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Changes in eating behaviour and meal pattern following Roux-en-Y gastric bypass

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Background: Little is known about eating behaviour and meal pattern subsequent to Roux-en-Y gastric bypass (RYGB), knowledge important for the nutritional care process. The objective of the study was to obtain basic information of how meal size, eating rate, meal frequency and eating behaviour change upon the RYGB surgery.
Materials and methods: Voluntary chosen meal size and eating rate were measured in a longitudinal, within subject, cohort study of 43 patients, 31 women and 12 men, age 42.6 (s.d. 9.7) years, body mass index (BMI) 44.5 (4.9) $kg\,m^{-2}$. Thirty-one non-obese subjects, 37.8 (13.6) years, BMI 23.7 (2.7) $kg\,m^{-2}$ served as a reference group. All subjects completed a meal pattern questionnaire and the Three-Factor Eating Questionnaire (TFEQ-R21).
Results: Six weeks postoperatively meal size was 42% of the preoperative meal size, ($P<0.001$). After 1 and 2 years, meal size increased but was still lower than preoperative size 57% ($P<0.001$) and 66% ($P<0.001$), respectively. Mean meal duration was constant before and after surgery. Mean eating rate measured as amount consumed food per minute was 45% of preoperative eating rate 6 weeks postoperatively ($P<0.001$). After 1 and 2 years, eating rate increased to 65% ($P<0.001$) and 72% ($P<0.001$), respectively, of preoperative rate. Number of meals per day increased from 4.9 (95% confidence interval, 4.4,5.4) preoperatively to 6 weeks: 5.2 (4.9,5.6), (not significant), 1 year 5.8 (5.5,6.1), ($P=0.003$), and 2 years 5.4 (5.1,5.7), (not significant). Emotional and uncontrolled eating were significantly decreased postoperatively, (both $P<0.001$ at all-time points), while cognitive restraint was only transiently increased 6 weeks postoperatively ($P=0.011$).
Conclusions: Subsequent to RYGB, patients display markedly changed eating behaviour and meal patterns, which may lead to sustained weight loss.
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Keywords: Roux-en-Y gastric bypass; meal size; eating rate; meal pattern; eating behaviour; TFEQ-R21

Introduction

Currently, the most successful long-term treatment for morbid obesity is obesity surgery including procedures such as Roux-en-Y gastric bypass (RYGB).[1] These operations successfully achieve and maintain long-term weight loss and improve mortality, morbidity and quality of life.[2–4] Until recently, the success of RYGB was commonly attributed to mechanical constraint through gastric volume reduction and calorie malabsorption secondary to the bypass of small intestine.[5] However, in patients, gastric pouch sizes do not correspond with weight loss or regain after gastric bypass.[6] The degree of malabsorption subsequent to RYGB is still controversial, although Odstrcil *et al.*[7] recently demonstrated a minor reduction in energy absorption after RYGB with a Roux-limb length of 150 cm and a biliopancreatic limb from 40 to 75 cm beyond the ligament of Treitz. Other mechanisms contributing to postoperative weight loss may include reduced hunger and/or increased satiation,[8] increased energy expenditure[9] and altered taste perception,[10] all of which may be mediated by alterations in gastrointestinal and central neuroendocrine signalling.[8–11] The Roux limb could also be an important determinant for regulating food intake after RYGB surgery[12]

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where the thresholds for eliciting distension-induced sensations have been shown to be strongly and negatively correlated to the preferred meal size. Also, psychosocial influences, for example, dietary counselling as well as individual food preferences and dislikes, food culture and previous experiences of dieting and emotional state may influence the gastrointestinal function as well as the behaviour of the individual. Moreover, involvements of 'endogenous' psychological mechanisms (for example, the perception and behavioural response to general and abdominal discomfort upon food intake) are equally important. The surgically altered gastrointestinal functionality is probably the start of a cognitive process where the individual makes preventive changes in behaviour to avoid dumping syndrome.[13]

As early as 1990, Kenler *et al.*[14] reported differences in food choice after different surgical approaches and some additional reports have shown consistent results.[15,16] However, there are fewer studies on changes in eating behaviour including meal size and number of meals, although both Wardé-Kamar *et al.*[17] and Silver *et al.*[18] have studied meal frequency after RYGB.

