Received: 22 May 2023 | Accepted: 26 October 2023

DOI: 10.1111/jhn.13258

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

ORIGINAL ARTICLE

Changes in nutrient composition and diet quality in the first 6 months following bariatric surgery: An observational cohort study

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Funding information
Nutrition and Healthcare Alliance

Abstract

Background: Bariatric surgery (BS) may result in inadequate nutrient intake and poor diet quality, which can lead to nutritional complications. The present study aimed to evaluate changes in macro- and micronutrient composition and diet quality in the first 6 months following BS.

Methods: One hundred seven participants undergoing BS (Roux-en-Y gastric bypass: $n = 87$, sleeve gastrectomy: $n = 20$) completed 3-day food records before and 6 months after surgery. Changes in energy, macronutrient (carbohydrates, protein, fat, dietary fibre) and micronutrient intake (folate, vitamin B12, vitamin D, calcium, iron) were evaluated. Diet quality was assessed by adherence to the Dutch food-based dietary guidelines.

Results: After BS, we observed a significant decrease in intake of energy and all macro- and micronutrients ($p < 0.01$ for all), except for calcium (−39.0 ± 404.6 mg; $p = 0.32$). Overall, nutrient composition slightly changed with an increase in the relative intake of protein (+1.1 ± 4.3 energy percentage [en%]; $p = 0.01$) and mono- and disaccharides (+4.2 ± 6.4 en%; $p < 0.001$) post-surgery. Consumption (median [Q1, Q3]) of vegetables (−50 [−120, 6] g day^{-1}), wholegrain products (−38 [−81, −8] g day^{-1}), liquid fats (−5 [−13, 2] g day^{-1}), red meat (−3 [−30, 4] g day^{-1}), processed meat (−32 [−55, 13] g day^{-1}), sodium (−0.7 [−1.1, −0.2] g day^{-1}) and unhealthy food choices (−2.4 [−5.0, 0.6] serves week^{-1}) significantly decreased after BS ($p < 0.01$ for all).

Conclusions: Our results demonstrate both favourable and unfavourable changes in macro- and micronutrient composition and diet quality in the first 6 months following BS. Insight into these changes can improve dietary counselling in this population. Future research into underlying causes, consequences and long-term changes in dietary intake is needed.

KEYWORDS

bariatric surgery, diet quality, food groups, macronutrients, nutrient composition, obesity

Key points

- Only small changes in nutrient composition and diet quality are observed 6 months after bariatric surgery.
- Favourable changes include a decrease in the intake of foods to limit, including unhealthy food choices (e.g., sweets and snacks), red and processed meat and sodium, as well as an increase in dairy consumption and relative protein intake.

- Unfavourable changes include reduced intake of vegetables and wholegrain products, a decreased fibre and micronutrient intake, and an increase in the intake of mono- and disaccharides.

INTRODUCTION

Bariatric surgery (BS) is currently the most effective treatment for severe obesity resulting in sustained weight loss, resolution of obesity-related comorbidities and improvement of quality of life.[1–3] In 2022, the global registry of The International Federation for Surgery for Obesity and Metabolic Disorders (IFSO) included 480,970 bariatric procedures of which the Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) were most commonly performed (30% and 60%, respectively).[4] Despite their effectiveness on weight reduction and improved health-outcomes, most bariatric procedures alter the anatomy and physiology of the gastrointestinal tract, thereby influencing intake, digestion and absorption of nutrients.[5,6] Reduced gastric capacity, gastrointestinal complaints such as reflux or vomiting, food intolerances, and changes in appetite, taste and smell post-surgery may result in inadequate dietary intake and eventually lead to nutritional complications such as anemia, osteoporosis and malnutrition.[5,7] Overall, nutritional deficiencies are frequently reported in this population, particularly for iron, folate, vitamin B12, vitamin D and calcium.[8] Next to lifelong multivitamin supplementation, dietary counselling aimed at optimising dietary intake and diet quality is crucial for improving nutritional status and long-term health after BS.[9] General dietary recommendations include prioritising protein intake, minimising high-sugar and high-fat foods, eliminating sugar-sweetened beverages and alcohol, and increasing the consumption of fibre-rich foods.[10,11] Within the Netherlands, BS patients are advised to use an energy-restricted diet based on the general Dutch food-based dietary guidelines issued in 2015 by the Health Council of the Netherlands.[12,13]

Overall, reductions in energy intake of approximately 45%–60% are reported at 6 months post-surgery.[14–17] However, it is unclear whether these changes are accompanied with changes in nutrient composition of the diet.[18] Furthermore, the decrease in energy intake may not only be a consequence of simply eating smaller portions of the same food items, but also the result of a change of intake towards healthier, less energy-dense foods.[19] In addition to quantifying energy and nutrient intake, analysis of diet quality has therefore gained interest. An improvement in diet quality could compensate for the absolute decrease in food intake and malabsorption of nutrients and may play an important role in weight loss outcome after BS.[9,20,21] However, this goal appears to be difficult to achieve because poor diet quality is frequently reported in this population.[9,20,22–25] Although most studies generally report a low consumption of protein, fibre, fruit and vegetables, and a high consumption of carbohydrates, sugars and fat,[22,26–29] others did observe beneficial changes in dietary intake after BS, characterised by an increased intake of protein-rich foods and vegetables[30] and a reduced consumption of sugar-containing snacks and beverages.[30,31] However, the findings are inconsistent across different time points after surgery and most studies were limited to small sample sizes ($n = 17$–100).[26,27,29–31] The present study aimed to evaluate short-term changes in macro- and micronutrient composition and diet quality in the first 6 months following BS.

METHODS

Study design and participants

The present study was conducted as part of the Eetscore study, a prospective cohort study on dietary intake and dietary assessment methods before and after BS.[32] Recruitment took place at Vitalys Obesity Clinic (Arnhem, the Netherlands) between October 2018 and September 2019. Participants were included approximately 6 weeks pre-surgery and followed up until 6 months post-surgery. During the pre- and post-operative period, all patients participated in an intensive multidisciplinary bariatric surgery support program that starts approximately 6 weeks before surgery until 9 months post-surgery. Exclusion criteria for the study were a non-Dutch eating pattern, suffering from an eating disorder, inability to fill in questionnaires or food records and having a previous bariatric procedure other than an adjustable gastric band in medical history. Participants with a missing or incomplete (< 2 days) food record at baseline and/or 6 months of follow-up were excluded from data analysis. Of the 200 participants who signed the informed consent and were included in the study, 107 participants completed the 3-day food record before and after surgery (Figure 1).

The study was approved by the Local Ethical Committee of Rijnstate Hospital and conducted according to the guidelines laid down in the Declaration of Helsinki. Written informed consent was obtained from all participants.

