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Original Research Article

Changes in dietary intake, food tolerance, hedonic hunger, binge eating problems, and gastrointestinal symptoms after sleeve gastrectomy compared with after gastric bypass; 1-year results from the Oseberg study—a randomized controlled trial

Lisa H. Barstad [1,*], Line K. Johnson [1], Heidi Borgeraas [1], Dag Hofsø [1,2], Marius Svanevik [1,3], Milada C. Småstuen [1], Jens K. Hertel [1], Jøran Hjelmesæth [1,4]

[1] *Morbid Obesity Center, Vestfold Hospital Trust, Tønsberg, Norway;* [2] *Department of Medicine, Vestfold Hospital Trust, Tønsberg, Norway;* [3] *Department of Gastrointestinal Surgery, Vestfold Hospital Trust, Tønsberg, Norway;* [4] *Department of Endocrinology, Morbid Obesity and Preventive Medicine, Institute of Clinical Medicine, University of Oslo, Oslo, Norway*

A B S T R A C T

Background: The randomized Oseberg study compared the effects of sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB), on the 1-y remission of type 2 diabetes and β-cell function (primary outcomes). However, little is known about the comparable effects of SG and RYGB on the changes in dietary intakes, eating behavior, and gastrointestinal discomfort.

Objectives: To compare 1-y changes in intakes of macro- and micronutrients, food groups, food tolerance, hedonic hunger, binge eating, and gastro-intestinal symptoms after SG and RYGB.

Methods: Among others, prespecified secondary outcomes were dietary intake, food tolerance, hedonic hunger, binge eating, and gastrointestinal symptoms assessed with a food frequency questionnaire, food tolerance questionnaire, Power of food scale, Binge eating scale, and Gastrointestinal symptom rating scale, respectively.

Results: A total of 109 patients (66% females), with mean (SD) age 47.7 (9.6) y and body mass index of 42.3 (5.3) kg/m^2, were allocated to SG ($n = 55$) or RYGB ($n = 54$). The SG group had, compared with the RYGB group, greater 1-y reductions in the intakes of: protein, mean (95% CI) between-group difference, −13 (−24.9, −1.2) g; fiber, −4.9 (−8.2, −1.6) g; magnesium, −77 (−147, −6) mg; potassium, −640 (−1237, −44) mg; and fruits and berries, −65 (−109, −20) g. Further, the intake of yogurt and fermented milk products increased by >2-folds after RYGB but remained unchanged after SG. In addition, hedonic hunger and binge eating problems declined similarly after both surgeries, whereas most gastrointestinal symptoms and food tolerance remained stable at 1 y.

Conclusions: The 1-y changes in dietary intakes of fiber and protein after both surgical procedures, but particularly after SG, were unfavorable with regard to current dietary guidelines. For clinical practice, our findings suggest that health care providers and patients should focus on sufficient intakes of protein, fiber, and vitamin and mineral supplementation after both SG and RYGB. This trial was registered at [clinicaltrials.gov] as [NCT01778738].

Keywords: dietary intake, bariatric surgery, sleeve gastrectomy, gastric bypass, food tolerance, macronutrients, micronutrients, dietary quality, eating behavior, gastrointestinal symptoms

Introduction

Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB), the 2 most commonly performed bariatric procedures worldwide, result in substantial weight loss, remission of obesity-related comorbidities, and improved quality of life [1–4]. Weight loss is induced by a reduced energy intake, mainly explained by reduced hunger and increased satiety [5]. In addition, reductions in hedonic hunger (the drive to eat food for pleasure in the absence of physiological hunger) [6, 7] and binge eating problems [8, 9] may improve eating habits after bariatric surgery.

Abbreviations used: BES, binge eating scale; CI, confidence interval; FFQ, food frequency questionnaire; GSRS, gastrointestinal symptom rating scale; PFS, power of food scale; PUFA, polyunsaturated fatty acid; RCT, randomized controlled trial; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

* Corresponding author.
E-mail address: liahha@siv.no (L.H. Barstad).

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Contrasting these beneficial effects, reduced food tolerance [10–13] and gastrointestinal side effects such as constipation, diarrhea, reflux, indigestion, pain, or dumping symptoms [14, 15] after surgery may lead to specific preferences or avoidance of certain food items. A recent systematic review and meta-analysis of observational and clinical studies showed an overall higher preference for proteins than fat, increased preference for healthy foods, and decreased hedonic hunger after surgery [16]. By contrast, another systematic review concluded that bariatric surgery can result in unbalanced diets, inadequate micronutrient- and protein intakes, and excessive intake of fats [17]. Furthermore, nutritional deficiencies may occur in 30% to 70% of patients, and lifelong vitamin- and mineral supplementation is needed [15]. Thus, an unbalanced diet in combination with poor adherence to vitamin and mineral supplementation, may contribute to weight regain and nutritional deficiencies as suggested in long-term studies [18–20]. Some studies have reported more healthy food choices (reduced energy density in foods and reduced interest in sweet and high fat food) comparing before and after RYGB [19, 21, 22] or before and after SG [13]. Only a few retrospective, observational or cross-sectional studies have compared the impact of RYGB and SG on hedonic hunger [23, 24], gastrointestinal problems [14, 25], food tolerance [25], or dietary intake of macronutrients, micronutrients, and various food items [14, 18, 25–27], showing no major differences between groups. Further, to our knowledge no study has compared the effects of SG and RYGB on binge eating problems. In summary, there is need for more complete understanding about eating habits and dietary intake in this patient group to help us develop better nutritional follow-up after bariatric surgery. Thus, more high quality evidence of the comparable effects of SG and RYGB on dietary intake, nutritional deficiencies, hedonic hunger, binge eating problems, and gastrointestinal symptoms is needed [17].

To fill the existing knowledge gaps, the objectives of the present analysis of prespecified secondary outcomes from the randomized Oseberg study are, first, to compare the changes in dietary intakes of macronutrients, micronutrients, and food groups, and second, to compare changes in food tolerance, hedonic hunger, binge eating problems, and gastrointestinal discomfort between SG and RYGB 1 y after surgery.

Methods

Trial design

The Oseberg study is an ongoing single-center, triple-blind, randomized (1:1) controlled trial (RCT) being conducted at a tertiary care center (Morbid Obesity Center, Vestfold Hospital Trust, Tønsberg, Norway). The study was *designed to confirm the superiority of gastric bypass compared with sleeve gastrectomy on remission of type 2 diabetes and β-cell function* (primary outcomes), as well as to compare the effects of the 2 procedures on a number of secondary outcomes of clinical relevance in individuals with severe obesity and type 2 diabetes [28]. The full study protocol has been published [28].

Participants

Patients with severe obesity and type 2 diabetes who were scheduled for bariatric surgery at the study center were enrolled and eligible for study participation if aged 18 y or older, current body mass index (BMI) of $\geq$33.0 kg/m^2 with previously verified BMI of $\geq$35 kg/m^2, and type 2 diabetes [HbA_{1c} of $\geq$6.5% (48 mmol/mol) or use of antidiabetic medications with HbA_{1c} of $\geq$ 6.1% (43 mmol/mol)]. Key exclusion criteria were previous major abdominal surgery, cancer, severe medical conditions associated with increased risk of complications, drug or alcohol addiction, pregnancy, and severe gastroesophageal reflux disease.

Interventions

The surgical procedures were performed laparoscopically. For RYGB, a 25 mL gastric pouch was created with an alimentary limb of 120 cm and a biliopancreatic limb of 60 cm. For SG, a 35-Fr bougie was used along the lesser curvature for calibration of the gastric tube with no routinely staple line reinforcement [29].

