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Eating Behavior & Taste in Obesity

Inauguraldissertation

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Erlangung der Doktorwürde (rer. hum. biol.)

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

ANOVA	Analysis of Variance
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index in kg/m^2
EBL	Excess BMI Loss
EWL	Excess Weight Loss
FFQ	Food Frequency Questionnaire
fMRI	Functional Magnetic Resonance Imaging
GB	Gastric Banding
GLP-1	Glucagon-like Peptide 1
non-OB	non-obese
NTS	Nucleus Tractus Solitarii
OB	Obese
pre RYGB	before RYGB surgery
post RYGB	after RYGB surgery
PFS	Power of Food Scale Questionnaire
PYY	Peptide Tyrosine Tyrosine
RYGB	Roux-en Y Gastric Bypass Surgery
SD	Standard Deviation
SEM	Standard Error of Mean
TFEQ	Three Factor Eating Behavior Questionnaire
VAS	Visual Analogue Scale

1 Introduction

1.1 Development of Obesity

The prevalence of overweight and obesity is increasing worldwide with a leveling off in developed countries, but still remains on an alarmingly high level [57, 113, 157, 158]. Genes play a role in the development of obesity, but the prevalence of obesity increases in a short period. The reason for this is seen primarily in changed living habits like overeating combined with a loss of movement [32, 184]. Overeating as a main factor in the development of obesity may result from inappropriate food choices as well as from an increased drive to eat highly palatable foods, high in sugar and fat content [45, 46, 97, 116, 147]. Thus, an increased preference for highly palatable food is suggested in obese subjects (OB) [8], especially because sugar and fat in combination are extremely pleasant and rewarding and therefore highly motivating for food intake [77]. The drive to eat such foods has recently been termed ‘Hedonic hunger’ [97]. Environmental factors like food availability, portion size, palatability and energy density of food, as well as the presence of food pictures, socioeconomic status, stress vulnerability and pricing strategies are suggested to provoke the consumption of highly palatable food supporting the development of obesity [185]. This lifestyle increases the risk of developing cardiovascular diseases [79, 124], type 2 diabetes mellitus [29], and different kind of cancer [2, 15, 79] in obesity and finally reduces quality of life [161].

1.2 Treatment of Obesity

Effective strategies to prevent obesity have not been established yet. Among other treatments, obesity is treated by conservative therapy approaches, which aim to change lifestyle regarding nutritional behavior and physical activity. These approaches mostly result in a short-termed weight loss of 5 – 10% [163, 171]. Even drug treatments with orlistat, sibutramine or rimonabant only lead to short-term weight loss with an average of an additional 3 to 6 kilograms [117]. Due to these disappointing results of long-term weight loss failure, bariatric surgery becomes more and more popular in the therapy of obesity [21–23, 36]. Bariatric surgery is currently the most effective and long-termed treatment of obesity and its co morbidities [91, 148].

1.3 Bariatric Surgery of Obesity

According to international guidelines, bariatric surgery is linked to a Body mass index (BMI) > 35kg/m^2 with obesity-related diseases or to a BMI ≥ 40 kg/m^2 without co-morbidities [60, 61, 91, 103]. Also patients' motivation and conservative therapy approaches with disappointing weight loss results are main reasons for bariatric procedures [108].

Procedures of bariatric surgery can be divided into restrictive, malabsorptive and combined procedures. Gastric band implantation (**Figure 1A**), as a restrictive procedure reduces the portion size of a meal, while the food passage through the gastrointestinal tract remains unchanged. Gastric band implantation leads to an excess weight loss (EWL) of 45-50%, while in the long term weight regain often takes place [3, 160]. On the one hand this weight regain might be explained by an adapted eating behavior including increased consumption of liquid and mushy foods, which can pass the gastric band. On the other hand the weight regain might be explained by intolerance of the gastric band with symptoms like emesis resulting in a dilatation of the esophagus. This dilatation reduces the effect of the gastric band. In such cases the gastric band is often removed and transformed into a gastric bypass [27]. For these reasons and because of the better weight loss results of typically 59% EWL [109] gastric bypass surgery is currently the gold standard in the treatment of obesity [104]. With this procedure, the largest part of the stomach, the whole duodenum and the proximal part of the jejunum are excluded from the food passage (**Figure 1B**). Thereby a restriction is combined with a variable extend of malabsorption.

Roux-en Y gastric bypass surgery (RYGB) can be divided in a proximal and a distal procedure. In both procedures, the largest part of the stomach is transected, thereby creating a small gastric pouch of approximately 30 ml which is anatomized to the proximal jejunum. In the proximal RYGB procedure, the biliopancreatic limb (duodenum and upper part of the proximal jejunum) is mostly side-to-side anastomized to the jejunum, 150 cm distal from the pouch-jejunal anastomosis, thereby creating a Roux-en Y or alimentary limb. In the distal RYGB procedure, the biliopancreatic limb is side-to-side anatomized to the ileum, 60 to 100 cm proximal from the Bauhin's valve, thereby establishing a rather short common channel. The length to the biliopancreatic limb as measured from the

ligament of Treitz is approximately 60 cm in the proximal and 60 to 100 cm in the distal RYGB procedure. Consequently, the proximal RYGB procedure, but especially the distal RYGB procedure is characterized by a nutritive undersupply [149].