Data collection

Demographic information

Socio-demographic (age, sex, educational level) and health-related information (type of surgery, smoking

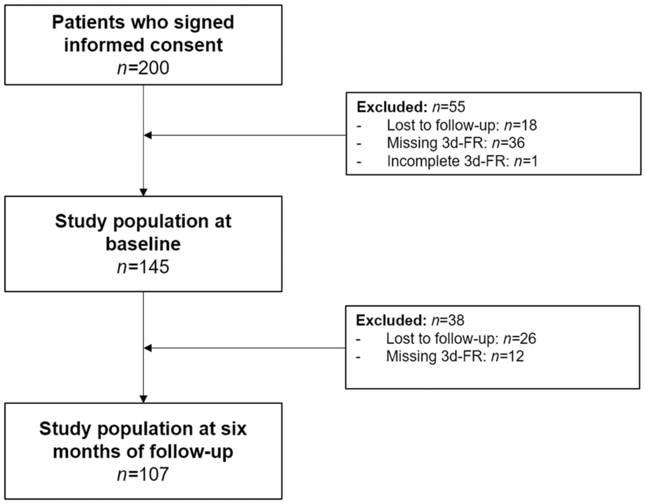

FIGURE 1 Flowchart of study population at baseline and follow-up. FR, food record.

status, comorbidities, anthropometrics) were obtained from electronic patient records. Educational level was defined using the International Standard Classification of Education (ISCED) 2011.[33] Anthropometric measurements were performed during standard visits at the hospital. Body weight was measured to the nearest 0.1 kg with a digital weighing scale (BC-420MA; Tanita), after removal of heavy clothing and shoes. Height was measured in standing position with a wall-mounted stadiometer (model 206; Seca). Body mass index (BMI) was calculated as body weight (kg) divided by squared height (m^2). Total body weight loss (TWL) at 6 months was calculated as weight loss divided by body weight before surgery, multiplied by 100%.

Dietary assessment

Dietary intake was assessed by means of estimated 3-day food records. At both time points, recorded days were randomly selected and consisted of two week days (Monday–Thursday) and one weekend day (Friday–Sunday). To remind participants to record all foods and drinks consumed, a preformatted food record was used including six meal occasions (breakfast, morning, lunch, afternoon, dinner, evening). All participants received verbal instructions and were provided with a written example by the researcher. They were asked to record all consumptions over the 3 days in as much detail as possible, to report cooking methods and to include the recipes for any mixed dishes. Portion sizes were reported in household measures or measured in grams or milliliters. Completed food records were reviewed for completeness with regards to portion sizes, cooking methods and description of foods. Telephone interviews with the participants were conducted in case of any uncertainties (approximately 1–2 weeks after completion of food records). Dietary intake data were entered in Compl-eat™, a computer-based nutrition calculation program that is linked to the Dutch Food Composition Database (NEVO-online, version 2016)[34] in accordance with standardised coding procedures. All consumed foods and meals were coded into as much detail as possible. Mixed dishes such as pasta or rice dishes were broken down into individual ingredients, including corresponding portion sizes, and coded as individual foods. In case of missing recipes for mixed dishes, standard recipes of the Dutch Food Composition Database were used.[34]

Evaluation of nutrient composition and diet quality

Macronutrient composition of the diet was evaluated by intake of total energy, total carbohydrates and mono- and disaccharides, total protein, plant-based and animal-based protein, total fat, saturated fat, monounsaturated fatty acids and polyunsaturated fatty acids (including alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid), and dietary fibre. Furthermore, dietary intake of a limited range of micronutrients for which bariatric patients often display low serum levels was assessed: folate, vitamin B12, vitamin D, calcium and iron. Use of vitamin and mineral supplementation was not included in the present study because the aim was to determine the nutritional value of reported food intake only.

Diet quality was assessed using the cut-off criteria of the Dutch Healthy Diet index 2015 (DHD2015-index). The development of the DHD2015-index has been described previously[35] and consists of 15 components representing the Dutch food-based dietary guidelines of 2015[13]: vegetables, fruit, wholegrain products, legumes, nuts, dairy, fish, tea, fats and oils, coffee, red meat, processed meat, sugar-sweetened beverages, alcohol, and sodium.[35] Because information on the type of coffee was not available from the food records, this component was not included in the analyses. In addition to these 15 components, the component "unhealthy food choices" was added based on the guideline of the Netherlands Nutrition Centre to limit the consumption of high-sugar and high-fat foods.[36] Consumption of unhealthy food choices was assessed as the number of servings per week and cut-off criteria were based on the work of de Rijk et al.[37] An overview of the 16 components and corresponding recommendations is provided in the Supporting information (Table S1).

Statistical analysis

General characteristics of the study population are reported as the median [Q1, Q3] for continuous data and as frequency (%) for categorical data.

Dietary intake data assessed by the 3-day food records were averaged over the number of completed days. Daily dietary intake is reported as the mean ± SD for normally distributed data and as the median [Q1, Q3] for non-normally distributed data. Changes in dietary intake from baseline to 6 months after surgery were tested with a paired *t*-test (normally distributed variables) or a Wilcoxon signed rank test (non-normally distributed variables). Data split according to sex are provided in the Supporting information (Tables S2–S4). Negative values indicate a decrease in intake.

All statistical analyses were performed using SPSS, version 25 (IBM Corp., Armonk, NY, USA). $p < 0.05$ (two-sided) was considered statistically significant.

RESULTS

Participant characteristics

The total study population consisted of 107 participants with a median age of 50.0 [39.0, 56.0] years and a median ICSED level of education of 3.5 [3.0–4.0] (Table 1). The majority was female (79.4%) and had never smoked (57.9%). Half of the study population had no comorbidities before surgery (50.5%). All participants underwent either RYGB (81.3%) or SG (18.7%). Median BMI decreased from 41.3 [38.9, 45.2] kg m^{-2} before surgery to 30.8 [28.5, 34.0] kg m^{-2} 6 months after surgery, resulting in a median TWL of 25.9% [21.1%, 29.4%].

Median follow-up time after surgery was 6.6 [6.4, 6.8] months.

TABLE 1 General characteristics of the total study population.

	Total study population (*n* = 107)	
Age (years)	50.0	[39.0, 56.0]
Sex (female)	85	(79.4)
Educational level[a]	3.5	[3.0–4.0]
Smoking status		
Never	62	(57.9)
Former	39	(36.4)
Current	6	(5.6)
Comorbidities		
None	54	(50.5)
Diabetes mellitus type 2	18	(16.8)
Dyslipidemia	21	(19.6)
Hypertension	35	(32.7)
OSAS	19	(17.8)
Adjustable gastric band in history	16	(15.0)
Type of surgery		
RYGB	87	(81.3)
SG	20	(18.7)
BMI before surgery (kg m²)	41.3	[38.9, 45.2]
BMI after surgery (kg m²)	30.8	[28.5, 34.0]
Waist circumference before surgery (cm)[b]	127.0	[117.0, 134.8]
Waist circumference after surgery (cm)[c]	101.0	[92.3, 110.0]
TWL since surgery (%)	25.9	[21.1, 29.4]

Note: Data are presented as median [Q1, Q3] and frequencies (valid percentages).
Abbreviations: OSAS, obstructive sleep apnea syndrome; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; BMI, body mass index; TWL, total body weight loss.
[a]Based on International Standard Classification of Education (ISCED). Missing for $n = 9$.
[b]Missing for $n = 11$.
[c]Missing for $n = 27$.