The 2 intervention groups received identical pre and postoperative care, including a low-calorie diet (<1200 kcal/d) in the 2 wk preceding surgery. In the pre and postoperative treatment program, patients were informed about the importance of lifestyle behavior change, diet, and physical activity and were advised to eat according to the Norwegian dietary guidelines for a healthy diet, including plenty of fruits and vegetables as well as whole-grain products, with limited amounts of saturated fat and sugar [30]. The patients were also given more specific nutritional advice with the aim of preventing common postprandial discomfort after bariatric surgery, including: *1)* Eat small and frequent meals, *2)* Limit the intake of carbonated beverages, soft *doughy* bread, pasta, rice, tough meats, and the skin and stringy parts of some fruits and vegetables. 3) Reduce intake of food with high fat and/or sugar content. The patients were advised to consume $\geq$60 grams of high quality protein daily after surgery according to the clinical guidelines, to preserve lean tissue mass during weight loss [31]. In addition to the 5 study visits (week 5, 16, 34, and 52) the first year after surgery, all patients were included in the standard follow-up program at the obesity clinic including: a group session held by a dietitian with focus on dietary intake after 2 mo, a group session with focus on physical activity after 6 to 12 mo and consultations with the bariatric physician after 4 mo and 1 y. Patients were referred to an individual dietary consultation with a dietitian if needed. All patients were prescribed identical oral vitamin and mineral supplements with 2 multivitamin/mineral tablets, each containing vitamin A, 250 μg; vitamin D, 10 μg; vitamin E, 10 mg; vitamin K, 120 μg; vitamin C, 75 mg; thiamin, 1.4 mg; riboflavin, 1.6 mg; niacin, 19 mg; vitamin B6, 1.6 mg; folic acid, 400 μg; vitamin B12, 2 μg; biotin, 30 μg; pantothenic acid, 5 mg; magnesium, 100 mg; iron, 15 mg; zinc, 12 mg; copper, 900 μg; manganese, 2.3 mg; selenium, 60 μg; chromium, 35 μg; iodine, 150 μg; and molybdenum, 45 μg, in addition to 1000 mg of calcium carbonate; 800 IU of vitamin D3; and 100 mg of ferrous sulfate (in premenopausal females), and intramuscular injections of 1 mg vitamin B12 every third month after postsurgical discharge. Compliance with vitamin and mineral supplements were registered at each study visit during the first year after surgery, and vitamin and mineral supplementation were adjusted as needed according to a standardized treatment algorithm after checking the blood levels of vitamins and minerals [28].

Outcomes

The prespecified secondary outcomes addressed in this study were the intake of macronutrients, vitamins, minerals, and food groups assessed at baseline and 1-y follow-up. The prespecified secondary patient-reported outcomes were food tolerance, hedonic hunger, binge eating problems, and gastrointestinal symptoms assessed at baseline, 5-week, and 1-y follow-up.

Dietary intake

The dietary intake was registered with a food frequency questionnaire (FFQ) developed by the Department of Nutrition at the University of Oslo in Norway. The nutrient intake estimated from the FFQ has been validated against weighed food records, and energy intake has been validated against doubly labeled water and Acti-Reg [32–34]. The dietary intake data at baseline was collected before the patient started their 2-week low-energy diet preceding surgery. The FFQ was completed during a personal dietary interview performed by the same registered dietitian (LKJ) at baseline and at 1-y follow-up where both the patients and the assessor were blinded to the allocated treatment. The FFQ included 256 different food items and dishes which were categorized under 16 main food groups: *1)* bread, *2)* cereals and cereal products (including rice and pasta), *3)* cakes, *4)* potatoes, *5)* vegetables, *6)* fruits and berries, *7)* meat (including red meat and white meat), *8)* fish, *9)* egg, *10)* milk (including yogurt), *11)* cheese, *12)* butter, margarine and oil, *13)* sugar and sweets, *14)* beverages, *15)* infant food, and *16)* miscellaneous. The participants were asked about their habitual intake of each food item per day, week, or month, and they could choose from different predefined serving sizes. In the present data analysis we picked out the food items that were either *1)* main contributors to macronutrients, *2)* recommended healthy food items, or *3)* food items associated with poor food tolerance. The following food items were included: bread; pasta and rice; potatoes including dishes with potatoes; vegetables; fruits and berries; red meat including red meat products, white meat including white meat products, fish including fish products; egg; yogurt and fermented milk products (dairy products which have been fermented with lactic acid bacteria); milk and cheese; butter, margarine and oil; and sugar and sweets. The intake of recommended vitamin- and mineral supplements in the study was also registered with the FFQ. Average daily intakes of food items, energy, macronutrients [protein, fat, saturated fat, monounsaturated fat, polyunsaturated fat (PUFA), carbohydrates, sugar and fiber, vitamins (A, B6, thiamin, riboflavin, niacin, folate, B12, C, D, and E), and minerals (calcium, iron, potassium, magnesium, phosphorus, zinc, selenium, and copper)] were computed by the Department of Nutrition at the University of Oslo, Norway, using an in-house food database and nutrient calculation software, KBS (Kostberegningssystem). The food database is based on the Norwegian Food Composition Table and is continuously supplemented with data on new food items. The contents of the vitamin and mineral supplements were added to the food database; therefore, the total intake of vitamins and minerals (from both the diet and supplements) could also be calculated.

Food tolerance

To evaluate specific food tolerance we used a part of the food tolerance questionnaire developed by Suter et al. [11] known as *Quality of alimentation*. Originally, this questionnaire was developed to assess food tolerance during follow-up visits after bariatric surgery, in a standardized manner. The questionnaire has also been used to assess and compare food tolerance after different bariatric surgical methods [11]. The questionnaire is divided into 4 parts, including an overall satisfaction regarding the quality of alimentation, timing of eating over the day, specific food tolerance of 8 different types of food (red meat, white meat, salad, vegetables, bread, rice, pasta, and fish), and frequency of vomiting. For the purpose of this study, we used only the part which asks the patient to evaluate the tolerance of each of the 8 specific types of food, scoring from 0 to 2; 0 (can't eat), 1 (can eat with some difficulties), and 2 (can eat without any difficulties) [11]. The sum of scores, known as the sum of specific food tolerance score, ranging from 0–16, was also calculated, with higher scores indicating better tolerance.

Hedonic hunger

The drive to eat food for pleasure in the absence of physiological hunger (hedonic hunger) was assessed with the *Power of Food Scale* (PFS) [7]. The PFS was designed to measure appetite for, rather than consumption of, palatable foods. The PFS questionnaire consists of 15 items reflecting an individual's responsiveness to the food environment. Each item is rated on a 5-level scale ranging from 1 (I do not agree at all) to 5 (I strongly agree). The 15 items are grouped under 3 domains: food available (food readily available but not present), food present (food present but not tasted) and food tasted (food when first tasted but not consumed). Thus, the scores of each subdomain indicate hedonic hunger motivation at different levels of food availability [6]. The PFS total score and subscale scores are derived from summing the item scores and dividing by the number of items. Higher scores indicate greater drive to eat for pleasure.

Binge eating problems

The presence of binge eating problems was assessed with the *Binge Eating Scale* (BES) [35]. The BES is a 16-item, self-reported questionnaire assessing binge eating severity among persons with obesity. It is designed to capture the behavioral (large amount of food consumed), as well as the cognitive and emotional (feeling out of control while eating, preoccupation with food and eating) features of objective binge eating in adults with overweight and obesity [35]. For each item, respondents are asked to select 1 of 3 or 4 response options, coded 0 to 2 or 0 to 3, respectively. The individuals' scores are summed and range from 0 to 46, with higher scores indicating more severe binge eating problems. Marcus et al. [36] created clinical cut-off scores for the BES representing none-to-minimal ($\leq$17 total score), moderate (18 to 26 total score), and severe ($\geq$27 total score) binge eating problems.

Gastrointestinal symptoms

The degree of gastrointestinal symptoms was assessed with the *Gastrointestinal Symptom Rating Scale* (GSRS) [37]. The questionnaire includes 15 questions about gastrointestinal symptoms with scores ranging from 1 (no discomfort at all) to 7 (very severe discomfort). The questions are grouped into the following subscales: GSRS-pain, -reflux, -indigestion, -constipation and -diarrhea, and the mean score for the questions in each subscale were calculated. Findings from the 1-y effects of SG and RYGB on gastroesophageal reflux disease symptoms, including GSRS-reflux score in the Oseberg study have been previously published [38].

Sample size

The Oseberg study was powered to detect differences in the primary outcome, remission of type 2 diabetes [28, 29]. With a two-sided 5% significance level and statistical power of 80% and alpha 0.05, a sample size of 55 in each group was required. To allow for drop outs, the sample size was set to 125 patients [29].

Randomization

Patients were randomly assigned (1:1) to undergo SG or RYGB with the use of a computerized random number generator with a block size of 10. Sequentially numbered, sealed opaque envelopes were used to conceal allocation, and the allocation was revealed in the operating theater by the bariatric surgeon on the day of the surgery.