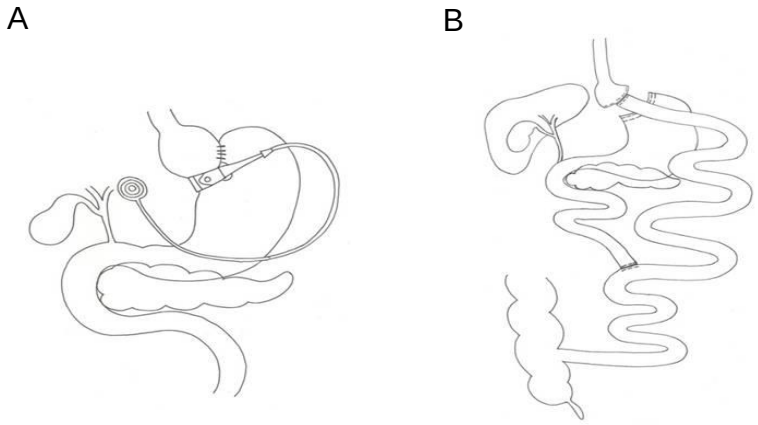

Figure 1 A: Adjustable Gastric Banding; B: Roux-en Y Gastric Bypass

1.4 Homeostatic & Hedonic Regulation of Eating Behavior in Normal Weight Subjects

High-calorie sweet and fatty food, so called highly palatable food and also food pictures are associated with positive emotions increasing the motivation to eat it, because of its rewarding value [49, 90]. Food reward contains two aspects: On the one hand liking, describing the hedonic value (pleasantness/palatability) of food with the typical ‘happy face’ expressed in human’s face when tasting sweets, mediated by the opioid and the cannabinoid receptor system [14, 176, 186]. On the other hand wanting, which reflects the drive (the motivational aspect) to consume highly palatable food, mediated by the unconscious dopamine reward system [12, 56, 176, 186]. Wanting results from a learned reward generated pleasure during tasting in the past, from a previously memorized experience [14]. Liking is related to the sensory process, while wanting is related to decision-making and motor action to obtain rewards [186]. We want to eat what we like [14]. But also wanting without liking palatable food is possible [14], which is similar to chronic substance abuse [137].

The mesolimbic dopamine reward system plays a key role in transforming liking into motivational wanting of palatable food. Emotional pleasure from

palatable foods (liking) is controlled by the orbito frontal cortex and the insular cortex. The motivational drive for food (wanting) triggered by food pictures or food is controlled by subcortical limbic structures (i.e. amygdala; ventral tegmental area; nucleus tractus solitarii: NTS) [132]. These processes are inhibited by leptin, a hormone produced by the white adipose tissue [43, 64, 78] and by insulin, a hormone produced by the pancreas as a response to increased glucose blood levels [93] and are activated by orexigenic hormones like ghrelin [1, 101].

The motivation to eat leads to food intake. When food is tasted, taste receptors in the mouth and in the small intestine generate taste signals to the primary taste cortex in the brain (i.e. insula), where neurons detect, recognize and evaluate intensity of all five taste modalities (sweet, salty, sour, bitter and umami) [81, 127, 151, 152]. Next to physiological responses like insulin release, tasting food activates brain reward areas [151, 152] in the secondary taste cortex in the brain (orbit frontal cortex; prefrontal cortex) and in the amygdale. Here neurons respond separately to the different taste modalities [127, 132, 175]. The activation of the orbito frontal cortex influences behavior (striatum and cingulated cortex) and the homeostatic control of feeding (hypothalamus) [127, 132]. In this so called cephalic phase of food intake, where food is visible and tasted, taste signals are sent by the NTS to the forebrain [132].

Short-term satiation is perceived by physical distension of the stomach and by secreted gastrointestinal satiety hormones (i.e., PYY: Peptide Tyrosine Tyrosine; GLP-1: Glucagon-like Peptide 1) as a response to digested food components, the so called gastric and intestinal phase of food intake. Physical distension of the stomach is directly transmitted by gastric mechanoreceptors via the nervus vagus to the NTS. Satiety hormones transmit the short-term satiety signal directly and indirectly via the nervus vagus into satiation circuits in the hindbrain (dorsal vagal complex encompasses the NTS, area postrema & dorsal motor nucleus of vagus). Many gastrointestinal hormones are also expressed by the brain. The NTS not only receives, but also projects signals via GLP-1 neurons to the mesolimbic reward system to reduce food intake [132].

Long-termed satiety is promoted directly, but also indirectly by food metabolites like fatty acids, amino acids and glucose in the post absorptive period via secretion of hormones like leptin from adipose tissue and insulin from pancreas

to the hypothalamus. The hypothalamus as a key structure for regulating long-term energy homeostasis and body weight coordinates the homeostatic regulation of food intake and the hedonic regulation of appetite via synaptic connections to the NTS hunger/satiety system and the corticolimbic reward system [132].

1.5 Eating Behavior and Taste Recognition in Obesity & after Bariatric Surgery

An increased hedonic drive to consume food in the absence of metabolic hunger was a matter of survival in view of an evolutionary history with food deficits [144]. In the modern world the commercialization of food supply makes it more and more difficult to make adequate food choices [144]. The reward value of palatable foods high in fat and sugar is the choice of most people [144]. But why are some individuals better at regulating intake of palatable foods than others? Is it possibly caused by differences in the sensitivity of taste, in food preference or at a motivational level? Why is food more rewarding to some people than to others? Bariatric surgery, as it shifts the obese state to a leaner state, is a welcomed metabolic model to get new insights into these questions.

Bariatric surgery requires limitations in food consumption to provoke weight loss [42]. The mechanisms of limitation in food consumption differ depending on surgery procedure. Gastric banding, with its small opening due to the band and RYGB surgery with its upper anastomosis, limits the consumption of food which cannot be chewed into small pieces, i.e. insoluble grains [16, 63, 118]. Gastric bypass surgery limits the consumption of simple carbohydrates and fatty foods, which lead to intestinal discomfort and diarrhea, collectively called dumping syndrome [63, 118].