Eating behaviour also includes the general relationship to food. Dietary restraint, which seems to be widespread in modern societies, is suggested to have a paradoxical role in the development of obesity.[19] Other types of eating behaviour have been identified, such as the loss of control over food intake and the tendency to overeat in the presence of emotional distress, but little is known about their prevalence after bariatric surgery.[20–22]

Many surgical weight loss programmes encourage the use of a multiphase diet to achieve the best possible conditions for weight reduction and to minimize side-effects like gastro-oesophageal reflux, early satiety and dumping syndrome.[23] For example, patients subjected to RYGB are instructed to eat several small meals per day.[24] The scientific background to existing guidelines[23,25] are more comprehensive in terms of vitamin and mineral needs than those related to eating behaviour and eating patterns. In order to provide evidence-based nutritional care on portion size, eating rate and number of meals more research is needed. Evidence-based guidelines are in particular needed for the RYGB procedure because this operation has become very prevalent and, as mentioned above, data are accumulating that RYGB influences appetite regulation and eating behaviour in a very complex fashion. However, as eating behaviour subsequent to RYGB is not completely consistent between different programmes it is difficult to investigate effect of interventions, or even construct the rationale for such interventions. The objective of the present investigation, therefore, was to obtain basic information of how eating behaviour and meal patterns change upon the RYGB surgery. These issues were approached in a laboratory setting where morbidly obese patients were studied before and after a standard RYGB, including attention and advice from a dietician according to existing guidelines. The first aim of the study was to examine if RYGB altered ingested portion size, meal duration and eating rate when the patients were exposed to food and were free to eat until feeling full. The second aim was to evaluate if pre-meal hunger, post-meal satiation and maintained satiety in relation to voluntary food ingestion differed before and after surgery. A third aim of the study was to examine the diurnal distribution and number of meals as well as the general relationship to food in terms of cognitive restraint (CR), uncontrolled eating (UE) and emotional eating (EE).

Materials and methods

Study design

This study was a longitudinal, within subject, cohort study of patients undergoing RYGB. The non-obese reference group was examined at one point in time, while the obese subjects were examined before, 6 weeks after, 1 and 2 years after a RYGB operation. At these times, subjects individually consumed a standardized *ad libitum* test meal in the laboratory. Meal duration and meal size were measured as well as pre-meal hunger and post-meal satiation. At each study visit, habitual meal patterns were recorded using a standardized questionnaire for the analysis of meal frequency and temporal distribution over the day and night. Eating behaviour in terms of CR, EE and UE was measured by an additional questionnaire.

Participants

Patients on the waiting list for laparoscopic RYGB were invited to participate in this study. Inclusion criteria were body mass index (BMI) 35–50 $kg\,m^{-2}$. Exclusion criteria were inability to understand instructions as well as insulin-treated diabetes mellitus. Fifty patients were recruited during the period from April 2004 until April 2008. Altogether, 47 patients (35 women and 12 men) were enrolled of which 43 completed the protocol. In addition to the study protocol, patients received standard dietary advice, in the standard clinical setting (for details, see Appendix Table A1). We carefully distinguished between the usual dietary advice and the visits in the study to avoid affecting patients' choice of meal size and eating rate in the laboratory. Any comments and discussions about food and eating behaviour arising during experiments were answered neutral, and as soon as possible the topic of conversation was changed to something else because of the risk of affecting the experimental situation, Appendix Table A1. Moreover, no precise guidance on appropriate meal sizes was given. The non-obese reference group included healthy volunteers that had expressed interest in being included in studies at the Sahlgrenska Academy, including students and staff at the University Hospital, as well as people who had no ties to the hospital.

The study was conducted according to the principles in the Declaration of Helsinki. The study protocol was approved from the Regional Ethical Review Board in Gothenburg (Dnr: S 674-03) and all subjects signed an informed consent before entering the study.

