hour recalls [10, 19, 21, 23] or a Food Frequency Questionnaire [27], without addressing energy balance, under-reporting, selective misreporting or under-eating. These biases and errors associated with measuring food intake [33, 34] are well reported

in populations with less severe obesity [35-38]. This has led researchers to caution against assuming subjects with obesity are in energy balance during studies of food intake, after detecting decreases in energy intake that corresponded closely to weight losses [39, 40]. Under-eating has also been observed [41, 42]. With consideration of these bias and errors, the most plausible energy intake data suggest high energy intakes for those individuals at the highest levels of obesity.

It is acknowledged that it would be beneficial to extend the review period to include 2015 publications as more reports with dietary data are published in this population [43, 44] Yet, the disparity between the need for informed nutrition therapy and the limited research that is primarily focused on comprehensively assessing dietary intake remains, particularly for non-surgical cohorts. Furthermore, caution is warranted in extrapolating data from the bariatric surgery literature to individuals not seeking intensive treatment, as differences between these groups of individuals has not been explored. Another limitation of this review is the arbitrary cut-offs used for the eligibility criteria. For example a maximum age cut-off of 60 years to acknowledge the age related decline in resting energy expenditure observed in normal populations [45, 46], yet it is uncertain whether this is biologically or clinically appropriate in populations with morbid obesity. As this area of nutrition research is extended, it is hoped that any future reviews will have sufficient data to exclude research with significant methodological shortcomings and compare studies that use the same nutritional assessment methods to allow direct comparisons and draw stronger conclusions.

This review confirms a greater need for high quality nutrition studies dedicated to collecting comprehensive dietary data from individuals with morbid obesity, and should extend to those from the general community rather than solely focusing on individuals seeking weight loss surgery. The preliminary evidence suggests there is scope for medical nutrition therapy in the treatment of morbid obesity and priority should be given to investigating food-based outcomes to determine the dietary components that contribute most to excessive energy intakes, including the contribution of high fat foods, caloric beverages, non-nutritive snacks, sweets, and the role of night eating. It is likely that a "true" understanding about energy intake and patterns of eating will only be gained by designing studies

that address the inherent methodological difficulties and errors associated with measuring food intake, particularly those observed in populations with obesity [47-49] However it is unclear how psychological factors such as guilt and embarrassment, known to contribute to under-reporting food intake [50] may be overcome in this population. It is plausible that sensitivity to social desirability bias could be heightened by clinically significant obesity, particularly if nutrition researchers are part of the treatment team. The reporting biases exhibited by morbidly obese individuals are not fully understood and deserve consideration in future nutrition studies. Future research should also recruit from a general community, in addition to those already seeking treatment. Also, an understanding of differences related to BMI may be better examined by consistent reporting of data by discrete categories of BMI and avoiding pooling data across wide BMI ranges, thereby recognising the variability in REE associated with variations in fat mass [15]. The consistent reporting of data by sex may also extend our understanding of sex differences. Many challenges exist for nutrition researchers and it is hoped this review will assist in broadening the recognition of the valuable work yet to be undertaken.

Acknowledgements

We wish to thank the medical librarian Debbie Booth, who assisted with the electronic search strategies and the dietitian research assistants: Amanda Smith, Ailsa McHardy, Annette Murphy, Natasha Jovceski and Rebecca Williams who participated as second reviewers for the literature search and quality checks.