Up to date assessments of the postsurgical food consumption in bariatric patients are rare. Most of the studies have analyzed energy content [17, 44, 105, 107, 169, 170, 178], macronutritive [5, 17, 44, 105, 107, 167, 178] or micronutritive ingredients [44, 47, 169, 170, 178]. Only a few studies have analyzed the frequency of food consumption [18, 50, 86, 141] and only some studies have compared the consumption of different kinds of foods between gastric banding (GB) and RYGB patients [18, 50, 86].

Eating behavior contains several aspects: Hunger as a physiological signal for food consumption, cognitive restraint as a tendency of some persons to restrict their food intake in order to control their body weight, disinhibition as a tendency for restraint to break down when confronted with emotional or external cues [156] and emotional eating as an excessive food intake in response to feelings instead of hunger. Studies on eating behavior assessing hunger, cognitive restraint and disinhibition in OB subjects revealed inconsistent results [35, 41, 65]. In patients after RYGB surgery increased cognitive restraint, reduced disinhibition and hunger were observed in previous studies, but only in short-termed assessments [68, 84, 123, 134, 155].

The drive to eat palatable food (wanting), the so called hedonic hunger, seems to be increased in obesity as found in our [136] and other previous research [28, 128, 136, 154]. RYGB surgery seems to reduce the hedonic hunger as our [136] and previous research [167] observed. While patients' desire to eat palatable foods was reduced in our previous research when food was available, present, and also if tasted two years after RYGB surgery if compared to OB subjects, RYGB patients' hedonic hunger did not differ from that of non-obese (non-OB) subjects when food was available or present, but surprisingly when tasted [136].

Results found in previous studies on liking palatable foods in OB subjects as compared to non-OB subjects were inconsistent [8, 45, 62, 76, 100, 119, 121, 125, 183]. Patients reported a decreased liking of palatable foods after RYGB surgery in the daily clinical practice of the Interdisciplinary Obesity Center, which is supported empirically in human [10, 25, 50, 86, 92, 114, 165, 167, 168] and animal studies [24, 70, 130, 143, 168]. Previous studies on taste recognition reported a reduced [116] as well as an unaltered [140, 147] sensitivity to recognize salty, a reduced [116, 147] as well as an unaltered [140] sensitivity to recognize sour, a reduced [116, 147] as well as an unaltered [140] sensitivity to recognize bitter and a reduced sensitivity to recognize umami [116, 121] in OB compared to non-OB subjects. There is also evidence that RYGB surgery changes taste recognition. Previous studies reported an increased sensitivity to taste sweet [25] and bitter [140] as well as an unaltered sensitivity to taste sweet [140] and bitter [25], as well as an unaltered sensitivity to taste sour after RYGB surgery [140]. Changes in

taste recognition might be explained through alterations in the sensory-discriminative, motivational or physiologic domains of taste function or through changes in dietary habits [152, 168] and food repulsion [168]. Results of these foregoing taste studies were collected at 30, 60, and 90 days [140] resp. 6 and 12 weeks [25] very short-termed after RYGB surgery and not all taste modalities [25, 140] were evaluated.

In obesity the increased body fat mass overproduces leptin resulting in a leptin resistance [132]. The missing central nervous effect of leptin on short-term satiation, gut hormones [71, 180] and reward [13] promotes weight gain [132]. Blood insulin levels are increased in OB subjects [132] possibly resulting in a central nervous insulin resistance also accelerating obesity [132]. Production and responses to satiety hormones, like PYY and Cholecystokinin is impaired in OB subjects increasing hunger feelings [139, 162]. The deregulation of gastrointestinal appetite regulating hormone responses which was observed in obesity [126] changes after RYGB surgery [104], but not after adjustable gastric banding [4, 52]. These appetite regulating hormones are suggested to play a role in taste processing as well as in hedonic drive in patients after RYGB surgery [4, 72, 122]. After gastric band implantation these alterations in gut hormone releases are missing [4], which suggest an unaltered hedonic hunger in these patients.

1.6 Research Questions to be answered

Against the above outlined background the following questions arise regarding '*Eating Behavior and Taste in Obesity*':

- Is eating behavior affected by obesity itself and also by bariatric surgery?
- Are food preferences and taste recognition affected by obesity per se and by bariatric surgery?

A series of studies were carried out between April 2010 and November 2012 to answer these questions.

2 Methods

Data was obtained by using different study designs and methods as described below.

2.1 Study Designs

We carried out four different studies, two ‘Taste Studies’ and two ‘Eating Behavior Studies’, one of each in a cross-sectional case control and one in a follow-up design as illustrated in **Figure 2**.