No economical or other compensation were given to the intervention group. The non-obese reference subjects received 50 Euros each for participating in the study.

Operation technique
The surgical procedures were all primary bariatric surgery completed laparoscopically. The operative RYGB technique, as described in detail elsewhere,[26] included an antecolic–antegastric Roux-en-Y construction with a 10 to 20 ml gastric pouch and a 100–150 cm Roux limb and no aim at restricting the gastro-jejunal anastomosis.

Measurements
Anthropometric measurements. Height was measured to the nearest 0.01 m with the subject standing with her or his back to a wall-mounted stadiometre in bare feet. Weight was measured to the nearest 0.1 kg with calibrated scales. BMI was calculated as weight in kilograms divided by height in metres squared (kg m^{-2}). Percentage weight loss (%WL) of preoperatively body weight was calculated.

Analysis of meal size, water intake, meal duration and eating rate. Meal size, water intake meal duration and eating rate were tested at 28 (3) days before surgery and 52 (3) days (6 weeks), 365 (4) days (1 year) and 744 (8) days (2 years) after surgery. On the test day, all subjects were instructed to eat a standardized light breakfast at 0700 hours (consisting of one small sandwich and 200 ml of milk or fruit juice containing 225 kcal) and arrived thereafter to the laboratory. Subjects remained in the laboratory until 1200 hours. At 1100 hours, they received a 375 g (6-week visit) or 750 g (preoperative, 1- and 2-year visit) meal consisting of a mixture of meat, potatoes and onions (Swedish hash) with an energy density of 1.5 kcal g^{-1}, 16 energy percent (E%) protein, 42 E% carbohydrate and 42 E% fat. Swedish hash was chosen because it is a popular dish that everyone in Sweden knows and it has been used before as a test meal.[27] In addition, potatoes and meat are mixed which is important as protein and carbohydrates provide different degree of satiation. Subjects were instructed to eat until they felt comfortably full. Tap water was available *ad libitum* throughout the whole experiment. Food and water intake were measured by weighed differences. Meal duration was measured in minutes and eating rate was calculated as g min^{-1}. Laboratory measurements of food intake in humans has been shown to have a good reliability in terms of meal size and eating rate therefore we tested the control group only once.[27,28]

Pre-meal hunger, post-meal satiation and maintained satiation. At each experimental meal occasion, patients rated their general perception of hunger before the meal, satiation after the meal and maintained satiety 1 h after the beginning of the meal, using visual analogue scales.[29] On the hunger scale, 0 indicated 'not at all hungry' and 100 indicated 'very, very hungry'. One the satiety scale, 0 indicated 'not at all full' and 100 indicated 'very, very full'.

Number of meals and meal distribution. A simplified and self-instructing questionnaire[30] describing habitual daily intake occasions and distribution over an ordinary 24-h period was used to examine daily meal patterns. Each time episode of food intake was recorded and allocated to four time periods over the day: morning (0600–1159 hours), afternoon (1200–1759 hours), evening (1800–2159 hours) and night (2200–0559 hours). Beverages only (with or without caloric content) were not regarded as a meal. The questionnaire was analysed in a specifically designed programme ('Description of Dietary questionnaire version 7' and 'Food weight associated with Dietary questionnaire E3', Björn Henning, Sahlgrenska Academy, Gothenburg University, 2008).

Eating behaviour. The Three-Factor Eating Questionnaire (TFEQ-R21) covers three eating behaviour scales.[31,32] The CR scale assesses the tendency to control food intake in order to influence body weight and body shape. The UE scale assesses the tendency to lose control over eating when feeling hungry or when exposed to external stimuli. The EE scale measures the propensity to overeat in relation to negative mood states, for example, when feeling lonely, anxious or depressed. TFEQ-R21 is comprised of 21 items. Higher scores indicate more CR, UE or EE.