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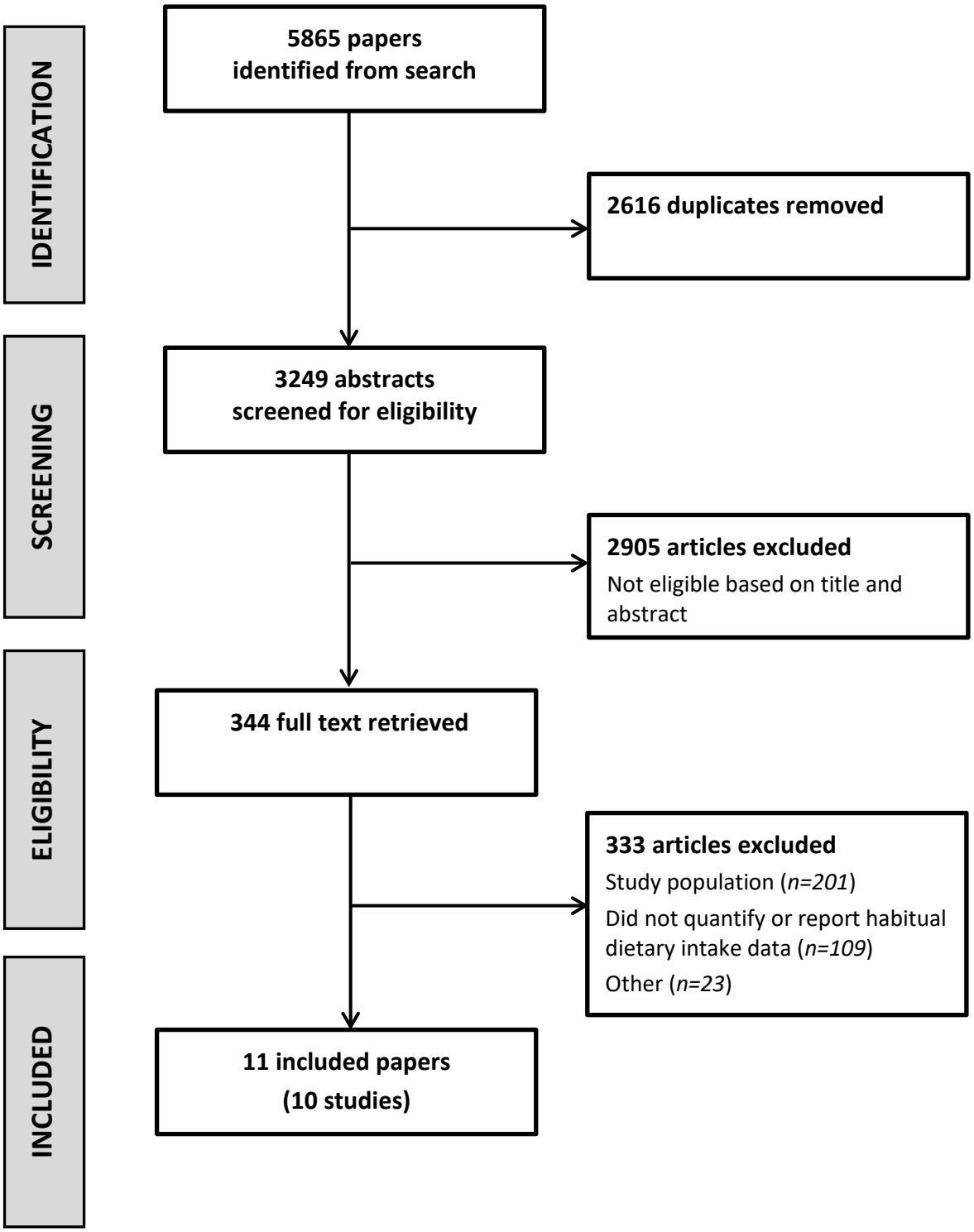

Figure 1: Flow diagram of article identification, retrieval and inclusion for systematic review.

Table 1: An example of the full search strategy, using the Medline database

Set No.	Search Terms	Medline results
1	Obesity, Morbid/	9799
2	(morbid* adj3 obes*).mp	13177
3	Super obes*.mp	247
4	Super super obes*.mp	38
5	Significant obes*.mp	83
6	(super adj3 obes*).mp	270
7	(bmi adj5 “40”).mp	1353
8	(extreme* adj3 obes*).mp	1110
9	(severe* adj3 obes*).mp	3419
10	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9	16933
11	Nutrient intake*.mp	5485
12	Diet/ or diet.mp	271612
13	Food group*.mp	2331
14	Energy intake.mp. or Energy Intake/	34642
15	Food Habits/	18654
16	Diet*.mp	457224
17	Nutritional intake*.mp	1517
18	Food Preferences/ or food preference*.mp	9384
19	(eating adj (behaviour* or behaviour)).mp	3280
20	Feeding Behavior/	35531
21	11 or 12 or 13 or 14 or 15 or16 or 17 or 18	505215
22	10 and 21	2431
23	limit 22 to English language	2117
24	limit 24 to humans	1949

25	limit 24 to yr="1980-Current"	1916
26	Limit 25 to "all adult (19 plus years)"	1266

Table 2: Summary of characteristics of included studies (n=10)

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
Aronoff et al.(1994)	USA	To study the relationship between day-time & night-time food intake in a morbidly obese night eater	1	28 / NR	65	0:1	Case study / Level IV	Negative	3-months of self-reported food records	Mean daytime intake & mean night time intake	Acceptable / reasonable
Busetto et al. (1996)	Italy	To analyse the relationship between eating pattern, vomiting frequency, weight loss & rate of	80	36 (11) / 18-59	48 (7.5) / 35-67.6	57:23	Prospective case series / Level IV	Positive	Pre-operative 24-hr recall with dietitian	Number of food contacts, total daily energy intake, macronutrient intake as % of	Poor