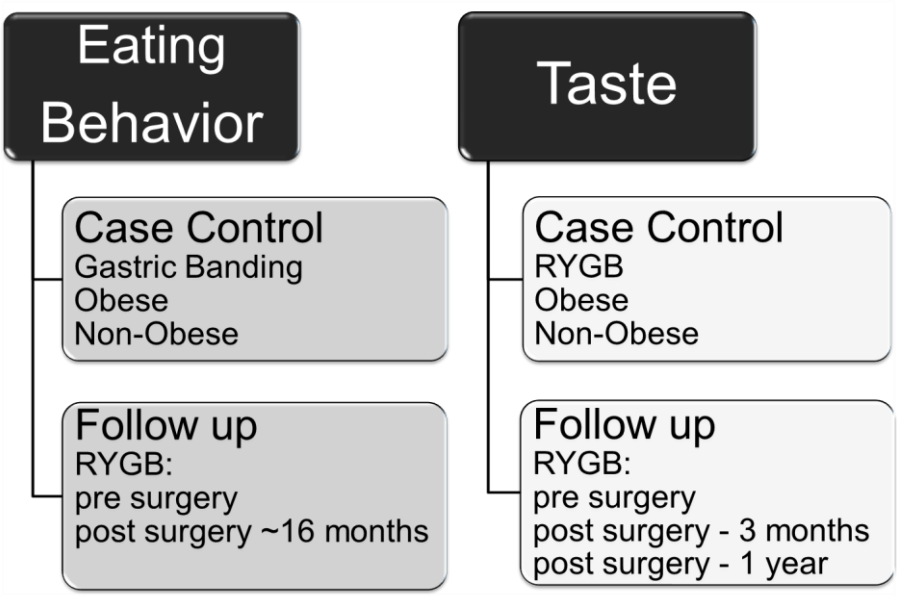

Figure 2 Study Designs

2.1.1 Eating Behavior Studies Setting

In both ‘Eating Behavior Studies’ patients filled in the Power of Food Scale Questionnaire (PFS), while the Food Frequency Questionnaire (FFQ) was only filled in by RYGB patients of the Follow-up Eating Behavior Study. The testing of eating behavior after RYGB and after gastric banding procedure followed a standardized order as can be seen in **Figure 3**. Subjects taking drugs known to affect eating behavior or taste perception were excluded from these studies. Each subject signed an informed consent form prior to participating in the study and the study protocol was approved by the cantonal Ethics Committee St.Gallen. The results of these studies are based on prospective collected data of the Interdisciplinary Obesity Center of the cantonal hospital St. Gallen.

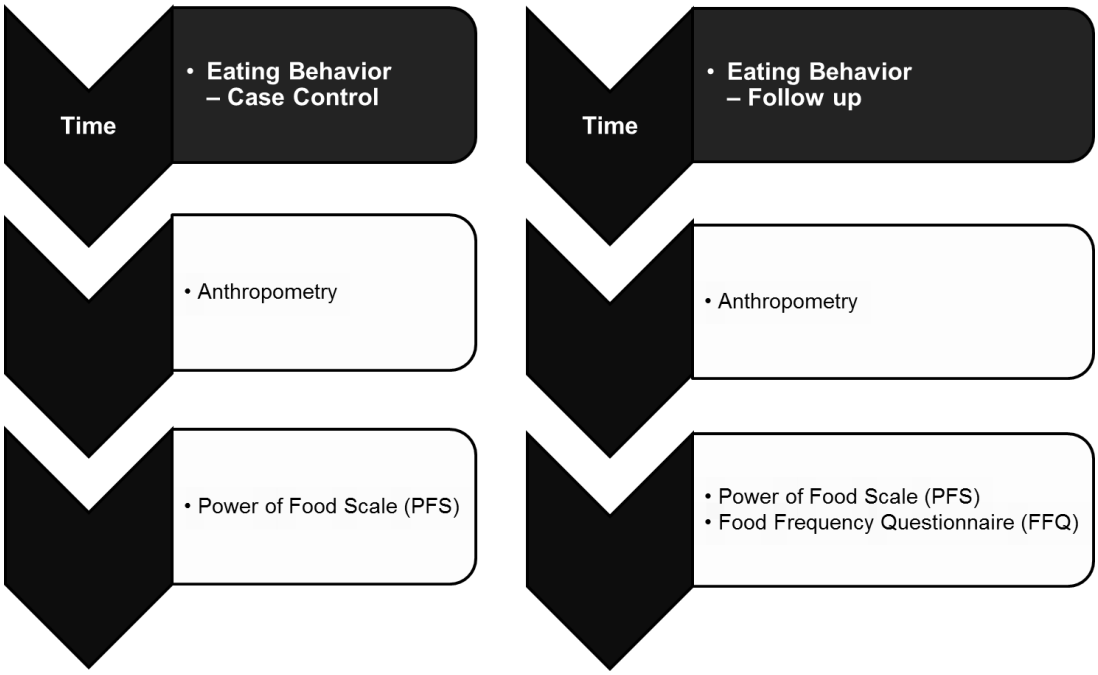

Figure 3 Study Design of the Eating Behavior Study

2.1.1.1 Eating Behavior Study – Case Control: Patients after Gastric Banding compared to Obese & Non-Obese Subjects

In a cross-sectional case control study GB patients filled in the PFS, which assessed hedonic hunger. In addition anthropometric data was assessed. Three groups of patients participated in our study, i.e. 116 patients who had undergone gastric banding surgery 88.6 ± 31.5 (16 – 156) months (about 7.5 years) before participation, 138 severely OB subjects (BMI > 35 kg/m^2) who attended our Interdisciplinary Obesity Center for evaluation for bariatric surgery, and 133 non-OB subjects (BMI 18 – 27 kg/m^2) recruited from the local community. Three different band systems had been implemented in the patients. One hundred and six patients received a *LAP-BAND*® (Allergan ®, Carpinteria, CA); 88 bands with a size of 10 cm, 18 bands with a size of 11 cm. Another 7 patients received a *Swedish adjustable gastric band* (Obtech Medical, 6310 Zug, Switzerland) and 3 patients an AMI band (Ami, GmbH, Feldkirch, Austria). Participants of the severely OB group and the non-OB control group largely overlap (n = 123 and n = 110; respectively) with respective groups of a previously published study [136]. Data of the PFS and anthropometric data (see **2.2.1**) was collected between September 2007 and October 2010.

2.1.1.2 Eating Behavior Study – Follow-up: Patients pre vs. post RYGB surgery

Forty four severely OB patients filled in the PFS as well as the FFQ, which assessed dietary habits before and between 11 and 39 (15.9 ± 0.9) months after RYGB surgery. Patients who had qualified for bariatric surgery according to international guidelines and were willing to undergo a RYGB procedure were included in the study. Thirteen patients underwent a proximal RYGB procedure while the remaining 31 patients underwent a distal RYGB procedure. Data was collected between September 2007 and September 2011.