Changes in nutrient composition

Energy intake at baseline was 1877 ± 470 kcal and decreased by 512 ± 433 kcal ($p < 0.001$) (Table 2). Similarly, daily intake of total carbohydrates (−51.7 ± 50.0 g), protein (−18.6 ± 24.3 g), fat (−23.2 ± 26.7 g) and fibre (−6.4 ± 6.1 g) significantly decreased at 6 months post-surgery ($p < 0.001$ for all).

Overall, nutrient composition of the diet slightly changed after BS with an increase in the relative intake of total protein (+1.1 ± 4.3 en%; $p = 0.01$) and mono- and disaccharides (+4.2 ± 6.4 en%, $p < 0.001$). Relative intake of total carbohydrates and fat remained similar between the two time points (+0.2 ± 7.7 en%; $p = 0.77$ and −0.8 ± 7.4 en%; $p = 0.25$, respectively).

Micronutrient intake of folate, vitamin B12, vitamin D and iron significantly decreased ($p < 0.01$), whereas the intake of calcium remained stable at 6 months post-surgery (–39.0 ± 404.6 mg; $p = 0.32$).

Changes in diet quality

Overall, consumption of vegetables, wholegrain products, liquid fats, red and processed meat, sodium and unhealthy food choices decreased, whereas the consumption of dairy tended to increase after BS (Table 3). Consumption of fruit, legumes, fish, tea, sugar-sweetened beverages and alcohol remained similar from baseline to 6 months post-surgery.

TABLE 2 Daily dietary intake of energy and macro- and micronutrients before and 6 months after BS in 107 participants.

	Intake			
	Baseline	**6 months**	**Change**	***p*-value**
Total energy (kcal)	1877 ± 470	1365 ± 376	−512 ± 433	<0.001
Carbohydrates				
Total carbohydrates (en%)	41.0 ± 5.9	41.2 ± 6.4	+0.2 ± 7.7	0.77
Total carbohydrates (g)	191.0 ± 52.3	139.3 ± 40.0	−51.7 ± 50.0	<0.001
Mono- and disaccharides (en%)	16.9 ± 5.2	21.0 ± 5.4	+4.2 ± 6.4	<0.001
Mono- and disaccharides (g)	78.2 ± 30.0	71.3 ± 24.0	−6.9 ± 33.1	0.03
Protein				
Total protein (en%)	18.2 ± 3.9	19.3 ± 3.5	+1.1 ± 4.3	0.01
Total protein (g)	84.1 ± 23.5	65.5 ± 20.7	−18.6 ± 24.3	<0.001
Plant-based protein (g)	29.3 ± 9.1	18.5 ± 6.2	−10.9 ± 8.7	<0.001
Animal-based protein (g)	54.2 ± 19.0	46.1 ± 17.8	−8.1 ± 21.9	<0.001
Total protein (g kg^{-1})[a]	1.1 ± 0.3	0.9 ± 0.3	−0.2 ± 0.3	<0.001
Fat				
Total fat (en%)	37.3 ± 6.6	36.4 ± 6.3	−0.8 ± 7.4	0.25
Total fat (g)	79.1 ± 28.0	55.9 ± 19.9	−23.2 ± 26.7	<0.001
Saturated fat (en%)	13.3 ± 3.2	13.4 ± 3.3	+0.1 ± 4.1	0.89
Saturated fat (g)	28.4 ± 11.2	20.6 ± 8.1	−7.8 ± 11.0	<0.001
Monounsaturated fatty acids (g)	27.6 ± 11.1	19.4 ± 8.0	−8.2 ± 11.5	<0.001
Polyunsaturated fatty acids (g)	15.7 ± 6.3	10.4 ± 4.7	−5.2 ± 6.4	<0.001
Alpha-linolenic acid (g)	1.5 [1.2, 2.0]	1.0 [0.7, 1.3]	−0.5 [−0.8, −0.1]	<0.001
Eicosapentaenoic acid (g)	0.03 [0.01, 0.06]	0.02 [0.01, 0.06]	0.00 [−0.03, 0.02]	0.36
Docosahexaenoic acid (g)	0.02 [0.01, 0.07]	0.02 [0.00, 0.07]	0.00 [−0.05, 0.02]	0.20
Fibre				
Total fibre (g)	21.0 ± 5.9	14.6 ± 5.2	−6.4 ± 6.1	<0.001
Micronutrients				
Folate (μg)[b]	245.9 [206.9, 293.1]	184.2 [148.3, 217.7]	−57.0 [−110.2, −12.8]	<0.001
Vitamin B12 (μg)	4.3 [3.2, 5.5]	3.7 [2.6, 4.6]	−0.7 [−2.1, 0.7]	0.002
Vitamin D (μg)	2.9 [1.9, 4.0]	1.9 [1.4, 2.8]	−0.7 [−2.1, 0.1]	<0.001
Calcium (mg)	982.1 ± 321.7	943.1 ± 346.7	−39.0 ± 404.6	0.32
Iron (mg)	10.0 ± 2.7	7.1 ± 2.3	−2.9 ± 2.8	<0.001

Note: Data are presented as mean ± SD or median [Q1, Q3]. Negative values indicate a decrease in intake.
Abbreviation: en%, energy percentage.
[a]Based on ideal body weight at a BMI of 25.
[b]Dietary folate equivalents (DFE). 1 DFE = 1 μg food folate = 0.6 μg of folic acid from fortified food.

Daily consumption of vegetables and wholegrain products markedly decreased (50 [−120, 6] g and 38 [−81, −8] g, respectively) ($p < 0.001$ for both). Similarly, the percentage of participants with a consumption according to the recommendation decreased from 28% to 13% for vegetables and from 58% to 19% for wholegrain products ($p < 0.01$ for both) (Figure 2). For fats and oils, daily consumption of liquid fats significantly decreased, whereas the consumption of solid fats remained similar (−5 [−13, 2] g vs. 0 [−2, 3] g, respectively). As a result, the percentage of participants adhering to the recommendation decreased from 62% to 47% ($p = 0.03$). Intake of red

TABLE 3 Consumption of food groups according to the Dutch food-based dietary guidelines before and 6 months after BS in 107 participants.