Statistical analysis
All data are expressed as mean (s.d.) for demographic data and 95% confidence intervals (CIs) for other variables. Normal distribution was tested with Kolmogorov–Smirnof test both for reference group and RYGB group at all measurement occasions. A nonsignificant result suggests that the variable can be normally distributed, which means that the one-way analysis of variance is appropriate as a significant test. Bonferroni correction was used to reduce the risk for type-I error. All variables related to the meal test (meal size, water intake, meal duration, eating rate, pre-meal hunger, post-meal satiation and maintained satiety) as well as the three factors of TFEQ were normally distributed while the number of meals were not normally distributed, 1 and 2 years postoperatively. Therefore, the simplified and self-instructing questionnaire describing habitual daily intake occasions, for all time points in the study, was calculated with the non-parametric Kruskal–Wallis test and *post hoc* Mann–Whitney *U*'s-test to adjust for type-I error. Pearson's correlation was used to examine associations. $P<0.05$ was considered significant. Calculations were done in SPSS Statistics, version 18 (SPSS, Chicago, IL, USA).

Results

Participants
Of the original 47 included subjects, two women were excluded in the preoperative assessment because they reported an unreasonably high daily energy intake (>50 kcal kg^{-1} body weight). Another two women were excluded because of development of breast cancer and chronic obstructive pulmonary disease, respectively, because these diseases can affect appetite. Consequently, 31 women

and 12 men, age 42.6 (9.7) years, BMI 44.5 (4.9) kg m^{-2} were followed for 2 years postoperatively. The non-obese reference group consisted of 20 women and 11 men, 37.8 (13.6) years, BMI 23.7 (2.7) kg m^{-2} (Table 1). During the postoperative follow-up, one patient could not attend the 6 weeks visit because of undergoing cholecystectomy surgery. At 1 year, one patient was pregnant and at 2 years one patient was breastfeeding. Otherwise all patients attended all planned visits in the study.

Body weight change

Preoperative body weight decreased from 132 (95% CI 125,138) kg to 114 (108,120) kg within 6 weeks after surgery ($P<0.001$, compared with preoperative state). After 1 year, body weight had further decreased to 91 (85,97) kg ($P<0.001$), and then stabilized at 90 (84,96) kg ($P<0.001$), during the second year. %WL was 14 (12,15) % at 6 weeks ($P<0.001$), 31 (28,33) % at 1 year ($P<0.001$), and 32 (28,35) % at 2 years ($P<0.001$).

Table 1 Demographics

	Intervention group, preoperative	*Non-obese reference*
N	43	31
Female/male	31/12	20/11
Age, years	42.6 (9.7)	37.8 (13.6)
Height, m	1.72 (0.10)	1.76 (0.10)
Weight, kg	131.7 (19.9)	73.6 (10.9)
Body mass index, kg m^{-2}	44.5 (4.9)	23.7 (2.7)

Data are shown as mean, (s.d.).

Meal size during ad libitum *meal*

Meal size was significantly smaller post- compared with the preoperative state (Figure 1a). Six weeks after surgery, subjects consumed mean 42% of the preoperatively meal size ($P<0.001$). After 1 and 2 years, meal size was 57% ($P<0.001$) and 66% ($P<0.001$) of preoperative meal size, respectively. Two subjects after 6 weeks (4.8%) and one subject after 1 year (2.4%) stopped eating because of reported discomfort or pain. All other subjects stopped eating because they felt comfortably full.

Water intake before and during ad libitum *meal*

Subjects consumed significantly less water 6 weeks after surgery ($P<0.001$) (Table 2). Water intake increased somewhat at 1 year ($P=0.129$), but decreased significantly after 2 years, still being below the preoperative water intake ($P=0.001$).

Meal duration during ad libitum *meal*

The mean meal duration was 12.0. (95% CI 10.6,13.4) min preoperatively, 12.0 (10.3,13.6) min 6 weeks, 10.9 (9.6,12.3) min 1 year and 11.2 (9.8,12.6) min 2 years post-surgery, with