2.1.2 Taste Studies Setting

Subjects of the two taste studies were invited to our clinical research unit to undergo a standardized assessment procedure. All subjects arrived at around 8.00 a.m. in the research unit and the testing procedure, comprising the assessment of anthropometric variables, appetite, hunger, wanting and linking ratings, 3 different distinct eating behavior questionnaires, a taste recognition task, and a hedonic sweet creamy test, was started. The taste recognition task was always performed before the hedonic sweet creamy test, which had concentrations at a suprathreshold level, to avoid exposing taste receptors to high concentrations. The testing followed a standardized order as can be seen in **Figure 4**.

All subjects were tested in a fasting state and eating was allowed until 8 p.m. before the testing day. The testing procedure was carried out in a silent room with minimal visual and olfactory distraction. Subjects taking drugs known to affect eating behavior or taste perception were excluded from the study. Each subject signed an informed consent form prior to participating on the study and the study protocol was approved by the cantonal Ethics Committee St. Gallen.

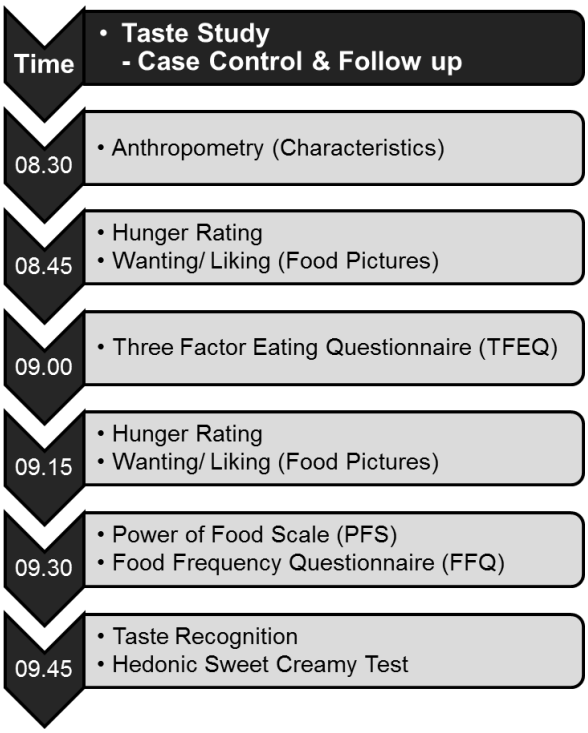

Figure 4 Study Design of the Taste Studies

2.1.2.1 Taste Study – Case Control: Patients after RYGB surgery compared to Obese & Non-Obese Subjects

For the cross-sectional Case Control Taste Study, we recruited 44 subjects who had undergone RYGB surgery at least 1 year before (RYGB group), 59 non-operated OB subjects seeking obesity treatment (OB group) from our outpatient clinic, and 51 non-OB subjects (non-OB group) by public advertisements. Subjects of the OB group had to have a BMI of at least 35 kg/m^2. In the RYGB group, the average time that elapsed from the RYGB surgery to the time of the study assessment ranged between 12 and 115 months (mean ± SD: 37.6 ± 4.1 month). Data was collected between March 2010 and February 2012.

2.1.2.2 Taste Study – Follow-up: Patients pre vs. post RYGB surgery

For the Follow-up Taste Study, we recruited 28 patients (9 men) who qualified for bariatric surgery according to international guidelines and were willing to undergo a RYGB procedure. Assessments were performed before, 3 months and 1 year after RYGB surgery. Twenty one patients underwent a proximal RYGB procedure while the remaining seven patients underwent a distal RYGB procedure. Data was collected between March 2010 and November 2012.

2.2 Assessments

2.2.1 Anthropometry

Body height and weight were measured in all subjects while they were wearing light clothes, but no shoes. Excess weight was calculated by the formula EW (kg) = [weight (kg) – (height (cm) – 100)], percent weight loss by the formula [(presurgical weight (kg) – current weight)/presurgical weight*100], percent excess weight loss (%EWL) by the formula [(presurgical weight – current weight)/(presurgical weight – (height (cm) – 100))*100] and percentage of excess BMI loss (%EBL) by the formula [((presurgical BMI – current BMI)/(presurgical BMI – 25))*100] [38]. Waist circumference was measured at the midpoint between the lower rib and iliac crest, hip circumference as the maximum circumference at the level of the buttocks [87]. Body composition was assessed by Bioelectrical Impedance Analysis (BIA; NutriPlus, Data-Input, Darmstadt, Germany).

2.2.2 Eating Behavior Questionnaires

Subjects filled in the following questionnaires, all of which measuring eating behavior traits rather than current states:

1. The Three Factor Eating Questionnaire (TFEQ) which assesses three dimensions of eating behavior, i.e. cognitive restraint eating, disinhibition, and general feelings of hunger [156].
2. The Power of Food Scale (PFS) which assesses appetite for, rather than consumption of, palatable foods and does not include any items describing actual food consumption [98].
3. The Food Frequency Questionnaire (FFQ) which assesses actual dietary habits and is composed of 24 different food categories [50]. Here, subjects rated the frequency of intake for each food category on a six level scale: 1 = ‘almost every day’, 2 = ‘several times a week’, 3 = ‘once a week’, 4 = ‘several times a month’, 5 = ‘once a month or less frequent’, 6 = ‘never’.

2.2.3 Appetite, Hunger, Wanting and Liking Ratings

Ratings on appetite and hunger were performed by using standard 100 mm 'Visual Analogue Rating Scales (VAS)' anchored at each end by 'not at all' and 'extremely' [58]. Subjects rated on the following items: hunger, satiety, fullness, prospective food consumption, as well as in an inverse scale the desire to eat something fatty, salty, sweet or savory. For these ratings regular paper sheets were used.