	Recommendation	Intake Baseline	6 months	Change	*p*-value
Vegetables (g day^{-1})	≥200 g	146 [94, 208]	87 [52, 140]	−50 [−120, 6]	<0.001
Fruit (g day^{-1})	≥200 g	187 [113, 255]	168 [111, 255]	−8 [−77, 51]	0.34
Wholegrain products (g day^{-1})	≥90 g	99 [58, 136]	47 [26, 73]	−38 [−81, −8]	<0.001
Legumes (g day^{-1})	≥10 g	0 [0, 0]	0 [0, 0]	0 [0, 0]	0.89
Nuts (g day^{-1})	≥15 g	0 [0, 3]	0 [0, 8]	0 [0, 8]	0.02
Dairy (g day^{-1})[a]	300–450 g	337 [222, 507]	418 [242, 534]	+25 [−121, 231]	0.05
Fish (g day^{-1})[b]	≥15 g	0 [0, 4]	0 [0, 4]	0 [−3, 4]	0.78
Tea (g day^{-1})	≥450 g	200 [0, 507]	133 [0, 517]	0 [−200, 105]	0.37
Fats and oils (g day^{-1})	Only consumption of liquid fats or ratio of liquid fats to solid fats ≥ 13				
Liquid fats (g day^{-1})		13 [5, 24]	7 [3, 12]	−5 [−13, 2]	<0.001
Solid fats (g day^{-1})		0 [0, 6]	1 [0, 6]	0 [−2, 3]	0.57
Red meat (g day^{-1})	≤45 g	27 [0, 45]	6 [0, 30]	−3 [−30, 4]	0.003
Processed meat (g day^{-1})	0 g	67 [33, 103]	43 [20, 65]	−32 [−55, 13]	<0.001
Sugar-sweetened beverages (g day^{-1})	0 g	58 [0, 150]	50 [0, 183]	0 [−67, 75]	0.89
Alcohol (g day^{-1})	≤10 g of ethanol	0 [0, 0]	0 [0, 0]	0 [0, 0]	0.12
Sodium (g day^{-1})[c]	≤1.9 g	2.2 [1.7, 2.9]	1.6 [1.2, 2.0]	−0.7 [−1.1, −0.2]	<0.001
Unhealthy food choices (serves week^{-1})	≤3 servings per week	5.9 [3.1, 9.7]	3.5 [1.5, 5.7]	−2.4 [−5.0, 0.6]	<0.001

Note: Data are presented as median [Q1, Q3]. Cut-offs are based on the DHD2015-index 36,38. Negative values indicate a decrease in intake.
[a]Maximum of 40 g of cheese included.
[b]Maximum of 4 g of lean fish included.
[c]The recommendation of < 6 g of table salt corresponding to ≤ 2.4 g of sodium was adjusted by 20% to compensate for missing data on added salt.

meat, processed meat and sodium also significantly decreased post-surgery ($p < 0.01$ for all), which resulted in an increased adherence to the recommendations for sodium (35%–73%; $p < 0.001$) and red meat (77%–87%; $p = 0.051$), but not for processed meat (3%–4%; $p = 0.99$). Consumption of unhealthy food choices decreased from 5.9 [3.1, 9.7] to 3.5 [1.5, 5.7] servings per week ($p < 0.001$), increasing the adherence to the recommendation from 24% to 41% after BS ($p = 0.009$).

Dairy was the only food group that showed a notable increase in daily consumption 6 months after surgery (+25 [−121, 231] g; $p = 0.052$), although not statistically significant. Although the percentage of participants with a dairy consumption within the recommended optimal range of 300–450 g remained similar between baseline and follow-up (25%–22%), the number of participants consuming over 450 g day^{-1} increased from 29% to 45% ($p = 0.051$). We also observed a slight increase in the consumption of nuts (0 [0, 3] to 0 [0, 8] g; $p = 0.02$), but median intake at 6 months was still extremely low and compliance with the recommendation did not change after BS (11%–20%; $p = 0.09$).

DISCUSSION

The present study aimed to evaluate short-term changes in macro- and micronutrient composition and diet quality in the first 6 months following BS. Favourable changes included a decrease in the intake of foods to limit, including unhealthy food choices (e.g., sweets and snacks), red and processed meat and sodium, as well as an increase in dairy consumption and relative protein intake after BS. However, unfavourable changes, including a reduced consumption of vegetables and wholegrain products, along with a decreased fibre and micronutrient intake, and an increase in the intake of mono- and disaccharides, were also observed 6 months post-surgery.

Overall, we found that macronutrient composition of the diet slightly changed with a postoperative increase in

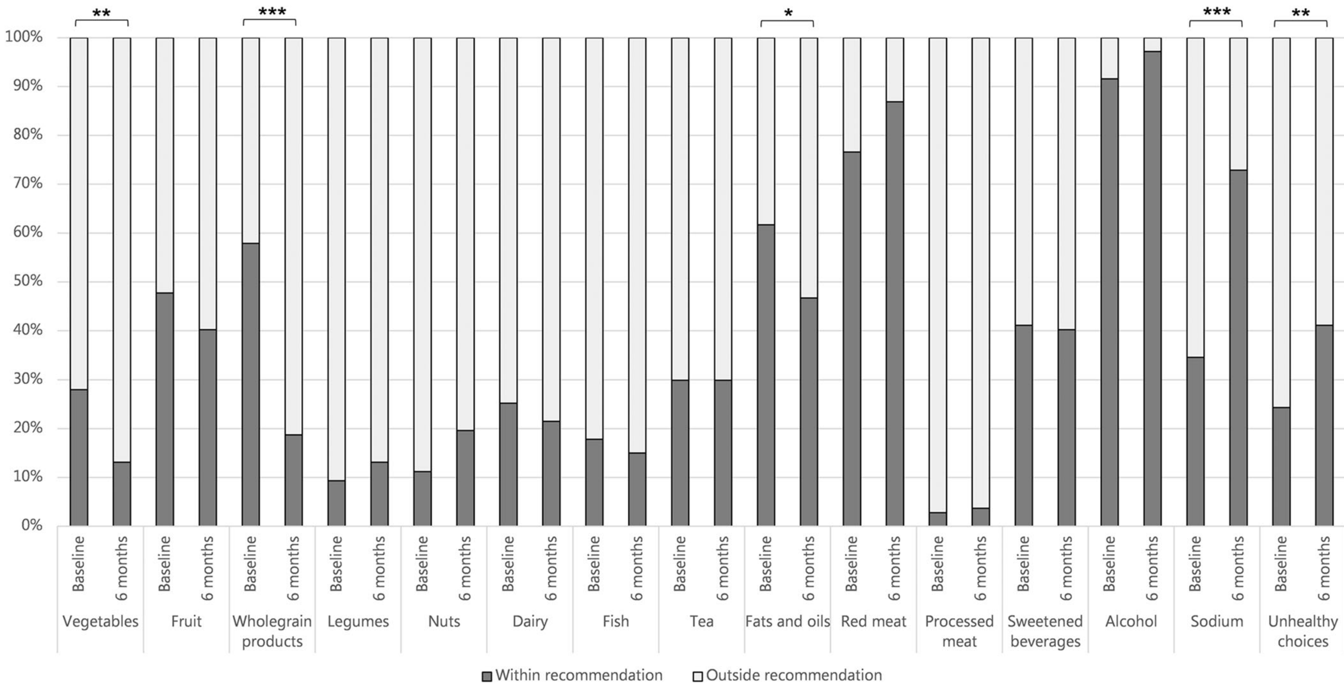

FIGURE 2 Adherence to the Dutch food-based dietary guidelines before and 6 months after BS in 107 participants. Significant difference between time points: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