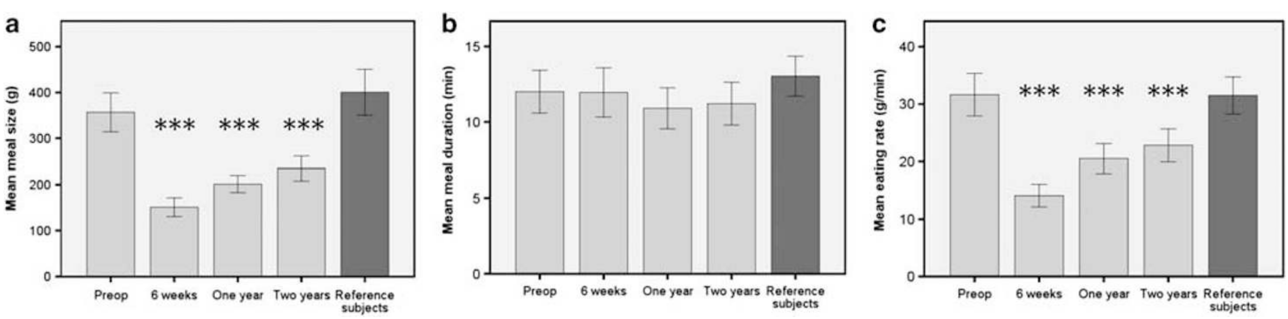

Figure 1 Average meal size (g) **(a)**, meal duration (min) **(b)** and eating rate (g min^{-1}) **(c)** of patients before ($N=43$) and 6 weeks ($N=42$), 1 year ($N=41$) and 2 years ($N=42$) after RYGB (light bars) and a reference group ($N=31$, dark bars), mean (95% CI). ***$P<0.001$.

Table 2 Water intake, pre-meal hunger, post-meal satiation and maintained satiation measured during test meal, meal numbers and meal distribution measured from a meal pattern questionnaire

	Pre-surgery (N=43)	*6 Weeks (N=42)*	*One year (N=41)*	*Two years (N=42)*	*Non-obese reference (N=31)*
Data from test meal					
Water intake during test meal (ml)	798 (684,911)	513 (437,590)***	634 (540,732) *NS*	549 (468,630)***	557 (455,659)
Pre-meal hunger (mm VAS)	57.8 (49.6,66.0)	46.8 (38.5,55.0) NS	57.6 (48.8,66.5) NS	60.8 (54.0,67.5) NS	72.6 (66.9,78.2)
Post-meal satiation (mm VAS)	77.5 (71.0,84.0)	81.2 (75.1,87.4) NS	84.6 (80.1,89.1) NS	86.4 (82.7,90.2) NS	75.2 (68.6,81.9)
Maintained satiation 1 h after meal start (mm VAS)	70.9 (63.3,78.5)	75.6 (68.6,82.6) NS	70.9 (63.8,78.0) NS	71.0 (63.7,78.3) NS	66.1 (59.4,72.8)
Data from meal pattern questionnaire					
Number of meals per day	4.9 (4.4,5.4)	5.2 (4.9,5.6) NS	5.8 (5.5,6.1)***	5.4 (5.1,5.7)*	4.6 (4.2,5.0)
Number of meals morning (0600–1159 hours)	1.4 (1.2,1.6)	1.8 (1.6,2.0) NS	2.0 (1.8,2.2)***	1.8 (1.6,2.0)*	1.32 (1.1,1.6)
Number of meals night (2200–0559 hours)	0.4 (0.2,0.6)	0.1 (0.0,0.2) NS	0.2 (0.1,0.4) NS	0.2 (0.1,0.3) NS	0.2 (0.0,0.3)

Abbreviations: CI, confidence interval; NS, not significant; VAS, visual analogue scales. Mean (95% CI), *$P<0.05$, ***$P<0.001$.

no difference at any time point pre- and postoperatively (Figure 1b). Mean meal duration in the non-obese reference group was 13.0 (11.7,14.4) min, which did not differ significantly compared with the patient group either before ($P=0.282$) or 2 years ($P=0.459$) after surgery.

Eating rate during ad libitum *meal*

Mean eating rate, measured as amount consumed food per minute, among patients was 45% 6 weeks postoperatively compared with preoperative eating rate, ($P<0.001$) and then increased after 1 year to 65% ($P<0.001$) and 2 years to 72% ($P<0.001$) of preoperative rate (Figure 1c). Eating rate did not differ significantly between the operated patients and the non-obese reference group either before surgery ($P=0.059$) or 2 years postoperatively ($P=0.657$).