For the assessment wanting and liking of distinct food categories, a computer task was applied during which a total of 42 different food pictures were displayed on a computer screen. The pictures were presented in a randomized order for three seconds (Presentation®; Neurobehavioral Systems, Inc., Albany, CA, USA). Each of the 42 food pictures belonged to one of the three following food categories (14 pictures in each category): high-calorie non-sweet (e.g., pizza), high-calorie sweet (e.g., ice cream) and low-calorie (e.g., salad) food pictures. During the presentation of each picture subjects were asked first to rate on 'How much do you want this food?' (wanting) and then on 'How pleasant is the taste of this food?' (liking) on a 1-5 point scale (1 = not at all; 5 = extremely) by pressing the respective number on a computer keyboard. By pressing 'enter' the next food picture was shown. Participants were instructed to view each picture quickly in order to give an accurate rating. Ratings on food pictures of each food category were averaged [56].

Both the ratings on the VAS as well as the rating on wanting/liking (picture presentation task) were performed twice at two different time intervals (8.45 - 9.00 a.m. and 9.15 – 9.30 a.m.).

2.2.4 Taste Recognition Task

A standardized taste recognition task [138] was performed by the subjects to assess recognition thresholds for 5 different tastes. The distinct tastes were tested in the following order: sweet, salty, sour, bitter, and umami. During the tasks subjects were provided with a series of 25 ml plastic cups (Medication cups, Wiegand AG, Bülach, CH) each filled with 10 ml of distinct solutions. During all distinct taste recognition tasks the subjects underwent a total of 5 tasting runs with increasing concentrations of the taste substance in each run. During each run the subjects were provided with 3 cups with two of them containing water and one the respective taste dissolved in water in a defined concentration. The order of the provided 3 cups in each run was randomized. The time interval between each specific taste testing task was set to be 60 seconds during which the subjects rinsed their mouth with water.

During the task, the subjects were asked to take a small sip of each solution getting the tongue soaked without swallowing, and then to spit out the solution after tasting. Water rinses were used between each run to prevent carry-over from one to the next run. The task of the subjects was to state when he/she first recognized a specific taste. If the subjects correctly stated the taste of the solution, the respective concentration was defined as the recognition threshold, and the specific taste task was terminated. The site staff captured the recognition thresholds in a 1-6 scale (recognized concentration: 1 - 5; 6: taste not recognized) during the task.

The following substance and concentrations were applied for the distinct tasting tasks. Sweet: Sucrose; 1.0, 2.5, 4.0, 8.0, 12.0 g/l. Salty: Sodium chloride; 0.2, 0.4, 0.6, 1.0, 1.5 g/l. Sour: Citric acid (acidum citricum monohydricum crist, PHEUR); 0.1, 0.3, 0.5, 0.7, 1.0 g/l. Bitter: Caffeine citrate (caffeine citrate, INRESA, NF XIII, Bartenheim, France); 0.1, 0.2, 0.4, 0.6, 1.0 g/l and Umami: Monosodium glutamate (L-Glutamic acid monosodium salt hydrate, SIGMA-ALDRICH Co., St. Louis, USA); 0.1, 0.2, 0.4, 0.6, 1.0 g/l.

The solutions were prepared every two weeks and stored in a refrigerator, but for the taste detection task solutions were provided at room temperature.

2.2.5 Hedonic Sweet Creamy Test

The aim of this standard tasting test [45] was to assess the usual taste experience [7] at suprathreshold concentration, in particular how much the subjects like (pleasantness) and want (wanting more) a distinct solution of different intensities of sweetness and creaminess and the combination of both. Also, the perception of sweetness and creaminess was assessed with each provided solution.

During the test, a tray of 16 ordered solutions (25 ml cups) containing very low fat milk (0.1% fat), whole milk (3.5% fat), half and half (19.8% fat) and cream (35.0% fat) in combination with distinct sugar contents (0%, 2.5%, 5%, 10% added sucrose by weight) was provided to the subjects [133]. The order of the provided solutions is summarized in **Table 1**.

Table 1 Hedonic Sweet Creamy Test - Test Solutions

	fat content			
sugar content	**0.1%**	**3.5%**	**19.8%**	**35.0 %**
0%	No. 1	No. 2	No. 3	No. 4
2.5%	No. 5	No. 6	No. 7	No. 8
5%	No. 9	No. 10	No. 11	No. 12
10%	No. 13	No. 14	No. 15	No. 16

The subjects were instructed to rinse their mouth with water before and after each tasting session during which they took a mouthful of each solution, swirled it in their mouth, performed their rating and spat it out or swallowed it thereafter. The subjects rated each solution using the following questions: ‘How sweet is it?’; ‘How creamy is it?’; ‘How pleasant is it?’; ‘How much would you like to have more?’). Ratings were performed by using a 100-mm Visual Analogue Scale (VAS) anchored with the descriptors ‘not at all’ and ‘extremely’ (sweet; creamy; pleasant; wanting more) at each end [31, 133, 138].

2.3 Statistical Analyses

Data was analyzed using the statistical software Superior Performing Software Systems PC Version 12.01 for Windows (SPSS Inc., Chicago, IL). Data was tested by the Kolmogorov-Smirnov-Test for normal distribution. Normal distributed data is provided as means ± standard error of mean (SEM). Non-normal distributed data is provided as median with 95% CV [88].

For metrically scaled variables differences between two related groups were tested by paired student‘s t-test. Differences between more than two groups were assessed by One-Way analysis of variance (ANOVA) or ANOVA with repeated measures followed by the post hoc Tukey test. In the case that ANOVA with repeated measures was performed, Greenhouse Geisser was chosen if sphericity was < 0.05 instead of the sphericity assumed significance value.