Blinding

All study personnel, patients, and the assessors of the primary and secondary outcomes were blinded to the allocations.

Ethics

The study protocol was approved by the Regional Committees for Medical and Health Research Ethics in Norway (2012/1427/REK sør-øst B). This study is registered with clinicaltrials.gov, NCT01778738.

Statistical analyses

The prespecified secondary outcome variables were measured at baseline, 5-wk (except for dietary intake), and 1-y follow-up, and were analyzed according to intention to treat principles using generalized linear mixed models for repeated measures with identity link (an equation where the dependent is equal to a linear combination of the independent variables). The results are reported as estimated means with 95% confidence intervals (CIs). The repeated measures models were not adjusted for possible confounders as there were no statistically significant differences between the groups at baseline. Pairs of categorical variables were compared with Fisher's exact test. All data analyses were performed using IBM SPSS version 25.0 and STATA version 15.0. *P*-values < 0.05 were considered statistically significant and all tests were two-sided. Because all analyzed outcomes were considered exploratory, no adjustments for multiple testing were performed [39].

Results

Between October 2012 and September 2017, 319 consecutive patients with type 2 diabetes were assessed for eligibility for the Oseberg study. After exclusion of 210 patients, 109 patients were randomly assigned to undergo SG ($n = 55$) or RYGB ($n = 54$) (Figure 1) [28]. The patients had a mean (SD) age of 47.7 (9.6) y, BMI of 42.3 (5.3) kg/m^2, and 66% were females. Moreover, the baseline characteristics did not differ between the groups (Supplementary Table 1) [28]. The number of patients who underwent the prespecified secondary outcome measurements at baseline, 5-week-, and 1-y follow-up are shown in Figure 1.

Intake of energy and macronutrients

At baseline, the total daily intakes of energy, protein, fat, carbohydrates, sugar, and fiber were similar between the 2 groups (Table 1). From baseline to 1-y, the overall average daily intakes of energy and macronutrients were reduced substantially: energy (−43%), protein (−37%), fat (−45%), carbohydrates (−45%), and fiber (−33%). The reduction in *protein* intake was significantly higher in the SG group than in the RYGB group, mean (95% CI) between-group difference −13 (−24.9, −1.2) g, $P = 0.031$ (Table 1). At 1-y, the percentage of patients with an intake of <60 g/d protein was 39% (SG) and 33% (RYGB), $P = 0.527$. Further, the intake of *fiber* decreased significantly more in the SG group compared with the RYGB group (−40% vs. −26%); between-group difference was −4.9 (−8.2, −1.6) g, $P = 0.004$ (Table 1). The percentage of patients with a fiber intake of ≥25 g/d was similar in the 2 groups at baseline (75% vs. 79%), but at 1-y follow-up, it was significantly lower in the SG group than in the RYGB group

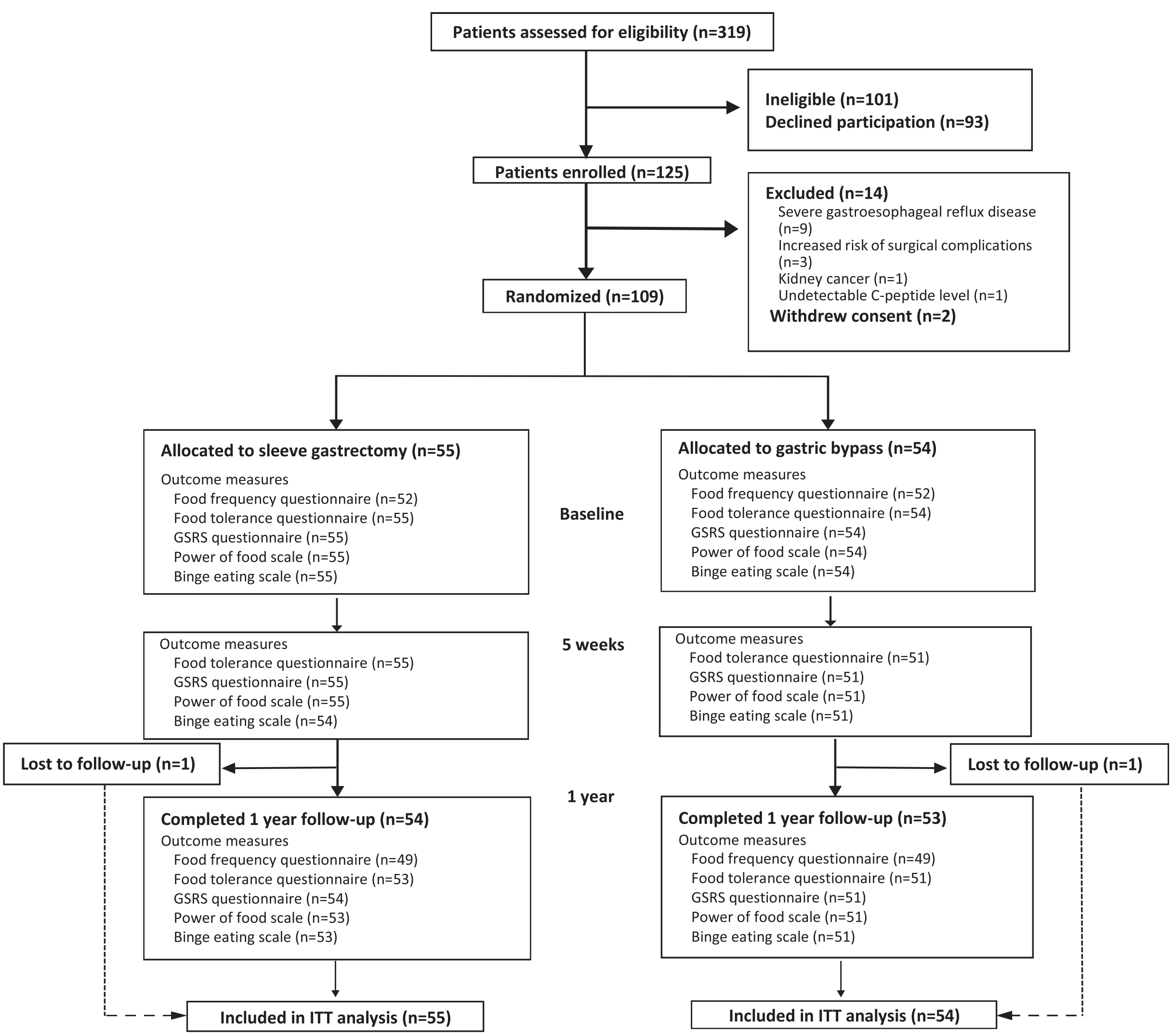

FIGURE 1. Flow chart of participants throughout the study.

TABLE 1
Baseline and 1-year daily intake of macronutrients, changes in intake and between-group differences