Pre-meal hunger, post-meal satiation and maintained satiety

At no time point did we find a significant effect of RYGB surgery on the perception of hunger before the meal, satiation after the meal or maintained satiety 1 h after meal start as measured with visual analogue scales (Table 2). The non-obese subjects experienced higher pre-meal hunger than did the patients 6 weeks postoperatively ($P<0.001$), and at 2 years postoperatively ($P=0.016$). There was no significant difference in satiation between the non-obese reference group and the obese patients before surgery ($P=0.571$), or 2 years postoperatively ($P=0.081$). Maintained satiety did not differ between the non-obese reference group and the obese group, neither preoperatively ($P=0.101$), nor at 2 years postoperatively ($P=0.262$).

Number of meals and meal distribution

Number of meals per day increased post-surgery although, only became significant at 1 year ($P<0.001$). Preoperatively, patients and non-obese subjects consumed equal numbers of meals per day ($P=0.587$), which they also did 2 years postoperatively ($P=0.542$), (Table 2).

Patients had increased their number of meals during the morning hours both at 1 year ($P<0.001$) and 2 years ($P=0.028$), (Table 2). There was no statistical difference regarding numbers of meals, preoperatively compared with postoperative states during the afternoon phase or during the evening phase after 6 weeks, 1 and 2 years ($P=>0.5$ for all three time points). Postoperatively, patients had a tendency to consume fewer meals at night (2200–0559 hours) compared with preoperatively, but these changes did not reach statistical significance (Table 2).

Correlations between meal size, eating rate and number of meals and %WL

Meal size correlated negatively to the %WL at 1-year postoperatively $r=-0.42$ ($P=0.006$) but not 2 years, $r=-0.36$ ($P=0.096$). Eating rate and number of meals showed no association with the %WL either at 1 or 2 years postoperatively.

Cognitive and emotional aspects of eating behaviour

Figure 2 illustrates the differences in eating behaviour. CR increased in the short term (6 weeks), but in the long term (1 and 2 years) after surgery there were no significant differences compared with the preoperative state. CR did not differ between the non-obese group and obese patients preoperatively ($P=0.990$), or 2 years postoperatively ($P=0.358$), (Figure 2a).

Patients seemed to experience fewer problems with UE and EE after surgery. UE decreased 6 weeks post-surgery compared with pre-surgery ($P<0.001$). This reduction persisted after 1 year ($P<0.001$), and 2 years ($P<0.003$). Compared with the non-obese subjects, obese patients had more problems with UE before surgery ($P=0.006$), but not after surgery ($P=0.896$), (Figure 2b).

EE showed consistency with UE in decreasing at 6 weeks after surgery ($P<0.001$). The reduction persisted at 1 year ($P<0.001$) and at 2 years ($P=0.046$). Compared with the non-obese group patients reported more problems with UE before surgery ($P=0.003$), however, after 2 years, the difference between the groups was nonsignificant ($P=0.718$) (Figure 2c).

Discussion

In this study, we have demonstrated clinically significant changes in eating behaviour and meal patterns after RYGB. We found a reduced *ad libitum* meal size with similar meal duration and thus slower eating rate and increased habitual meal frequency. Furthermore, we have shown that both EE