percentage energy from proteins at 6 months. Still, only 59% of the participants had an adequate protein intake according to the recommended goal of ≥ 60 g day^{-1} after BS,[10,38] which is in line with previous research.[14,16,17,39,40] Adequate protein intake is needed to prevent the loss of fat-free mass, hair loss, poor wound healing and oedema,[40] and may increase satiety and therefore be an important factor in maintaining weight loss after surgery.[15] The relative increase in protein intake post-surgery might be explained by the slight increase in dairy because this was the only food group that showed a notable increase in daily consumption, whereas the consumption of most other food groups decreased post-surgery. This might also explain the fairly stable intake of calcium, whereas the intake of all other micronutrients decreased after BS. Because only a minority of the participants reported to consume plant-based protein sources such as legumes (14%) and nuts (41%), many bariatric patients may benefit from increasing their consumption of plant-based protein sources. In addition to the intake of protein-rich foods, protein supplementation could also contribute to achieving the recommended goal of 60 g day^{-1} in patients who fail to consume adequate amounts of protein. In the present study, additional protein supplementation was not routinely advised and only a few participants reported the use of artificial sources of protein (e.g., protein bars, powders and shakes).

The inadequate consumption of vegetables and wholegrain products observed in the present study is in line with the findings of Schiavo et al.,[27] who also found an inadequate intake of vegetables and complex carbohydrates in a cohort of patients ≥ 4 years after SG. Vegetable consumption in the present study was already low at baseline (146 g) and further decreased at 6 months after surgery (87 g), with only 13% reaching the recommended amount of 200 g day^{-1}. Inadequate vegetable consumption is common within the general Dutch population with a mean consumption of 131 g day^{-1}.[41] Because 85% of vegetables in the Dutch diet are consumed during dinner,[42] which was also true for the present study, including vegetables at other eating occasions during the day could improve vegetable consumption, particularly in the bariatric population because of their higher meal frequency. The reduced intake of wholegrain products could be a reflection of food intolerances to bread, cereals, pasta and rice,[9,43–45] as well as prioritising protein intake over the consumption of grains to limit overall energy intake, as generally advised after BS. Together with the large decrease in the consumption of vegetables and wholegrains, dietary fibre intake in the present study decreased to 14.6 ± 5.2 g day^{-1} with only 10% reaching the recommended intake of 14 g per 1000 kcal[10] at 6 months post-surgery, which is in accordance with low fibre intakes reported in previous research in the bariatric population.[14,29,45–48] Next to the general health benefits of dietary fibre, inadequate fibre intake in this population has also been linked to constipation, which is a common problem after BS.[45,46] In addition to increasing the consumption of vegetables and wholegrains, the consumption of other fibre-rich foods such as (low sugar) fruits, legumes and nuts could also contribute to a higher fibre intake.

The number of unhealthy food choices such as sweet and savory snacks significantly decreased from 5.9 to 3.5 servings per week. Next to a positive impact of dietary counselling, changes in taste could offer an explanation for this finding. After BS, taste sensitivity to sweet and fatty stimuli appears to increase, along with a reduced hedonic response to these stimuli.[49] However, consumption of sugar-sweetened beverages did not decrease in the present study, despite the beneficial changes observed in previous research.[31,50] At the same time, a relative increase in the intake of mono- and disaccharides was observed (16.9 ± 5.2 en% to 21.0 ± 5.4 en%), implying that high-sugar foods and drinks comprised a relatively larger part of the diet after surgery compared to before. In the study by Kapoor et al.,[51] deselection of high-fat and/or high-sugar foods at an ad libitum buffet was prevalent but not universal, suggesting that food preferences may not change favourably in all patients after BS.[19,51] This may also explain the large variation in the intake of sugar-sweetened beverages post-surgery (0–183 g day^{-1}). Reducing the intake of unhealthy food choices is not only needed for improved weight loss outcomes,[21] consumption of high-sugar foods and drinks could also lead to common post-surgical gastrointestinal symptoms such as dumping syndrome.[10,11,28] Identifying potential contributing factors to the variation in food preferences post-surgery could be useful to help identify patients that need additional support in making the desired dietary changes.[19]

Many factors could underlie the observed changes in dietary intake after BS. Although it was beyond the scope of the present study to explain its causality, the small changes in nutrient composition and diet quality could indicate that dietary intake in the present study was mainly altered by the reduction of the amount of food intake and not in the type of food consumed, as reported by several other studies.[52,53] However, there are several other factors to take into account, such as nutritional counseling and education about healthy food choices, food intolerances and changes in taste, food preferences, and food reward in the brain.

The intensive multidisciplinary bariatric surgery support program may be a motivation for dietary changes after BS, which is supported by the increased consumption of protein-rich foods and the decreased consumption of unhealthy food choices, which represent two major targets in the program. It might also be that the reduced consumption of sweet and fatty foods is a consequence of the decreased preference for sweet and fatty taste and increase in sweet taste sensitivity that is observed after BS,[49,54] or results from previous experiences of food-related complaints such as dumping syndrome or reflux after ingesting such foods.[30,54] Moreover, neuroimaging studies have shown differences in the neural responses to high- and low-energy food stimuli pre- and post-BS.[55,56] These changes may be influenced by alterations in the signaling from the gut to the brain, as well as changes in the microbiota and in the secretion of digestive hormones such as glucagon-like peptide-1 and ghrelin.[54] More studies are needed to understand these mechanisms in greater detail.

Overall, dietary counselling remains a key component in the bariatric surgery program, especially during the first months post-surgery because short-term changes in dietary intake have been related to longer term weight outcomes. For example, short-term reductions in energy intake at 6 months post-surgery were associated with greater weight loss over 10 years in the Swedish Obese Subjects study.[15] This association is consistent with the research from Ostad et al.[47] and Nymo et al.,[21] who also reported better weight loss outcomes when intake of energy was lower. Additionally, attention should be paid to the qualitative aspects of the diet to optimise weight outcomes. Masood et al.[57] suggested that weight regain after BS might be less due to excessive consumption of food and more to a poor selection of healthy foods. Indeed, multiple other studies found poor diet quality to be associated with weight regain in the late postoperative period.[9,20–22] Overall, poor diet quality is commonly reported in this population.[9,20,22–25] Two studies showed that diet quality of individuals who had previously undergone bariatric surgery was lower compared to individuals with normal weight.[23,25] This highlights the importance of improving dietary habits in the first month following surgery and not solely relying on the initial benefits of the bariatric procedure.