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
		gastric band complications in morbid obesity after gastric banding								energy, food consistency (liquid, soft, solid) as percent of energy	
Gortz et al. (1990)	USA	To study the effects of vagotomy on spontaneous ingestive behaviour	7	33 / 18-50	44 / 38-51	6:1	Prospective case series – pre-test post-test / Level IV	Neutral	Pre-operative 4-d food records with dietitian instruction	Total daily energy intake, macronutrient intake as a % of energy, daily liquid volume and per cent energy per day	Very good / excellent

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
Moize et al.(2011)	Spain	To evaluate food intake and the prevalence of nutritional deficiencies in Spanish bariatric surgery candidates	231 and 46 controls	45.9 (10.3) Control 42.5 (10.9)	48.4 (6.7) / NR Control 23.1 (2.5) / NR	Female 72.3% Control 78.3%	Prospective case series with matched controls / Level III-2	Positive	Pre-operative 4-d food records with dietitian instruction & 24-h food recall	Total daily energy intake, macronutrient intake (grams) and % of energy, calcium, phosphorus, magnesium and iron	Very good / excellent
Raymond et al. (1986)	USA	To quantitate changes in weight, body composition,	13	34.8 / 20-50	44.7 / 35.5-57.1	10:3	Prospective interrupted time series	Positive	Pre-operative 3-d food	Total daily energy and protein (g) reported	Acceptable / reasonable

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
		energy and protein intake during the first year after gastric partitioning for morbid obesity					/ Level IV		record or 24-h food recall		
Ruz et al. (2009) & Ruz et al. (2011)	Chile	To evaluate the effects of RYGB on zinc & iron status and absorption at different stages after surgery	67	36.9 (9.9) / 18-55	45.2 (4.7) / NR	67:0	RCT / Level II	Positive	Pre-operative 3-d food records with dietitian instruction	Total daily energy, protein (g), iron (mg) and zinc (mg) intake	Acceptable / reasonable

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
Sarwer et al. (2012)	USA	To investigate the efficacy of post-operative dietary counselling to improve outcomes after bariatric surgery	84 Baseline data on 67 only	42 (9.9) / NR	51.64 (9.2) / NR	53:31	RCT / Level II	Positive	Block FFQ	Estimates of total daily energy and macronutrient intake as a percent of energy. Also reports sweet intake as percent of energy.	Poor
Solga et al. (2004)	USA	To determine whether overall calorie intake and diet composition are	70	44 (9) / NR	55 / 41-97	89%: 11%	Retrospective consecutive series	Positive	24-h food recall with dietitian	Total daily energy and macronutrient intake as a percent of energy	Poor

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
		associated with severity of NAFLD histopathology					/ Level IV				
Sovik et al. (2013)	Norway & Sweden	To investigate changes in gastrointestinal symptoms, bowel function, eating behaviour, dietary intake and psychosocial functioning after	60	GB 35.2 ± 7 DS 36.1 ± 5.3	GB 54.8 ± 3.24 DS 55.2 ± 3.49	42:18	RCT / Level II	Positive	4-d food record	Total daily energy intake & macronutrient intake (grams /d)	Acceptable / reasonable

Reference	Country	Purpose	Participants				Study design / NHMRC grading	Study quality *	Dietary measure	Dietary outcome	Dietary reporting quality **
			N	Age (SD) Years / range	BMI (SD) kgm^{-2} / range	Female: Male					
		gastric bypass and duodenal switch									
Strain et al. (1992)	USA	To document the caloric intake of very obese persons and investigate the food choices and dietary composition that maintain severe obesity	46 Note 23 of recruited data not able to be included	29 / 19-46	Inpt 69 / 35-90 Outpt Women: 48.3 ± 7.6 Men: 51 ± 13.2	22:24	Observational / Level IV	Neutral	Outpatients – 7-d food record with trained therapist nutritionist Inpatients – observed intake	Energy per kilogram of body weight and daily caloric intake of food groups	Poor

SD, standard deviation; RYGB, roux-en-Y gastric bypass; GB, gastric bypass; DS, duodenal switch; BMI, body mass index; d, day; h, hour; RMR, resting metabolic rate; BMR, basal metabolic rate; PABA, para-aminobenzoic acid; NR, not reported; FFQ, food frequency questionnaire; Inpt, In-patient; outpt, Out-patient.

*Overall methodological study quality was assessed using the American Dietetic Association critical appraisal tool [17].