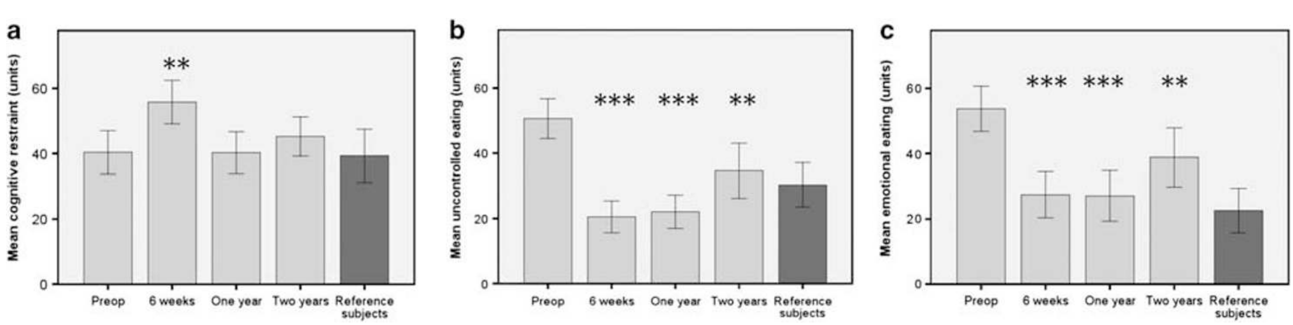

Figure 2 CR **(a)**, UE **(b)** and EE **(c)**, in patients (light bars) before ($N=43$) and 6 weeks ($N=42$), 1 year ($N=41$) and 2 years ($N=42$) after RYGB and a reference group ($N=31$, dark bars), mean (95% CI). Higher scores indicate more UE, restrained or EE. **$P<0.01$, ***$P<0.001$.

and UE were significantly decreased postoperatively while CR was only transiently increased at 6 weeks postoperatively.

We consider the subjects under study being representative for morbidly obese patients undergoing RYGB as we consciously aimed to avoid selection bias by selecting particularly suitable patients, yet subjects were recruited over a long time period. The degree of attendance to follow-up visits was high (97%) and the percentage body weight loss found in this study was similar for what has been reported previously to this surgical technique.[33]

Patients exhibited a decreased meal size, similar meal durations before and 6 weeks, 12 or 24 months after RYGB when offered a mixed meal *ad libitum*. Thus, patients ate for the same amount of time, but ate less food per minute. Population studies have demonstrated that eating rate is positively correlated with BMI,[34–36] while experimental studies have shown that reduction of eating rate is accompanied with reduced caloric intake and increased satiety.[37–39] Men usually have higher eating rates than women, so the higher proportion of men in the reference group might have had a part in the lack of between-group differences (Andrade AM, Melanson KJ. Do men eat faster than women? Gender differences in energy intake and appetite when eating rate is manipulated'. Obesity 2009; 17 (S2, poster 470): S178) and Greene *et al.*[40]

Potential mechanisms for postoperative changes in eating rate and other eating behaviours such as the general relationship to food warrant further investigation. For example, changes in appetite-regulatory hormones may lead to less intense hunger, which in turn may reduce eating rate and energy intake,[8,41] and greater hunger is associated with increased eating rate and energy intake.[42] Interactions between eating rate and satiety hormones have been demonstrated in humans.[43] Also the risk of dumping syndrome, which is caused when the indigestible food reaches the intestinal mucosa quickly after meals, probably has a role in the reduced eating rate.[13]

One of the limitations of using visual analogue scales in single-meal studies is that they have a large inter-individual variability, however, this may be of less concern in this within-subject design. Thus, within-subject comparisons are more sensitive and accurate than between-subject comparisons, which therefore could reduce the number of subjects needed for studies with appetite scores.[29] The present results indicated that the appetite ratings were unaltered after RYGB as the reduced food intake did not correlate with scoring of pre-meal hunger or post-meal satiation. This may indicate improved satiety signalling, reflected by greater satiety per kcal ingested. Both satiation after meal and maintained satiety measured 1 h after meal start remained unaltered after RYGB, although, the number of meals per day increased postoperatively. However, the study purpose was not to measure satiety over 24 h, so there may still be alterations in experience of hunger and satiety between meals not caught in this study where we only assessed just before and after the test meal.

Zheng *et al.*[44] analysed meal patterns in RYGB-operated rats and found not only a reduction of total food intake, but also a reduced meal size and increased meal frequency, similar to patterns in this present report. Thus, the results found in this study may be due to both physiological changes and those depending on dietary counselling.