Poor diet quality can also result in low micronutrient intake and thereby contribute to the development of nutritional deficiencies. Overall, nutritional deficiencies are frequently reported in this population, particularly for iron, folate, vitamin B12, vitamin D and calcium.[8] In the present study, the significant reduction in energy intake was accompanied with a reduced intake of folate, vitamin B12, vitamin D and iron. In general, reported dietary micronutrient intake was already low before surgery and worsened post-surgery, which is in accordance with previous research.[16,26] Nonetheless, it is not realistic to expect micronutrient intake from diet alone to provide the required levels needed to prevent micronutrient deficiencies after BS. To illustrate, intake of iron at 6 months post-surgery was 7.1 ± 2.3 mg, whereas daily iron requirements are estimated to be 45–60 mg after BS.[38] For vitamin B12, the disagreement between intake and requirement is even more pronounced with a median intake of 3.7 [2.6–4.6] μg versus a requirement of 350–1000 μg vitamin B12 per day.[38] This was also demonstrated in the study of Gesquiere et al.,[58] who showed that dietary intake of iron and vitamin B12 comprised only a small part of total micronutrient intake when intake from supplements was included (25% and 5%, respectively) at 12 months after RYGB. For these reasons, adequate daily vitamin and mineral supplementation is also needed to prevent nutritional deficiencies after BS.

The main strength of the present study was the focus on both nutrient composition and diet quality assessed by the consumption of different food groups. This approach aligns with the trend to comprehensively represent the totality of the diet by focusing on foods and beverages rather than individual nutrients. Nevertheless, our results should also be interpreted in light of certain limitations. First, loss to follow-up was relatively high, with only half of the study population completing the 3-day food records at both time points, which may limit the power and generalisability of our findings. Nevertheless, the study population was still found representative of the general Dutch bariatric patient population,[59] indicating a minor risk of selection bias. Second, reporting dietary intake on only 3 days may not have been representative of usual dietary intake because this is likely not sufficient to capture the daily variation in food intake. This could have resulted in an underestimation of foods that are not consumed on a daily basis. Third, under-reporting of energy intake is a common bias in nutrition research, particularly among participants with overweight or obesity.[18,60,61] In a previous study using data of the same cohort, we estimated that 57% of the 140 participants potentially under-reported their energy intake at baseline.[32] However, the degree of under-reporting post-surgery could not be identified because most techniques largely rely on the condition of weight stability. Therefore, the magnitude and direction of under-reporting, as well as potential consequences for data interpretation, remain unknown in the present study. Still, we can assume that the preoperative and postoperative measurements are subject to the same biases and that the direction and magnitude of change is consistent over time. Last, the use of a preformatted food record prevented us from gaining insight into other relevant aspects of eating behaviour such as meal frequency and separation of liquid and solid foods. Given the general biases that are common to many types of traditional dietary intake assessment methods, such as food records, 24-h recalls, and food frequency questionnaires, we would advocate for novel methods that can overcome these challenges in future studies.

CONCLUSIONS

To conclude, our results demonstrate both favourable and unfavourable changes in macro- and micronutrient composition and diet quality during the first 6 months after BS. Insight into these changes may help dietitians and other healthcare practitioners to understand potential pitfalls with respect to improving dietary counselling of their patients. Based on the findings of the present study, increasing the consumption of plant-based protein sources such as legumes and nuts could improve absolute protein intake, whereas the consumption of vegetables and wholegrain products should be targeted to improve fibre intake. Although the consumption of unhealthy food choices decreased after surgery, more attention is needed to also limit the consumption of sugar-sweetened beverages to reduce sugar intake. Moreover, an overall improvement in diet quality could also improve micronutrient intake, although additional supplementation will always be necessary to meet the required levels for preventing micronutrient deficiencies after BS.

Future research into potential contributing factors underlying changes in dietary intake and its consequences post-surgery could be useful to help identify patients that need additional support in making the desired dietary changes. Furthermore, larger studies focusing on long-term changes in dietary intake are needed as eating behaviour is likely to change over time.

AUTHOR CONTRIBUTIONS

Conceptualisation, Funding acquisition: MB, LD, JV, EH. Methodology: LH, AB, MB, LD, JV, EH. Investigation, Project administration: LH. Formal analysis: LH, AB, JV. Writing-original draft: LH, AB, JV. Writing-review & editing: LH, AB, MB, LD, JV, EH.

ACKNOWLEDGEMENTS

We thank Hanne de Jong for her support with data entry. This project was financially supported by the Nutrition and Healthcare Alliance, the Netherlands. The Nutrition and Healthcare Alliance had no role in the design, analysis or writing of this article.

CONFLICTS OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ETHICAL STATEMENT

This study was approved by the Local Ethical Committee of Rijnstate Hospital (2018–1214) and conducted according to the guidelines laid down in the Declaration of Helsinki

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PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jhn.13258.