For ordinal scaled variables, differences between more than two related groups were tested by Friedman test and for pairwise comparisons by Wilcoxon signed-rank test. Differences between more than two independent groups were tested by the Kruskal-Wallis-H test, and for pairwise comparisons by the Mann-Whitney U test, [88]. *P*-value < 0.05 was considered significant [88].

3 Results

Results of the Eating Behavior and Taste Studies are summarized in the following.

3.1 Eating Behavior Study – Case Control: Patients after Gastric Banding compared to Obese & Non-Obese Subjects

3.1.1 Subjects' Characteristics

Subject characteristics of GB patients, OB and non-OB subjects, who participated in this study, are summarized in **Table 2**.

Table 2 Participant characteristics of 133 non-obese (non-OB), 138 obese (OB) and 116 gastric banding (GB) subjects

Characteristics	**non-OB**	**OB**	**GB**
female/male	109/24	109/29	92/24
age (years)	40.6 ± 13.7 (21 – 69)	40.9 ± 11.7 (19 – 67)	44.5 ± 10.3[a] (21 – 69)
current BMI (kg/m^2)	22.3 ± 2.0 (18.4 – 26.9)	44.7 ± 6.1[b] (35.4 – 66.6)	35.3 ± 5.6[b] (25.4 – 52.5)
pre-operation BMI (kg/m^2)	-	-	44.9 ± 4.8 (36.4 – 57.5)
months since operation	-	-	88.6 ± 31.5 (16 – 156)

Data is mean ± SD and ranges. [a]p = 0.035 vs. non-OB, [b]p < 0.001 vs. non-OB, p-value by One-Way ANOVA, post hoc Tukey.

3.1.2 Power of Food Scale (PFS)

Results of the PFS scores are illustrated in **Figure 5**. The PFS domain scores on 'food available' and 'food present' as well as in the aggregated domain score showed a marked difference across the 3 study groups (all p < 0.001 for respective overall ANOVA models) which was not the case in regard of the 'food tasted' domain (p = 0.13).

OB subjects had higher 'food available' (2.6 ± 1.0 vs. 1.8 ± 0.6; $p < 0.001$), 'food present' (3.0 ± 1.1 vs. 2.3 ± 0.9; $p < 0.001$), and aggregated PFS (2.8 ± 0.9 vs. 2.3 ± 0.6; $p < 0.001$) domain scores than non-OB subjects (Fig. 1) [136]. Gastric banding patients displayed significantly lower 'food available' (2.2 ± 0.8) and 'food present' (2.5 ± 1.0) domain scores as well as a lower aggregated domain score (2.5 ± 0.8) than the non-OB subjects (all $p < 0.001$). However, while the 'food present' and aggregated domain score in the gastric banding patients did not differ from that in the non-OB control group (both $p > 0.30$), gastric banding patients still displayed markedly higher 'food available' domain scores ($p = 0.001$).