	SG (*n* = 55)	RYGB (*n* = 54)	Between-group difference	*P* value
Energy, kcal				
Baseline	2801 (2552, 3049)	2601 (2354, 2850)	198 (−152, 550)	
1 y	1462 (1207, 1716)	1609 (1354, 1863)	−147 (−507, 213)	0.423
Change from baseline	−1339 (−1617, −1061)	−993 (−1272, −714)	−346 (−740, 48)	0.085
Protein, g				
Baseline	119.2 (110.2, 128.3)	111.1 (102.0, 128.4)	8.2 (−4.7, 21.0)	
1 y	70.4 (61.2, 79.7)	75.3 (66.1, 84.5)	−4.8 (−17.9, 8.2)	0.468
Change from baseline	−48.8 (−57.2, −40.5)	−35.8 (−44.2, −27.4)	−13.0 (−24.9, −1.2)	0.031
Total fat, g				
Baseline	117.8 (106.1, 129.4)	107.7 (96.0, 119.3)	10.1 (−6.4, 26.6)	
1 y	59.5 (48.8, 70.1)	64.4 (52.5, 76.3)	−4.9 (−21.8, 12.0)	0.571
Change from baseline	−58.2 (−71.1, −45.4)	−43.3 (−56.2, −30.3)	−15.0 (−33.2, 3.3)	0.108
Saturated fat, g				
Baseline	44.6 (39.9, 49.3)	41.1 (36.4, 45.8)	3.6 (−3.1, 10.2)	
1 y	23.3 (18.5, 28.2)	23.8 (19.0, 28.7)	−0.5 (−7.3, 6.3)	0.884
Change from baseline	−21.3 (−26.8, −15.8)	−17.2 (−22.8, −11.7)	−4.1 (−11.9, 3.8)	0.309
Monounsaturated fat, g				
Baseline	42.2 (38.0, 46.5)	38.5 (34.2, 42.8)	3.7 (−2.3, 9.8)	
1 y	21.2 (16.8, 25.6)	23.0 (18.6, 27.4)	−1.8 (−8.0, 4.4)	0.571
Change from baseline	−21.0 (−25.6, −16.5)	−15.5 (−20.1, −11.0)	−5.5 (−11.9, 0.9)	0.091
Polyunsaturated fat, g				
Baseline	20.4 (18.0, 22.7)	18.6 (16.3, 21.0)	1.8 (−1.6, 5.1)	
1 y	9.2 (6.8, 11.6)	11.6 (9.2, 14.0)	−2.4 (−5.8, 1.0)	0.168
Change from baseline	−11.2 (−14.0, −8.4)	−7.0 (−9.8, −4.3)	−4.2 (−8.1, −0.2)	0.039
Carbohydrates[1], g				
Baseline	293 (263, 323)	275 (246, 305)	17 (−34, 35)	
1 y	148 (117, 178)	166 (136, 197)	−18.7 (−62, 25)	0.397
Change from baseline	−146 (−182, −109)	−109 (−146, −73)	−36 (−88, −15)	0.166
Sugar, g				
Baseline	49.5 (35.7, 63.4)	52.2 (38.4, 66.1)	−2.7 (−22.3, 16.9)	
1 y	21.6 (7.3, 35.8)	22.9 (8.7, 37.2)	−1.4 (−21.5, 18.8)	0.894
Change from baseline	−28.0 (−45.4, −10.5)	−29.3 (−46.7, −11.8)	1.3 (−23.4, 26.0)	0.918
Fiber, g				
Baseline	33.0 (30.8, 35.2)	32.0 (29.8, 34.2)	1.0 (−2.1, 4.2)	
1 y	20.0 (17.7, 22.2)	23.8 (21.6, 26.1)	−3.8 (−7.0, −0.7)	0.018
Change from baseline	−13.1 (−15.4, −10.7)	−8.2 (−10.5, −5.8)	−4.9 (−8.2, −1.6)	0.004
Energy from protein, %				
Baseline	17.8 (16.9, 18.6)	17.5 (16.6, 18.3)	0.3 (−0.9, 1.5)	
1 y	19.5 (18.6, 20.3)	19.1 (18.3, 19.9)	0.4 (−0.8, 1.6)	0.513
Change from baseline	1.7 (0.7, 2.7)	1.6 (0.6, 2.6)	0.1 (−1.3, 1.5)	0.884
Energy from fat, %				
Baseline	37.1 (35.6, 38.7)	37.1 (35.5, 38.6)	0.09 (−2.1, 2.3)	
1 y	36.4 (34.8, 38.0)	35.1 (33.6, 36.7)	1.2 (−1.0, 3.5)	0.279
Change from baseline	−0.8 (−2.5, 0.9)	−1.9 (−3.7, 0.2)	1.1 (−1.3, 3.6)	0.363
Energy from saturated fat, %				
Baseline	13.9 (13.1, 14.7)	14.0 (13.2, 14.8)	−0.09 (−1.2, 1.0)	
1 y	14.1 (13.3, 15.0)	13.1 (12.3, 14.0)	0.9 (−1.9, 0.2)	0.100
Change from baseline	0.2 (−0.8, 1.3)	−0.9 (−1.9, 0.2)	1.1 (−0.4, 2.6)	0.143
Energy from monounsaturated fat, %				
Baseline	13.3 (12.6, 14.1)	13.3 (12.6, 14.0)	0.09 (−0.9, 1.1)	
1 y	12.9 (12.2, 13.6)	12.5 (11.8, 13.2)	0.4 (−0.6, 1.4)	0.386
Change from baseline	−0.4 (−1.2, 0.3)	−0.8 (−1.5, −0.1)	0.3 (−0.7, 1.3)	0.520
Energy from polyunsaturated fat, %				
Baseline	6.5 (6.0, 7.0)	6.5 (6.0, 7.0)	−0.01 (−0.7, 0.7)	
1 y	5.8 (5.3, 6.3)	6.2 (5.8, 6.7)	−0.5 (−1.2, 0.2)	0.184
Change from baseline	−0.7 (−1.3, −0.2)	−0.3 (−0.8, 0.3)	−0.5 (−1.3, 0.3)	0.250
Energy from carbohydrates[1], %				
Baseline	41.6 (40.0, 43.3)	42.0 (40.3, 43.6)	−0.3 (−2.7, 2.0)	
1 y	40.4 (42.1, 38.7)	41.7 (43.3, 40.0)	−1.3 (−3.7, 1.1)	0.290
Change from baseline	−1.2 (3.0, −0.5)	−0.28 (−2.0, 1.5)	−1.0 (−3.4, 1.5)	0.452
Energy from sugar, %				
Baseline	6.1 (4.6, 7.6)	7.1 (5.6, 8.6)	−1.0 (−3.1, 1.1)	
1 y	5.8 (4.3, 7.4)	5.3 (3.8, 6.9)	0.5 (−1.7, 2.7)	0.648
Change from baseline	−0.3 (−1.9, 1.4)	−1.8 (−3.4, −0.1)	1.5 (−0.8, 3.8)	0.204

The data are analyzed according to intention to treat principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment × time interaction, and a random intercept. The results are presented as estimated means (95% CI).

RYBG, Roux-en-Y gastric bypass; SG, sleeve gastrectomy

[1] Carbohydrates include starch, glycogen and sugars

TABLE 2
Baseline and 1-year daily total intake of vitamins and minerals, changes in intake and between-group differences