REFERENCES

1. Gloy VL, Briel M, Bhatt DL, Kashyap SR, Schauer PR, Mingrone G, et al. Bariatric surgery versus non-surgical treatment for obesity: a systematic review and meta-analysis of randomised controlled trials. BMJ. 2013;347:f5934.
2. O'Brien PE, Hindle A, Brennan L, Skinner S, Burton P, Smith A, et al. Long-term outcomes after bariatric surgery: a systematic review and meta-analysis of weight loss at 10 or more years for all bariatric procedures and a single-centre review of 20-year outcomes after adjustable gastric banding. Obes Surg. 2019;29(1): 3–14.
3. Sjöström L, Peltonen M, Jacobson P, Sjöström CD, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. JAMA. 2012;307(1):56–65.
4. Brown WA, Shikora S, Liem R, Holland J, Campbell AB, Sprinkhuizen SM, et al. Seventh IFSO Global Registry Report. 2022.
5. Lupoli R, Lembo E, Saldalamacchia G, Avola CK, Angrisani L, Capaldo B. Bariatric surgery and long-term nutritional issues. World J Diabetes. 2017;8(11):464–74.
6. Steenackers N, Vanuytsel T, Augustijns P, Tack J, Mertens A, Lannoo M, et al. Adaptations in gastrointestinal physiology after sleeve gastrectomy and Roux-en-Y gastric bypass. Lancet Gastroenterol Hepatol. 2021;6(3):225–37.
7. Osland E, Powlesland H, Guthrie T, Lewis CA, Memon MA. Micronutrient management following bariatric surgery: the role of the dietitian in the postoperative period. Ann Transl Med. 2020;8(Suppl 1):S9.
8. Gasmi A, Bjørklund G, Mujawdiya PK, Semenova Y, Peana M, Dosa A, et al. Micronutrients deficiences in patients after bariatric surgery. Eur J Nutr. 2022;61(1):55–67.
9. Zarshenas N, Tapsell LC, Neale EP, Batterham M, Talbot ML. The relationship between bariatric surgery and diet quality: a systematic review. Obes Surg. 2020;30(5):1768–92.
10. Moizé VL, Pi-Sunyer X, Mochari H, Vidal J. Nutritional pyramid for post-gastric bypass patients. Obes Surg. 2010;20(8):1133–41.
11. Sherf Dagan S, Goldenshluger A, Globus I, Schweiger C, Kessler Y, Kowen Sandbank G, et al. Nutritional recommendations for adult bariatric surgery patients: clinical practice. Adv Nutr. 2017;8(2):382–94.
12. Janssen-Burg W, van der Kaaden I, den Otter J, Punt M, Slabbekoorn A, Smelt M, et al. Dieetbehandelingsrichtlijn Bariatrische chirurgie bij obesitas II en III. 2017.
13. Kromhout D, Spaaij CJK, de Goede J, Weggemans RM. The 2015 Dutch food-based dietary guidelines. Eur J Clin Nutr. 2016;70(8):869–78.
14. Farias G, Silva RMO, da Silva PPP, Vilela RM, Bettini SC, Dâmaso AR, et al. Impact of dietary patterns according to NOVA food groups: 2 y after Roux-en-Y gastric bypass surgery. Nutrition. 2020;74:110746.
15. Kanerva N, Larsson I, Peltonen M, Lindroos AK, Carlsson LM. Changes in total energy intake and macronutrient composition after bariatric surgery predict long-term weight outcome: findings from the Swedish Obese Subjects (SOS) study. Am J Clin Nutr. 2017;106(1):136–45.
16. Raatz SK, Johnson LK, Caliquary A, King WC, Kalarchian MA, Devlin MJ, et al. Reported nutrient intake over 7 years after Roux-en-Y gastric bypass in the Longitudinal Assessment of Bariatric Surgery-3 (LABS-3) psychosocial study. Surg Obes Relat Dis. 2020;16(8):1022–9.
17. Sherf Dagan S, Keidar A, Raziel A, Sakran N, Goitein D, Shibolet O, et al. Do bariatric patients follow dietary and lifestyle recommendations during the first postoperative year? Obes Surg. 2017;27(9):2258–71.
18. Redpath TL, Livingstone MBE, Dunne AA, Boyd A, le Roux CW, Spector AC, et al. Methodological issues in assessing change in dietary intake and appetite following gastric bypass surgery: a systematic review. Obes Rev. 2021;22(6):e13202.
19. Nielsen MS, Christensen BJ, Ritz C, Holm L, Lunn S, Tækker L, et al. Factors associated with favorable changes in food preferences after bariatric surgery. Obes Surg. 2021;31(8):3514–24.
20. Da Silva FBL, Gomes DL, De Carvalho KMB. Poor diet quality and postoperative time are independent risk factors for weight regain after Roux-en-Y gastric bypass. Nutrition. 2016;32(11–12): 1250–3.
21. Nymo S, Lundanes J, Aukan M, Sandvik J, Johnsen G, Graeslie H, et al. Diet and physical activity are associated with suboptimal weight loss and weight regain 10-15 years after Roux-en-Y gastric bypass: a cross-sectional study. Obes Res Clin Pract. 2022;16:163–9.
22. Freire RH, Borges MC, Alvarez-Leite JI, Correia MITD. Food quality, physical activity, and nutritional follow-up as determinant of weight regain after Roux-en-Y gastric bypass. Nutrition. 2012;28(1):53–8.
23. Harbury C, Collins CE, Callister R. Diet quality is lower among adults with a BMI >/=40kgm(-2) or a history of weight loss surgery. Obes Res Clin Pract. 2019;13(2):197–204.
24. Harbury CM, Verbruggen EE, Callister R, Collins CE. What do individuals with morbid obesity report as a usual dietary intake? A narrative review of available evidence. Clin Nutr ESPEN. 2016;13:e15–22.
25. Hong YR, Yadav S, Suk R, Lee AM, Newsome FA, Johnson-Mann CN, et al. Assessment of physical activity and healthy eating behaviors among US adults receiving bariatric surgery. JAMA Netw Open. 2022;5(6):e2217380.
26. Marques da Silva M, Waitzberg DL, Sala P, Barcelos S, Santo MA, Martinez AC, et al. Nutritional guidance, monitoring, and supplementation before and after bariatric surgery—are we doing this correctly? Nutrición Hospitalaria. 2021;38(3):478–87.
27. Schiavo L, Di Rosa M, Tramontano S, Rossetti G, Iannelli A, Pilone V. Long-term results of the Mediterranean diet after sleeve gastrectomy. Obes Surg. 2020;30(10):3792–802.
28. Soares FL, Bissoni de Sousa L, Corradi-Perini C, Ramos da Cruz MR, Nunes MGJ, Branco-Filho AJ. Food quality in the late postoperative period of bariatric surgery: an evaluation using the bariatric food pyramid. Obes Surg. 2014;24(9):1481–6.
29. Ziadlou M, Hosseini-Esfahani F, Mozaffari Khosravi H, Hosseinpanah F, Barzin M, Khalaj A, et al. Dietary macro- and micro-nutrients intake adequacy at 6th and 12th month post-bariatric surgery. BMC Surg. 2020;20(1):232.
30. Ullrich J, Ernst B, Wilms B, Thurnheer M, Schultes B. Roux-en Y gastric bypass surgery reduces hedonic hunger and improves dietary habits in severely obese subjects. Obes Surg. 2013;23(1): 50–5.
31. Miller GD, Norris A, Fernandez A. Changes in nutrients and food groups intake following laparoscopic Roux-en-Y gastric bypass (RYGB). Obes Surg. 2014;24(11):1926–32.
32. Heusschen L, Berendsen AA, Balvers MG, Deden LN, de Vries JH, Hazebroek EJ. Relative validity of a short screener to assess diet quality in patients with severe obesity before and after bariatric surgery. Public Health Nutr. 2022;25:1–11.
33. Commission E, Eurostat, Co-operation OfE, Development. ISCED 2011 operational manual—guidelines for classifying national education programmes and related qualifications: Unesco; 2015.
34. NEVO-online versie 2016/5.0 Bilthoven, Nederland: RIVM.