The fact that patients after RYGB shift their eating behaviour towards a pattern with smaller meals and higher meal frequency is intriguing with regard to the resulting weight loss. Epidemiological as well as experimental studies have shown inconsistent results regarding an association between meal frequency and BMI in both normal weight and obese subjects.[45–47] For example, Hampl *et al.*[48] found that increased meal frequency was positively associated with energy intake but not with BMI. However, it has also been demonstrated that frequent eating would be associated with poorer weight loss after RYGB.[49,50] These inconsistent results may be due to the snacks' size and content that might be of importance for weight status after RYGB in the same way as demonstrated in non-operated obese.[51]

Behavioural and/or cognitive shifts may also contribute for the changes found in meal frequency, size and eating rate as suggested by other studies[20,21] as well as for weight loss and weight loss maintenance by non-surgical means.[52–54] These potential shifts after RYGB have relevance, because factors such as CR and disinhibition have been associated with eating patterns, and if these factors change during treatment, they might influence eating rate and other eating behaviours.[55]

The strength of this study is that we actually measured the portion size, meal duration and eating rate both preoperatively and up to 2 years postoperatively. Direct assessment of portion sizes are certainly interesting, even if it is possible to reasonably estimate the meal size based on assumed energy requirements. Even more interesting is the meal duration and eating rate, which add new and potentially important clinical knowledge that are both important for clinicians in the nutrition care process and for the patient in daily life.

A limitation of this study is that the test meals were administered in a laboratory setting, which may not reflect habitual eating habits of patients. The test meal of Swedish hash has a high-fat content, 42 E%. Patients after RYGB often change their food choices to a low-fat diet[14,15,56] and therefore patients maybe would have eaten larger portions if served a low-fat meal.

In summary, patients exhibit reduced *ad libitum* meal size with maintained meal duration resulting in a decreased eating rate while hunger and satiety scores did not change after undergoing RYGB surgery. Habitual meal frequency tended to increase after RYGB. In addition, larger numbers of meals were consumed in mornings. Emotional and UE were significantly decreased postoperatively while CR was only transiently increased 6 weeks postoperatively. In conclusion, patients display major changes in food intake behaviour and meal pattern suggesting that RYGB drives the individual to an eating behaviour that promotes weight loss.

Conflict of interest

The authors declare no conflict of interest.

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The authors' responsibility were as follows; AL, LF, HL and TO designed research. AL conducted research, analysed data, performed statistical analysis of data and wrote the paper. IL, MB, KJM, IB, HBF, TO and LF interpretation of data and revision of paper. All authors read and approved the final paper. This work was supported through the Research Council of the Western Region of Sweden, Swedish Research Council (VR Medicine) and by the Deutsche Forschungsgemeinschaft (DFG).

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Appendix

1. Pre-surgery:
Three weeks preoperative weight loss using very-low calorie diets (VLCD) or low-calorie diets (LCD).
2. Nutrition care post-surgery:
Day 1–7: full liquid diet including protein drinks or VLCD/LCD.
Day 8–30: semi-solid or soft food including protein drinks or VLCD/LCD.
Day 31–60: solid food, except hard digestible foods such as raw carrots, asparagus.
Day 61 and thereafter: solid food.
3. Food choice:
Small amounts of food of good nutritional value.
Reduced intake of sugar and saturated fat.
Good quality of fat.
Protein rich foods with every meal.
4. Advises regarding eating behaviour:
Chew thoroughly.
Eat slowly.
Do not drink together with meals.
5. Supplementation standard:
Complete multivitamin- and mineral tablet, 1×1.
Vit B12 1 mg, 1×1.
Calcium 500 mg, 1×2.
Vit D 400 IE, 1×2.
Fe 2+ 100 mg, 1×1 (women).
6. Blood tests:
Preoperatively.
Postoperatively 6 and 12 months, thereafter annually at primary health care.
7. Number of visits:
Preoperatively; Group information at two occasions.
  Individual assessment and information at one occasion.
  Daily availability by telephone.
Postoperatively; Before patient leaving hospital.
  Individually at the reception after.
    6 weeks
    6 months
    12 months
  Daily availability by telephone.
  Liberally additional visits if necessary.
Thereafter, the primary health care is responsible for follow-ups.