	SG (n = 55)	RYGB (n = 54)	Between-group difference	P value
Vitamin A, µg				
Baseline	1428 (1233, 16239)	1250 (1055, 1445)	178 (−98, 454)	
1 y	1747 (1546, 1948)	1932 (1732, 2133)	−185 (−469, 98)	0.201
Change from baseline	319 (68, 569)	682 (431, 933)	−364 (−718, −9)	0.045
Vitamin D, µg				
Baseline	16.3 (12.1, 20.4)	13.4 (9.2, 17.5)	2.9 (−3.0, 8.8)	
1 y	32.8 (28.6, 37.1)	37 .4 (33.1, 41.7)	−4.6 (−10.6, 1.5)	0.138
Change from baseline	16.6 (10.7, 22.4)	24.0 (18.2, 29.9)	−7.5 (−15.8, 0.8)	0.078
Vitamin E, mg				
Baseline	21.1 (17.7, 24.6)	17.7 (14.3, 21.2)	3.4 (−1.5, 8.3)	
1 y	28.2 (26.6, 31.7)	33.3 (29.7, 36.8)	−5.1 (−10.2, −0.1)	0.047
Change from baseline	7.0 (2.4, 11.7)	15.5 (10.9, 20.2)	−8.5 (−15.1, −1.9)	0.012
Thiamin, mg				
Baseline	2.6 (2.3, 2.9)	2.4 (2.1, 2.9)	0.2 (−0.2, 0.7)	
1 y	3.5 (3.2, 3.8)	4.3 (4.0, 4.6)	−0.8 (−1.2, −0.3)	<0.0001
Change from baseline	0.9 (0.5, 1.3)	1.9 (1.5, 2.4)	−1.0 (−1.6, −0.4)	<0.0001
Riboflavin, mg				
Baseline	2.8 (2.4, 3.1)	2.3 (2.0, 2.7)	0.4 (−0.1, 1.0)	
1 y	4.2 (3.8, 4.5)	4.8 (4.5, 5.2)	−0.7 (−1.2, −0.1)	0.013
Change from baseline	1.4 (0.9, 1.9)	2.5 (2.0, 3.0)	−1.1 (−1.8, −0.4)	0.001
Niacin, mg				
Baseline	32.8 (29.8, 35.9)	30.2 (27.2, 33.3)	2.6 (−1.7, 6.9)	
1 y	38.1 (34.9, 41.2)	45.3 (42.2, 48.5)	−9.3 (−11.7, −2.9)	<0.0001
Change from baseline	5.2 (1.3, 9.1)	15.1 (11.2, 19.0)	−9.9 (−15.4, −4.3)	<0.0001
Vitamin B6, mg				
Baseline	2.6 (2.3, 2.9)	2.3 (1.9, 2.6)	0.3 (−0.2, 0.8)	
1 y	4.4 (4.0, 4.7)	5.3 (4.9, 5.6)	−0.9 (−1.4, −0.4)	<0.0001
Change from baseline	1.8 (1.3, 2.2)	3.0 (2.6, 3.4)	−1.2 (−1.9, −0.6)	<0.0001
Folate, µg				
Baseline	383 (346, 420)	350 (313, 387)	33 (−19, 86)	
1 y	475 (437, 513)	563 (524, 601)	−88 (−142, −34)	0.001
Change from baseline	92 (43, 140)	213 (164, 261)	−121 (−190, 52)	0.001
Vitamin B12, µg				
Baseline	10.3 (9.1, 11.5)	8.6 (7.4, 9.8)	1.8 (0.04, 3.5)	
1 y	9.8 (8.5, 11.0)	11.0 (9.7, 12.2)	−1.2 (−2.9, 0.6)	0.194
Change from baseline	−0.5 (−1.8, 0.8)	2.4 (1.1, 3.7)	−2.9 (−4.7, −1.1)	0.002
Vitamin C, mg				
Baseline	123 (106, 140)	132 (115, 148)	−8.4 (−32.0, 15.3)	
1 y	158 (141, 175)	211 (194, 228)	−53 (−77, −29)	<0.0001
Change from baseline	35 (14, 56)	79 (59, 100)	−44 (−73, −15)	0.003
Iron, mg				
Baseline	16.2 (7.0, 25.4)	14.7 (5.5, 23.8)	1.5 (−11.4, 14.5)	
1 y	35.9 (26.4, 45.3)	53.9 (44.4, 63.3)	−18.0 (−31.4, −4.7)	0.008
Change from baseline	19.7 (6.8, 32.5)	39.2 (26.4, 52.1)	−19.6 (−37.8, 1.4)	0.035
Calcium, mg				
Baseline	1302 (1103, 1502)	1198 (998, 1397)	105 (−177, 387)	
1 y	1899 (1694, 2104)	2076 (1871, 2281)	−177 (−467, 113.2)	0.232
Change from baseline	597 (319, 874)	878 (601, 1156)	−282 (−64, 111)	0.160
Potassium, mg				
Baseline	4888 (4487, 5290)	4587 (4186, 4988)	302 (−266, 869)	
1 y	3124 (2712, 3535)	3462 (3052, 3873)	−339 (−920, 242)	0.253
Change from baseline	−1765 (−2186, −1344)	−1124 (−1547, −702)	−640 (−1237, −44)	0.035
Magnesium, mg				
Baseline	511 (461, 560)	469 (420, 518)	511 (461, 560)	
1 y	382 (331, 433)	417 (367, 468)	−35 (−106, 36)	0.334
Change from baseline	−128 (−178, −79)	−52 (−102, −2)	−77 (−147, −6)	0.033
Phosphorus, mg				
Baseline	2287 (2105, 2469)	2094 (1913, 2276)	192 (−64, 450)	
1 y	1413 (1227, 1599)	1512 (1326, 1697)	−99 (−361, 164)	0.461
Change from baseline	−874 (−1055, −693)	−583 (−765, −401)	−291 (−548, −35)	0.026
Zinc, mg				
Baseline	17.7 (15.2, 19.2)	15.7 (13.7, 17.7)	1.5 (−1.4, 4.4)	
1 y	26.1 (24.1, 28.2)	30.2 (28.1, 32.3)	−4.1 (−7.0, −1.1)	0.007
Change from baseline	8.9 (6.1, 11.7)	14.5 (11.6, 17.3)	−5.6 (−9.5, −1.6)	0.006
Selenium, µg				
Baseline	72.0 (63.5, 80.6)	63.8 (55.2, 72.3)	8.2 (−3.8, 20.3)	

(*continued on next page*)

TABLE 2 (*continued*)

	SG (n = 55)	RYGB (n = 54)	Between-group difference	P value
1 y	100.7 (91.9, 109.5)	116.3 (107.5, 125.0)	−15.6 (−28.0, −3.2)	0.014
Change from baseline	28.6 (17.8, 39.4)	52.4 (41.6, 63.3)	−23.8 (−39.1, −8.5)	0.002
Copper, mg				
Baseline	1.8 (1.6, 2.0)	1.6 (1.4, 1.8)	0.2 (−0.1, 0.4)	
1 y	2.6 (2.4, 2.9)	3.0 (2.8, 3.2)	−0.4 (−0.7, 0.08)	0.013
Change from baseline	0.9 (0.6, 1.1)	1.4 (1.1, 1.7)	−0.5 (−0.9, −0.1)	0.008

The data are analyzed according to intention to treat principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment × time interaction, and a random intercept. The results are presented as estimated means (95% CI).
RYBG, Roux-en-Y gastric bypass; SG, sleeve gastrectomy

(14% vs. 35%; P = 0.019). The absolute intake of PUFAs declined more in the SG group compared with the RYGB group. By contrast, the percentage of total energy intake after 1 y from total fats (36%), saturated fats (14%), monounsaturated fats (13%), PUFAs (6%), carbohydrates (41%) and sugars (6%) were unchanged from baseline, whereas the relative energy contribution from proteins (19%) increased slightly after SG and RYGB (1.7% vs 1.6%) (Table 1).

Intake of vitamins and minerals

The total daily intake (diet and supplements) of vitamin A, vitamin E, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin C, iron, zinc, selenium, and copper increased in both groups, and significantly more after RYGB than after SG (Table 2). By contrast, the total vitamin D and calcium intakes increased similarly in both groups (Table 2). Further, the total intakes of magnesium, potassium, and phosphorus were significantly reduced, and more so after SG than after RYGB (Table 2). When analyzing the intake of vitamins and minerals from the diet only (excluding supplements), the intake of all vitamins and minerals decreased, and the intakes of thiamin, niacin, vitamin B6, vitamin B12, iron, potassium, phosphorus, and selenium were significantly more reduced in the SG groupthan in the RYGB group (Supplementary Table 2).

Intake of food groups

From baseline to 1-y follow-up, the intake of fruits and berries declined significantly in the SG group (−31%), but did not change after RYGB, mean (95% CI) between-group difference; −65 (−109, −20) g, P = 0.004 (Table 3). The intake of yogurt and fermented milk products increased significantly in the RYGB group only (139%), between-group difference; −59 (−104, −13) g, P = 0.012 (Table 3). With the exception of egg, for which the intake did not change significantly in either treatment group, the reported changes in intake of the remaining food groups did not differ significantly between the treatment groups (Table 3). The overall reduction in intake was −54% for bread, −61% for pasta and rice, −58% for potatoes, −39% for vegetables, −43% for meat, −26% for fish, −35% for milk and cheese, −62% for butter, oil and margarine, and −58% for sugar and sweets.

Food tolerance

The sum of specific food tolerance score at baseline was high in both groups, indicating few difficulties with specific foods in both treatment groups (Table 4). There was no difference in changes in the sum of specific food tolerance score between the groups. There was a significant between-group difference in change of tolerance for white meat and rice, with a significant decrease observed in the SG group (Table 4).

Hedonic hunger

The PFS total score and score for each subscale; food available, food present, and food tasted, decreased similarly in both study groups from baseline to 1 y, indicating a reduced appetite drive to consume for pleasure in the absence of physiological hunger after both SG and RYGB (Table 5).

Binge eating problems

The mean BES score decreased in both study groups, with no significant between-group difference in change (Table 5). The percentage of patients with a moderate BES score at baseline and 1 y decreased from 13% to 6% in the SG group and from 19% to 6% in the RYGB group. In the SG group only 1 patient had a score corresponding to severe binge eating at baseline and was categorized as having none-to-minimal binge eating after 1 y, and another patient with moderate binge eating score at baseline had a score corresponding to severe binge eating after 1 y. No patients in the RYGB group were identified with severe binge eating at either baseline or 1-y postoperatively.