** Overall dietary reporting quality was assessed according to the methodology of Burrows et al. (2012) [18].

Table 3: Summary of studies (n=10) dietary outcome data according to dietary methodology

	24 hour recall		24 hour recall & food record		Food records					FFQ
	Busetto et al. (1996)	Solga et al. (2004)	Moize et al. (2011)	Raymond et al. (1986)	Aronoff et al. (1994)	Gortz et al. (1990)	Ruz et al. (2009)	Sovik, et al (2013)	Strain et al. (1992)	Sarwer et al. (2012)
Energy (kcal/day) / (range)	2833 ± 1428	2700 ± 942 (1762-4867)	Males: 2584 (2337-2830) Females: 2093 (1991-2196)	2592	2322 ± 873	2800 ± 260	1675 ± 639	GB 2691 (2384-2998) DS 2470 (2130-2810)	Inpatient - male 4475 ± 516 - female 3250 ± 561 Outpatients 3350	Std care 2503 ± 170 DC 2092 ± 201
CHO % (range)	44.9 ± 11.4	46 ± 11 (26-69)	Males:38.7 (36.2-41.1) Females:39.3 (37.8-40.8)	NR	NR	45	NR	NR	NR	Std care 43.6 ± 1.4 DC 45.70± 1.6

	24 hour recall		24 hour recall & food record		Food records					FFQ
Fat % (range)	36.4 ± 9.7	37 ± 11 (26-57)	Males:41.9 (39.6-44.2) Females:43 (41.7-44.4)	NR	NR	40	NR	NR	NR	Std care 42.6 ± 1.1 DC 40.44 ±1.30
Protein % (range)	16.8 ± 4.9	18 ± 10 (12-84)	Males:19.1 (17.7-20.5) Females:17.3 (16.4-18.1)	NR	NR	15	NR	NR	NR	Std care 15.3 ± 0.6 DC 15.1 ± 0.7

Values: mean ± SD

Abbreviations:

CHO, carbohydrates; NR, not reported; GB, gastric bypass group; DS, duodenal switch group; Std care, standard care group; DC, dietary counselling group

Table 4: Summary of other miscellaneous dietary outcomes

Study	Dietary outcome		
Aronoff et al.(1994)	Mean day time intake (Kcal): 1286 ± 386 Mean night time intake (kcal): 1036 ± 487		
Busetto et al. (1996)	No of food contact % of energy from liquid foods % of energy from soft foods % of energy from solid foods	4.3 ± 1.0 14.5 ± 13.0 13.3 ± 11.8 72.0 ±15.3	
Gortz et al. (1990)	Liquid volume ml/ 24 hr Liquid calories / 24 hr Protein g/day	1850 ± 364 550 ± 100 (20% of ingested energy) 117.4 ± 12.7	
Moize et al. (2011)		Males (n=64)	Females (n=167)
	Carbohydrate (g)	193.4 (128.3-258.6)	243.7 (204.1-283.3)
	Protein (g)	105.8 (94.7-116.9)	94.5 (87.8-101.3)
	Lipids (g)	104.1 (98-110.1)	108.1 (104.4-111.7)
	Saturated fat (g)	30.4 (27.5-33.2)	31.5 (29.7-33.3)
	Mono fat (g)	48.6 (44.6-52.6)	50.4 (47.9-52.9)
	Poly fat (g)	9.3 (8.4-10.3)	10.1 (9.5-10.7)
	Calcium (mg)	911.9 (806.7-1017.1)*	928 (864-992.1)*
	Phosphorus (mg)	1459.5 (1331.6-1587.4)	1370.8 (1293.7-1447.9
	Magnesium (mg)	246.2 (227.6-264.9)*	244.7 (233.4-256.16)*
	Iron (mg)	16.2 (14.23-18.17)	18-50 yrs: 12.8 (12.2-13.4)*

Study	Dietary outcome		
			51 yrs: 13.1 (12.3-13.9)
Ruz et al. (2009)	Protein (g/d) Dietary iron intake (mg/d)	69.1 ± 21.4 9.4 ± 4.8	
Ruz et al. (2011)	Dietary zinc intake (mg/d)	9.1 ± 3.5	
Raymond et al. (1986)	Protein (g/d)	92	
Sarwer et al. (2012)	Sweets (% of daily energy intake) Standard care group Dietary counselling group	 15.37 ± 1.71 19.14 ± 1.95	

* not meeting recommended dietary intake

Values: mean ± SD

Abbreviations: Mono, monounsaturated; Poly, polyunsaturated