35. Looman M, Feskens EJ, de Rijk M, Meijboom S, Biesbroek S, Temme EH, et al. Development and evaluation of the Dutch Healthy Diet Index 2015. Public Health Nutr. 2017;20(13):2289–99.
36. Brink E, van Rossum C, Postma-Smeets A, Stafleu A, Wolvers D, van Dooren C, et al. Development of healthy and sustainable food-based dietary guidelines for the Netherlands. Public Health Nutr. 2019;22(13):2419–35.
37. de Rijk MG, Slotegraaf AI, Brouwer-Brolsma EM, Perenboom CW, Feskens EJ, de Vries JH. Development and evaluation of a diet quality screener to assess adherence to the Dutch food-based dietary guidelines. Br J Nutr. 2021;128:1–11.
38. Mechanick JI, Apovian C, Brethauer S, Garvey WT, Joffe AM, Kim J, et al. Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures—2019 update: cosponsored by American Association of Clinical Endocrinologists/American College of Endocrinology, The Obesity Society, American Society for Metabolic amp; Bariatric Surgery, Obesity Medicine Association, and American Society of Anesthesiologists. Off J Am Soc Bariatric Surg. 2020;16(2):175–247.
39. Ito MK, Gonçalves VSS, Faria SLCM, Moizé V, Porporatti AL, Guerra ENS, et al. Effect of protein intake on the protein status and lean mass of post-bariatric surgery patients: a systematic review. Obes Surg. 2017;27(2):502–12.
40. Steenackers N, Gesquiere I, Matthys C. The relevance of dietary protein after bariatric surgery: what do we know? Curr Opin Clin Nutr Metab Care. 2018;21(1):58–63.
41. Van Rossum CTM, Buurma-Rethans EJM, Dinnissen CS, Beukers MH, Brants HAM, Dekkers ALM, et al. The diet of the Dutch. Results of the Dutch National Food Consumption Survey 2012-2016. Bilthoven: National Institute for Public Health and the Environment; 2020.
42. van der Krieken SE, van Dooren C, Mensink F, Velema E, van der Vossen-Wijmenga WP, Stafleu A. Vegetables. Fact sheet: Netherlands Nutrition Centre; 2018.
43. Boerlage TCC, van de Laar AWJM, Westerlaken S, Gerdes VEA, Brandjes DPM. Gastrointestinal symptoms and food intolerance 2 years after laparoscopic Roux-en-Y gastric bypass for morbid obesity. Br J Surg. 2017;104(4):393–400.
44. Freeman RA, Overs SE, Zarshenas N, Walton KL, Jorgensen JO. Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Res Clin Pract. 2014;8(2):e183–91.
45. Grosse CS, Cope VC. Dietary fibre intake and bowel habits after bariatric surgery: a structured literature review. Obes Surg. 2019;29(7):2247–54.
46. Afshar S, Kelly SB, Seymour K, Woodcock S, Werner AD, Mathers JC. The effects of bariatric procedures on bowel habit. Obes Surg. 2016;26(10):2348–54.
47. Ostad AN, Barghchi H, Jangjoo A, Ranjbar G, Rezvani R, Bahrami LS, et al. Macro- and micro-nutrient intake adequacy in gastric bypass patients after 24 months: a cross-sectional study. Clin Nutr Res. 2021;10(4):341–52.
48. Reichmann MTF, Todeschini S, Setter N, Vilela RM, Radominski RB. Comparison of the dietary intake amongst women in the late postoperative period after Roux-en-Y gastric bypass with the bariatric food pyramid. Nutr Hosp. 2019;36(3):599–603.
49. Ahmed K, Penney N, Darzi A, Purkayastha S. Taste changes after bariatric surgery: a systematic review. Obes Surg. 2018;28(10):3321–32.
50. Molin Netto BD, Earthman CP, Farias G, Landi Masquio DC, Grotti Clemente AP, Peixoto P, et al. Eating patterns and food choice as determinant of weight loss and improvement of metabolic profile after RYGB. Nutrition. 2017;33:125–31.
51. Kapoor N, Al Najim W, Menezes C, Price RK, O'Boyle C, Bodnar Z, et al. A comparison of total food intake at a personalised buffet in people with obesity, before and 24 months after Roux-en-Y-gastric bypass surgery. Nutrients. 2021;13(11):3873.
52. Livingstone MBE, Redpath T, Naseer F, Boyd A, Martin M, Finlayson G, et al. Food intake following gastric bypass surgery: patients eat less but do not eat differently. J Nutr. 2022;152(11):2319–32.
53. Søndergaard Nielsen M, Rasmussen S, Just Christensen B, Ritz C, le Roux CW, Berg Schmidt J, et al. Bariatric surgery does not affect food preferences, but individual changes in food preferences may predict weight loss. Obesity. 2018;26(12):1879–87.
54. Aguas-Ayesa M, Yárnoz-Esquíroz P, Olazarán L, Gómez-Ambrosi J, Frühbeck G. Precision nutrition in the context of bariatric surgery. Rev Endocr Metab Disord. 2023;24:979–91.
55. Baboumian S, Pantazatos SP, Kothari S, McGinty J, Holst J, Geliebter A. Functional Magnetic Resonance Imaging (fMRI) of neural responses to visual and auditory food stimuli pre and post Roux-en-Y Gastric Bypass (RYGB) and Sleeve Gastrectomy (SG). Neuroscience. 2019;409:290–8.
56. Ochner CN, Kwok Y, Conceição E, Pantazatos SP, Puma LM, Carnell S, et al. Selective reduction in neural responses to high calorie foods following gastric bypass surgery. Ann Surg. 2011;253(3):502–7.
57. Masood A, Alsheddi L, Alfayadh L, Bukhari B, Elawad R, Alfadda AA. Dietary and lifestyle factors serve as predictors of successful weight loss maintenance postbariatric surgery. J Obes. 2019;2019:1–6.
58. Gesquiere I, Foulon V, Augustijns P, Gils A, Lannoo M, Van der Schueren B, et al. Micronutrient intake, from diet and supplements, and association with status markers in pre- and post-RYGB patients. Clin Nutr. 2017;36(4):1175–81.
59. DICA. DATO Bariatrische chirurgie—Jaarrapportage 2018. 2018.
60. Poslusna K, Ruprich J, de Vries JHM, Jakubikova M, van't Veer P. Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice. Br J Nutr. 2009;101(Suppl 2):S73–85.
61. Trijsburg L, Geelen A, Hollman PC, Hulshof PJ, Feskens EJ, Van't Veer P, et al. BMI was found to be a consistent determinant related to misreporting of energy, protein and potassium intake using self-report and duplicate portion methods. Public Health Nutr. 2017;20(4):598–607.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Heusschen L, Berendsen AAM, Balvers MGJ, Deden LN, de Vries JHM, Hazebroek EJ. Changes in nutrient composition and diet quality in the first 6 months following bariatric surgery: An observational cohort study. J Hum Nutr Diet. 2023;1–12. https://doi.org/10.1111/jhn.13258