Gastrointestinal symptoms

The GSRS scores for pain, indigestion, constipation, and diarrhea did not change significantly from baseline to 1-y in either treatment group (Table 6). By contrast, the mean GSRS-reflux score declined significantly after RYGB but was unchanged after SG, between-group difference was 0.43 (0.07, 0.80), P = 0.020 (Table 6).

Discussion

Little is known about the comparable effects of SG and RYGB on dietary changes, food tolerance, eating behavior, and gastrointestinal problems [16, 17]. In view of this, we compared the 1-y changes in the corresponding prespecified secondary outcomes in patients with obesity and type 2 diabetes who were assigned to either SG or RYGB groups in the randomized Oseberg study. The main novel findings were that the intakes of protein, fiber, magnesium, potassium, fruits, and berries declined more after SG than after RYGB. In addition, food tolerance, hedonic hunger, and binge eating problems declined similarly after both surgeries, although most gastrointestinal symptoms remained stable at 1 y postoperatively.

Macronutrients

Proteins

Although the mean daily protein intake was slightly more reduced after SG, the percentage of total energy intake from proteins increased by nearly 2% in both groups. The latter finding confirms the findings of a recent meta-analysis [16] showing a small 1-y postoperative increase,

TABLE 3
Baseline and 1-year daily intake of different food groups, changes in intake and between-group differences

	SG (n = 55)	RYGB (n = 54)	Between-group difference	P value
Bread, g				
Baseline	213 (192, 234)	206 (185, 226)	7 (−22, 37)	
1 y	88 (67, 109)	105 (83, 126)	−16 (−46, 14)	0.287
Change from baseline	−124 (−147, −102)	−101 (−124, −79)	−24 (−55, 8)	0.149
Pasta and rice, g				
Baseline	69 (54, 83)	59 (44, 74)	9 (−10, 31)	
1 y	21 (6, 36)	28 (12, 43)	−6 (−27, 15)	0.577
Change from baseline	−47 (−66, −29)	−31 (−50, −13)	−16 (−42, 10)	0.231
Potatoes and dishes with potatoes, g				
Baseline	88 (75, 101)	89 (76, 102)	−1 (−18, 19)	
1 y	32 (18, 45)	43 (30, 56)	−11 (−30, 8)	0.246
Change from baseline	−56 (−73, −40)	−46 (−63, −29)	−10 (−34, 13)	0.393
Vegetables, g				
Baseline	321 (285, 358)	320 (284, 358)	0.5 (−51, 52)	
1 y	185 (147, 222)	213 (175, 250)	−28 (−81, 25)	0.302
Change from baseline	−137 (−178, −95)	−108 (−149, −67)	−29 (−87, 30)	0.338
Fresh fruits and berries, g				
Baseline	150 (119, 180)	159 (129, 189)	−9 (−52, 34)	
1 y	103 (72, 134)	177 (146, 208)	−74 (−118, −30)	0.001
Change from baseline	−47 (−78, −15)	18 (−13, 49)	−65 (−109, −20)	0.004
Red meat and red meat products, g				
Baseline	132 (119, 145)	124 (111, 137)	8 (−10, 27)	
1 y	64 (51, 78)	74 (61, 88)	−10 (−29, 9)	0.293
Change from baseline	−68 (−82, −54)	−49 (−64, −35)	−19 (−37, 2)	0.071
White meat and white meat products, g				
Baseline	37 (29, 43)	39 (32, 45)	−2.7 (−13, 7.1)	
1 y	25 (18, 32)	25 (18, 32)	0.01 (−10, 10)	0.998
Change from baseline	−11 (−18, −4.1)	−14 (−20, −6.8)	2.7 (−6.8, 12)	0.576
Fish and fish products, g				
Baseline	68 (55, 81)	61 (49, 74)	6 (−12, 24)	
1 y	42 (28, 55)	54 (40, 67)	−12 (−31, 7)	0.207
Change from baseline	−26 (−40, −12)	−8 (−22, 6)	−18 (−38, 1)	0.066
Egg, g				
Baseline	31 (21, 41)	25 (15, 35)	6.3 (−7.7, 20)	
1 y	27 (17, 37)	21 (11, 31)	5.8 (−8.6, 20)	0.432
Change from baseline	−3.9 (−18, 10)	−3.4 (−17, 11)	−0.6 (−20, 19)	0.955
Yogurt, fermented milk products, g				
Baseline	63 (39, 87)	36 (12, 60)	27 (−7, 61)	
1 y	54 (30, 79)	86 (61, 111)	−32 (−66, 4)	0.078
Change from baseline	−8 (−40, 24)	50 (17, 82)	−59 (−104, −13)	0.012
Milk and cheese, g				
Baseline	491 (396, 586)	381 (285, 476)	110 (−24, 245)	
1 y	295 (197, 393)	276 (178, 374)	19 (−120, −157)	0.790
Change from baseline	−196 (−316, −76)	−105 (−225, 15)	−91 (−261, 78)	0.290
Butter, margarine, oil, g				
Baseline	44 (36, 52)	42 (34, 50)	2 (−9, 13)	
1 y	15 (7, 24)	20 (12, 28)	−5 (−16, 7)	0.412
Change from baseline	−29 (−39, −18)	−22 (−32, −11)	−7 (−21, 7)	0.346
Sugar and sweets, g				
Baseline	51 (38, 63)	60 (47, 72)	−9 (−27, 9)	
1 y	19 (6, 32)	25 (12, 38)	−6 (−25, 12)	0.498
Change from baseline	−32 (−48, −15)	−34 (−51, −18)	3 (−21, 26)	0.828

The data are analyzed according to intention to treat (ITT) principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment x time interaction, and a random intercept. The results are presented as estimated means (95% CI).
SG, sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass

standardized mean difference (SMD) = 0.24, in percentage energy from proteins, but differs slightly from the 1-y findings of an observational study demonstrating a higher 1-y increase in percentage energy obtained from proteins after SG (≈3%) than after RYGB (≈1%) [18]. We were also concerned about the high prevalence of insufficient daily protein intake (< 60 g/d) 1 y after SG (39%) and RYGB (33%), which, however, is in line with long-term results from the previously mentioned study (50% vs. 41%) [18].

Fiber

A structured literature review reported inadequate fiber intake after bariatric surgery, ranging from 10 g–22 g/d after RYGB [40]. We partly confirm these results, but, to our knowledge, our RCT is the first to indicate that daily fiber intake may be more reduced after SG than RYGB. We were particularly concerned that only 14% (SG) and 35% (RYGB) of the participants obtained the recommended daily fiber intake of ≥ 25 g/day [41] 1 y after surgery.

TABLE 4
Baseline, 5-weeks and 1-year specific food tolerance score,[1] changes in scores from baseline to 1 year and between-group differences

	SG group ($n = 55$)	RYGB group ($n = 54$)	Between-group difference	P value
Food tolerance score, total sum of specific food scores[1]				
Baseline	15.0 (14.3, 15.8)	14.7 (13.9, 15.5)	0.31 (−0.78, 1.41	
5 wk	12.2 (11.4, 12.9)	13.1 (12.3, 13.9)	−0.9 (−2.0, 0.2)	0.099
1 y	13.0 (12.2, 13.8)	13.9 (13.1 14.7)	−0.95 (−2.07, 0.16)	0.094
Change baseline to 1 y	−2.1 (−3.0, −1.1)	−0.78 (−1.77, 0.20)	−1.27 (−2.65, 0.11)	0.072
Food tolerance score, red meat				
Baseline	1.8 (1.7, 2.0)	1.9 (1.7, 2.0)	−0.02 (−0.2 to 0.2)	
5 wk	1.4 (1.2, 1.5)	1.7 (1.5, 1.8)	−0.3 (−0.5, −0.08)	0.005
1 y	1.6 (1.4, 1.7)	1.8 (1.6, 1.9)	−0.2 (−0.4, −0.007)	0.042
Change baseline to 1 y	−0.3 (−0.4, −0.1)	−0.07 (−0.2, 0.09)	−0.2 (−0.4, 0.04)	0.111
Food tolerance score, white meat				
Baseline	2.0 (1.9, 2.1)	1.9 (1.8, 2.0)	0.06 (−0.08, 0.2)	
5 wk	1.8 (1.7, 1.9)	1.9 (1.8, 2.0)	−0.1 (−0.3, 0.002)	0.054
1 y	1.8 (1.7, 1.9)	1.9 (1.8, 2.0)	−0.2 (−0.3, −0.03)	0.021
Change baseline to 1 y	−0.2 (−0.3, −0.07)	0.02 (−0.1, 0.2)	−0.2 (−0.4, −0.03)	0.021
Food tolerance score, salad				
Baseline	1.9 (1.8, 2.0)	1.9 (1.8, 2.0)	0.001 (−0.2, 0.2)	
5 wk	1.5 (1.3, 1.6)	1.5 (1.4, 1.7)	−0.09 (−0.3, 0.1)	0.375
1 y	1.7 (1.6, 1.9)	1.8 (1.7, 2.0)	−0.1 (−0.3, 0.1)	0.333
Change baseline to 1 y	−0.2 (−0.4, 0.008)	−0.08 (−0.3, −0.1)	−0.1 (−0.4, 0.2)	0.465
Food tolerance score, vegetables				
Baseline	1.9 (1.8, 2.0)	1.9 (1.8, 2.0)	0.001 (−0.2, 0.2)	
5 wk	1.7 (1.6, 1.8)	1.7 (1.6, 1.9)	−0.04 (−0.2, 0.1)	0.683
1 y	1.8 (1.6, 1.9)	1.8 (1.7, 1.9)	−0.07 (−0.2, 0.1)	0.443
Change baseline to 1 y	−0.2 (−0.3, −0.01)	−0.1 (−0.3, 0.06)	−0.07 (−0.3, 0.2)	0.549
Food tolerance score, bread				
Baseline	1.8 (1.6, 2.0)	1.7 (1.6, 1.9)	0.06 (−0.2, 0.3)	
5 wk	1.3 (1.1, 1.4)	1.3 (1.1, 1.4)	0.003 (−0.2, 0.2)	0.983
1 y	1.5 (1.3, 1.6)	1.4 (1.2, 1.6)	0.04 (−0.2, 0.3)	0.731
Change baseline to 1 y	−0.3 (−0.6, −0.1)	−0.3 (−0.6, −0.1)	−0.02 (−0.3, 0.3)	0.922
Food tolerance score, rice				
Baseline	1.9 (1.6, 2.0)	1.8 (1.6, 1.9)	0.1 (−0.09, 0.4)	
5 wk	1.4 (1.3, 1.6)	1.7 (1.5, 1.8)	−0.2 (−0.5, 0.002)	0.048
1 y	1.5 (1.3, 1.6)	1.7 (1.5, 1.9)	−0.2 (−0.4, 0.01)	0.064
Change baseline to 1 y	−0.4 (−0.6, −0.2)	−0.05 (−0.3, 0.2)	−0.3 (−0.6, −0.06)	0.018
Food tolerance score, pasta				
Baseline	1.8 (1.7, 2.0)	1.8 (1.6, 1.9)	0.06 (−0.2, 0.3)	
5 wk	1.4 (1.2, 1.6)	1.5 (1.4, 1.7)	−0.1 (−0.4, 0.1)	0.314
1 y	1.4 (1.3, 1.6)	1.6 (1.4, 1.7)	−0.1 (−0.4, 0.1)	0.340
Change baseline to 1 y	−0.4 (−0.6, −0.2)	−0.2 (−0.4, −0.02)	−0.2 (−0.5, 0.1)	0.246
Food tolerance score, fish				
Baseline	1.8 (1.7, 2.0)	1.8 (1.7, 2.0)	0.02 (−0.2, 0.2)	
5 wk	1.7 (1.6, 1.9)	1.8 (1.6, 1.9)	−0.04 (−0.2, 0.2)	0.711
1 y	1.8 (1.6, 1.9)	1.9 (1.7, 2.0)	−0.1 (−0.3, 0.07)	0.215
Change baseline to 1 y	−0.08 (−0.2, 0.1)	0.07 (−0.09, 0.2)	−0.1 (−0.4, 0.08)	0.204

The data are analyzed according to intention to treat (ITT) principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment x time interaction, and a random intercept. The results are presented as estimated means (95% CI).

FTS, food tolerance score; RYBG, Roux-en-Y gastric bypass; SG, sleeve gastrectomy

[1] Food tolerance scale is scored from 0 to 2; 0 (can't eat), 1 (can eat with some difficulties/restrictions) and 2 (can eat without any difficulties).

Fats

Our findings of unchanged energy percentage from total fats after both SG and RYGB, are in line with the systematic review of changes in macronutrient composition after RYGB by Redpath et al. [42], but in contrast to Guyot et al. [16] who showed a small 1-y *reduction* in energy percentage from fat after RYGB ($n = 21$ studies) and SG ($n = 2$ studies), SMD = 0.20. This apparent discrepancy may be explained by a relatively small number of patients in our study, as there was a non-significant trend toward reduced energy percentage from fat after RYGB, −1.9%, 95% CI (−3.7, 0.2).

Micronutrients

We confirm previous studies showing an inadequate intake of vitamins and minerals from the diet without supplements after bariatric surgery [18, 43, 44], but, to our knowledge, our study is the first to show a lower micronutrient intake after SG than RYGB. Even when the diet was supplemented with oral vitamin and mineral supplementation, the intakes of potassium, magnesium, and phosphorus were still more reduced after SG than after RYGB, which could be partly explained by the fact that the recommended supplements did not contain potassium and phosphorus.

TABLE 5
Baseline, 5-weeks and 1-year PFS[1]- and BES[2] scores, changes in scores from baseline to 1 year and between-group differences

	SG group (n = 55)	RYGB group (n = 54)	Between-group difference	P value
PFS				
PFS total score				
Baseline	2.6 (2.4, 2.8)	2.3 (2.1, 2.5)	0.3 (0.02, 0.6)	
5 wk	1.9 (1.7, 2.0)	1.8 (1.6, 1.9)	0.1 (−0.2, 0.4)	0.456
1 y	1.9 (1.7, 2.1)	1.8 (1.6, 2.0)	0.1 (−0.2, 0.4)	0.566
Change baseline to 1 y	−0.7 (−0.9, −0.5)	−0.5 (−0.7, −0.3)	0.2 (−0.5, 0.1)	0.131
PFS available, score				
Baseline	2.3 (2.1, 2.5)	2.0 (1.8, 2.2)	0.3 (−0.03, 0.6)	
5 wk	1.7 (1.5, 1.9)	1.6 (1.4, 1.8)	0.1 (−0.2, 0.4)	0.482
1 y	1.7 (1.5, 1.9)	1.6 (1.4, 1.8)	0.1 (−0.2, 0.4)	0.482
Change baseline to 1 y	−0.6 (−0.8, −0.4)	−0.4 (−0.6, −0.2)	−0.2 (−0.5, 0.1)	0.189
PFS present, score				
Baseline	2.8 (2.5, 3.0)	2.5 (2.2, 2.7)	0.3 (−0.01, 0.6)	
5 wk	1.8 (1.6, 2.0)	1.7 (1.5, 2.0)	0.09 (−0.2, 0.4)	0.579
1 y	2.0 (1.7, 2.2)	2.0 (1.7, 2.2)	0.01 (−0.3, 0.3)	0.935
Change baseline to 1 y	−0.8 (−1.1, −0.6)	−0.5 (−0.8, −0.3)	−0.3 (−0.7, 0.04)	0.085
PFS tasted, score				
Baseline	2.6 (2.4, 2.9)	2.3 (2.1, 2.6)	0.3 (−0.02, 0.6)	
5 wk	2.0 (1.8, 2.2)	1.9 (1.7, 2.1)	0.1 (−0.2, 0.4)	0.472
1 y	2.1 (1.8, 2.3)	1.9 (1.7, 2.1)	0.2 (−0.1, 0.5)	0.297
Change baseline to 1 y	−0.6 (−0.8, −0.4)	−0.5 (−0.7, −0.2)	−0.1 (−0.4, 0.2)	0.432
BES				
BES total score				
Baseline	11.1 (9.6, 12.6)	11.0 (9.5, 12.6)	0.06 (−2.1, 2.2)	
5 wk	6.8 (5.3, 8.4)	6.6 (5.1, 8.2)	0.2 (−2.0, 2.0)	0.882
1 y	6.9 (5.4, 8.5)	5.6 (4.3, 7.2)	1.3 (−0.9, 3.5)	0.246
Change baseline to 1 y	−4.2 (−5.8, −2.6)	−5.4 (−7.1, −3.8)	1.3 (−1.0, 3.6)	0.281

The data are analyzed according to intention to treat (ITT) principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment x time interaction, and a random intercept. The results are presented as estimated means (95% CI).
BES, binge eating scale; PFS, Power of food scale; RYBG, Roux-en-Y gastric bypass; SG, sleeve gastrectomy
[1] PFS scores within each subscale ranges from 1 to 5 (don't agree at all to strongly agree). Higher scores indicate a greater responsiveness to the food environment.
[2] Binge eating scale score; each response for 16 items is coded 0 to 3 and the sum ranges from 0-46, with higher scores indicating more severe binge eating problems.

Foods

Some observational studies have reported no major changes in food choices or differences in changes after SG and RYGB [14, 45]. By contrast, our RCT of patients with type 2 diabetes showed a substantially decreased intake of fresh fruits and berries after SG compared with no change after RYGB. This finding is difficult to explain, but one might speculate that higher degree of satiety [25] and more reflux symptoms after SG than after RYGB [38], may contribute to a reduced fruit intake. Satiety was, however, not assessed in the present study. In addition, the intake of yogurt and fermented milk products increased by >2 folds after RYGB but remained unchanged after SG. Further studies are needed to verify or reject these findings.

Food tolerance, hedonic hunger, binge eating, gastrointestinal symptoms

In accordance with Kvehaugen et al. [25] we found only minor reductions of food tolerance after bariatric surgery, with no differences between groups for the overall food tolerance. The current study also supports and extends the main findings of a cross-sectional study comparing RYGB with SG 2 to 4 y after surgery, showing similar gastrointestinal symptom scores (except for reflux) between groups [46]. The current RCT showed no substantial changes in abdominal pain, indigestion, constipation, and diarrhea after either surgery.

There was a clinically relevant and similar decrease in hedonic hunger in both study groups, which is in line with the 6-month results from a recent prospective cohort study [24]. However, we do not exactly know how the change in food preference affects dietary composition, although it has been suggested to increase protein intake and decrease intake of fat and sugar [16, 22]. A systematic review of binge eating disorder and bariatric surgery, mostly RYGB, showed reduced binge eating problems after surgery [8]. Further, a prospective cohort study of females before and 1 y after SG reported a substantial reduction of binge eating problems [47]. We confirm previous findings of reduced binge eating problems after bariatric surgery, and add evidence indicating similar beneficial effects of SG and RYGB on binge eating.

The main strength of the Oseberg study is the randomized design and blinding of patients, medical staff, and data collectors. All patients received the same dietary advice before surgery with no bias by assumed effects of the different surgical method on dietary behaviors. There are limitations to this study. First, sample size calculations were not made for the secondary outcomes presented, and the results should be considered exploratory and hypothesis generating. Second, all participants had type 2 diabetes, and most were Caucasians, limiting the generalizability to other patient populations. Third, is the relative short-term follow-up of 1 y. Fourth, there is a risk of inaccurate dietary data reporting due to recall bias and misreporting. In individuals with obesity and, in general, females are more prone to misreporting their dietary intakes [48]. However, we have used a validated FFQ, and the dietary interview was performed by the same dietitian who was blinded

TABLE 6
Baseline, 5-weeks and 1-year GSRS[1] scores, changes in scores from baseline to 1 year and between-group differences

	SG ($n = 55$)	RYGB ($n = 54$)	Between-group difference	P value
GSRS abdominal pain score				
Baseline	1.94 (1.72, 2.16)	2.04 (1.82, 2.27)	−0.10 (−0.42, 0.21)	
5 wk	2.27 (2.04, 2.49)	2.09 (1.86, 2.32)	0.18 (−0.50, 0.14)	0.283
1 y	2.09 (1.87, 2.32)	1.91 (1.68, 2.14)	0.18 (−0.14, 0.50)	0.265
Change baseline to 1 y	0.15 (−0.08, 0.39)	−0.13 (−0.38, 0.12)	0.29 (−0.05, 0.62)	0.097
GSRS reflux score				
Baseline	1.57 (1.35, 1.79)	1.63 (1.41, 1.85)	−0.06 (−0.37, 0.25)	
5 wk	1.52 (1.30, 1.74)	1.29 (1.06, 1.51)	0.23 (−0.55, 0.08)	0.150
1 y	1.59 (1.37, 1.81)	1.21 (0.99, 1.44)	0.38 (0.06, 0.69)	0.020
Change baseline to 1 y	0.01 (−0.24, 0.27)	−0.42 (−0.68, −0.16)	0.43 (0.07, 0.80)	0.020
GSRS indigestion score				
Baseline	2.54 (2.27, 2.81)	2.45 (2.18, 2.72)	0.09 (−0.29, 0.47)	
5 wk	2.46 (2.20, 2.73)	2.76 (2.49, 3.04)	−0.30 (−0.09, 0−68)	0.130
1 y	2.48 (2.21, 2.74)	2.55 (2.28, 2.83)	−0.08 (−0.46, 0.31)	0.693
Change baseline to 1 y	−0.07 (−0.19, 0.32)	0.10 (−0.37, 0.16)	−0.17 (−0.54, 0.20)	0.369
GSRS constipation score				
Baseline	1.90 (1.59, 2.21)	1.80 (1.49, 2.12)	0.10 (−0.34, 0.54)	
5 wk	2.51 (2.20, 2.82)	2.13 (1.81, 2.45)	0.38 (−0.82, 0.07)	0.097
1 y	2.18 (1.87, 2.49)	1.85 (1.53, 2.17)	0.33 (−0.12, 0.78)	0.149
Change baseline to 1 y	0.28 (−0.05, 0.61)	0.05 (−0.29, 0.38)	0.23 (−0.24, 0.70)	0.341
GSRS diarrhea score				
Baseline	1.96 (1.67, 2.24)	2.09 (1.80, 2.37)	−0.13 (−0.53, 0.27)	
5 wk	1.93 (1.64, 2.20)	1.91 (1.62, 2.20)	0.02 (−0.42, 0.39)	0.931
1 y	1.75 (1.47, 2.04)	1.91 (1.62, 2.20)	−0.16 (−0.57, 0.25)	0.446
Change baseline to 1 y	−0.20 (−0.51, 0.10)	−0.17 (−0.49, 0.14)	−0.03 (−0.47, 0.41)	0.894

The data are analyzed according to intention to treat (ITT) principles using generalized linear mixed models for repeated measures with identity link. The linear mixed models contained treatment group as a fixed effect, time as a discrete variable, a treatment x time interaction, and a random intercept. The results are presented as estimated means (95% CI).
GSRS, gastrointestinal symptom rating scale; RYBG, Roux-en-Y gastric bypass; SG, sleeve gastrectomy
[1] GSRS scores within each subscale ranges from 1 to 7 (no discomfort at all to very severe discomfort).

to the allocated treatment also at 1-year follow-up. In addition, possible bias is likely to be similar in both treatment groups, thus a comparison of the groups would still provide valid statistical inference. Furthermore, we used an interviewer-based FFQ which can give more accurate results than a self-administered FFQ [49].

In conclusion, the 1-y changes in dietary intakes of fiber and proteins after both surgical procedures, but particularly after SG, were unfavorable with regard to current dietary guidelines. The potential mediating effects of changes in food tolerance, hedonic hunger, binge eating problems, or gastrointestinal discomfort on dietary intakes were not assessed, but could be addressed in future studies. For clinical practice, our findings suggest that health care providers and patients should focus on sufficient intakes of protein, fiber, and vitamin and mineral supplementation after both SG and RYGB.

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Author contribution

DH, LKJ, MS, JH and JKH designed research; LKJ, DH and MS conducted research; LHB and HB analyzed data; LHB, LKJ, HB and JH wrote the paper; LHB and JH had primary responsibility for final content. MCS contributed to the quality control of the statistical analyses. All authors read and approved the final manuscript.

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Data Availability

Access to data collected from this study, including deidentified individual participants data, will be made available following publication upon e-mail request to the corresponding author. Data will be shared with investigators whose proposed use of data has been approved by the Oseberg steering committee, and is in accordance with the consent given by the participants and Norwegian laws and legislations.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2022.11.016.

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