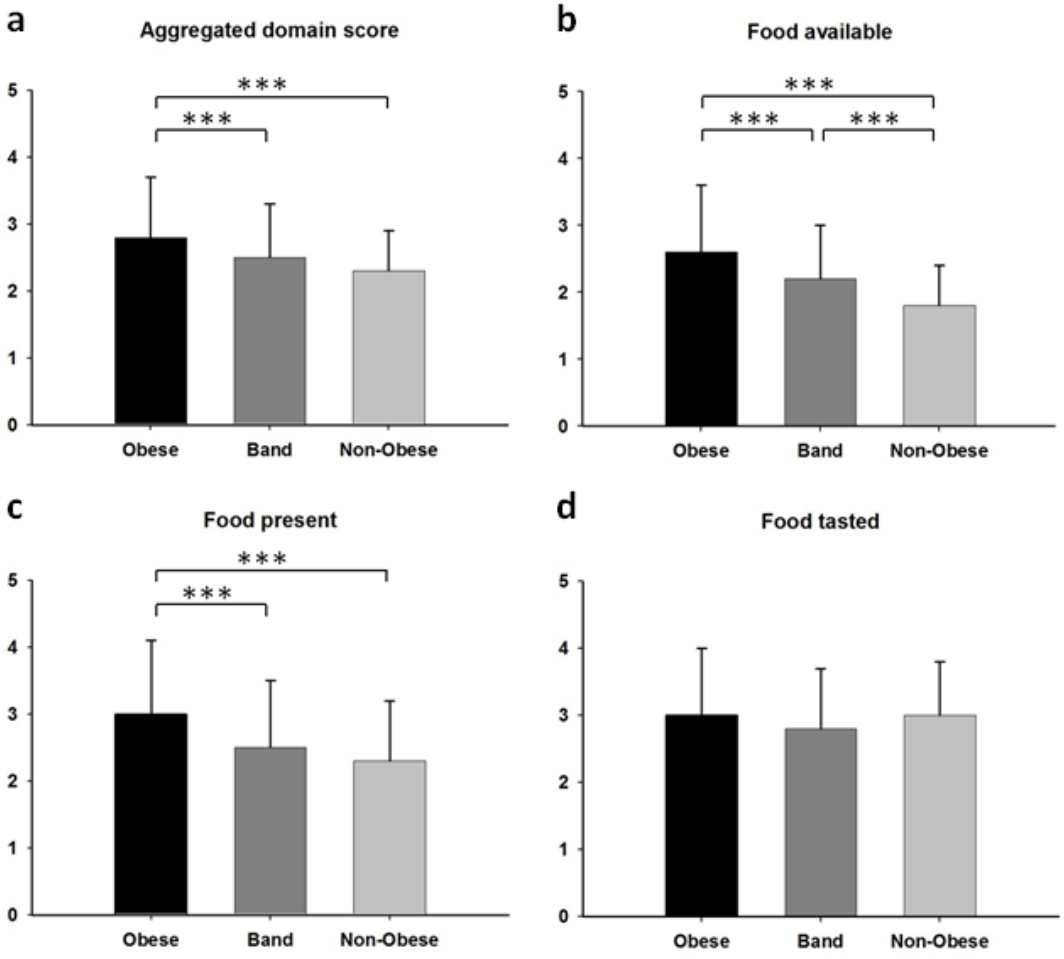

Figure 5 Mean ± SD (a) aggregated Power of Food Scale (PFS) score and scores of the PFS sub-domains (b) 'food available' (regarding food readily available in the environment but not physically present), (c) 'food present' (regarding food present but not tasted), and (d) 'food tasted' (regarding food when first tasted but not consumed) in 133 non-obese control participants, 138 severely obese patients and 116 gastric banding patients; ***$p < 0.001$ (post hoc Tukey tests)

3.2 Eating Behavior Study – Follow-up: Patients pre vs. post RYGB Surgery

3.2.1 Subjects' Characteristics

Subject characteristics of 44 patients before and after RYGB surgery, who participated in the Follow-up Eating Behavior Study, are summarized in **Table 3**.

Table 3 Body weight measures of 44 patients (33 females) before and between 11 and 39 (15.9 ± 0.9) months after Roux-en Y gastric bypass surgery (RYGB).

characteristics	**pre RYGB**	**post RYGB**	**Δ**	**Δ%**
body weight (kg)	131.6 ± 2.8	81.1 ± 1.7[a]	50.6 ± 1.9	38.1 ± 1.0
BMI (kg/m^2)	47.3 ± 1.1	29.1 ± 0.6[a]	18.1 ± 0.8	37.7 ± 1.0
excessive weight (kg)	64.0 ± 2.7	13.9 ± 1.7[a]	50.1 ± 2.0	79.5 ± 2.1
excessive BMI (kg/m^2)	22.3 ± 1.1	4.1 ± 0.6[a]	18.2 ± 0.7	83.7 ± 2.1

Data is mean ± SEM and ranges. Δ = changes after RYGB surgery (postsurgical value -presurgical value). [a]$p < 0.001$ vs. pre RYGB, *p*-value by Student`s t-test.

3.2.2 Power of Food Scale (PFS)

Results of the PFS score are shown in **Figure 6**. After the surgery patients show markedly lower aggregated PFS domain scores (3.0 ± 0.1 vs. 2.3 ± 0.1; $p < 0.001$) than before surgery and also the subdomains 'food available' (2.8 ± 0.2 vs. 2.0 ± 0.1), 'food present' (3.2 ± 0.1 vs. 2.1 ± 0.1) and 'food tasted' (3.2 ± 0.1 vs. 2.8 ± 0.1) were found to be markedly reduced (all $p < 0.001$).

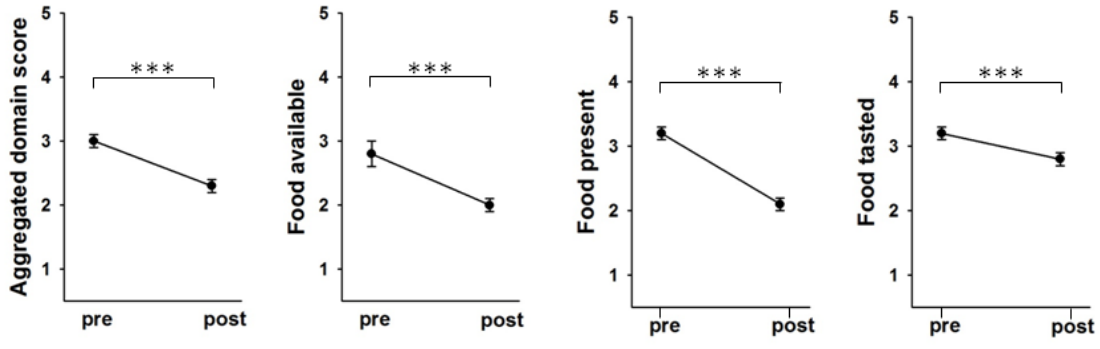

Figure 6 Mean ± SEM aggregated Power of Food Scale (PFS) score and scores of the PFS sub-domains 'food available' (regarding food readily available in the environment but not physically present) 'food present' (regarding food present but not tasted) and 'food tasted' (regarding food when first tasted but not consumed) in 44 patients before (pre) and on average 15.9 ± 0.9 (11 - 39) months after (post) Roux-en Y gastric bypass surgery; ***$p < 0.001$ by Student's t-test.

3.2.3 Food Frequency Questionnaire (FFQ)

Results of the FFQ before and 15.9 ± 0.9 months after RYGB surgery are illustrated in **Figure 7**. After the RYGB surgery patients showed a more frequent consumption of foods rich in protein such as poultry (2.7 ± 0.2 vs. 3.0 ± 0.2; p = 0.005), fish (3.5 ± 0.2 vs. 4.0 ± 0.2; p = 0.007), and eggs (2.6 ± 0.2 vs. 3.3 ± 0.2; p = 0.002), while consuming distinctly less fatty sweets such as chocolate (3.2 ± 0.2 vs. 2.7 ± 0.2; p = 0.048), cake, biscuits, and cookies (3.4 ± 0.2 vs. 3.0 ± 0.2; p = 0.09) and also tended to consume less fruit juice/soft drinks (3.8 ± 0.3 vs. 3.2 ± 0.3; p = 0.08) than presurgically. Furthermore, patients consumed cooked vegetables more frequently after RYGB surgery than before the surgery (1.6 ± 0.1 vs. 2.2 ± 0.2; p = 0.005).

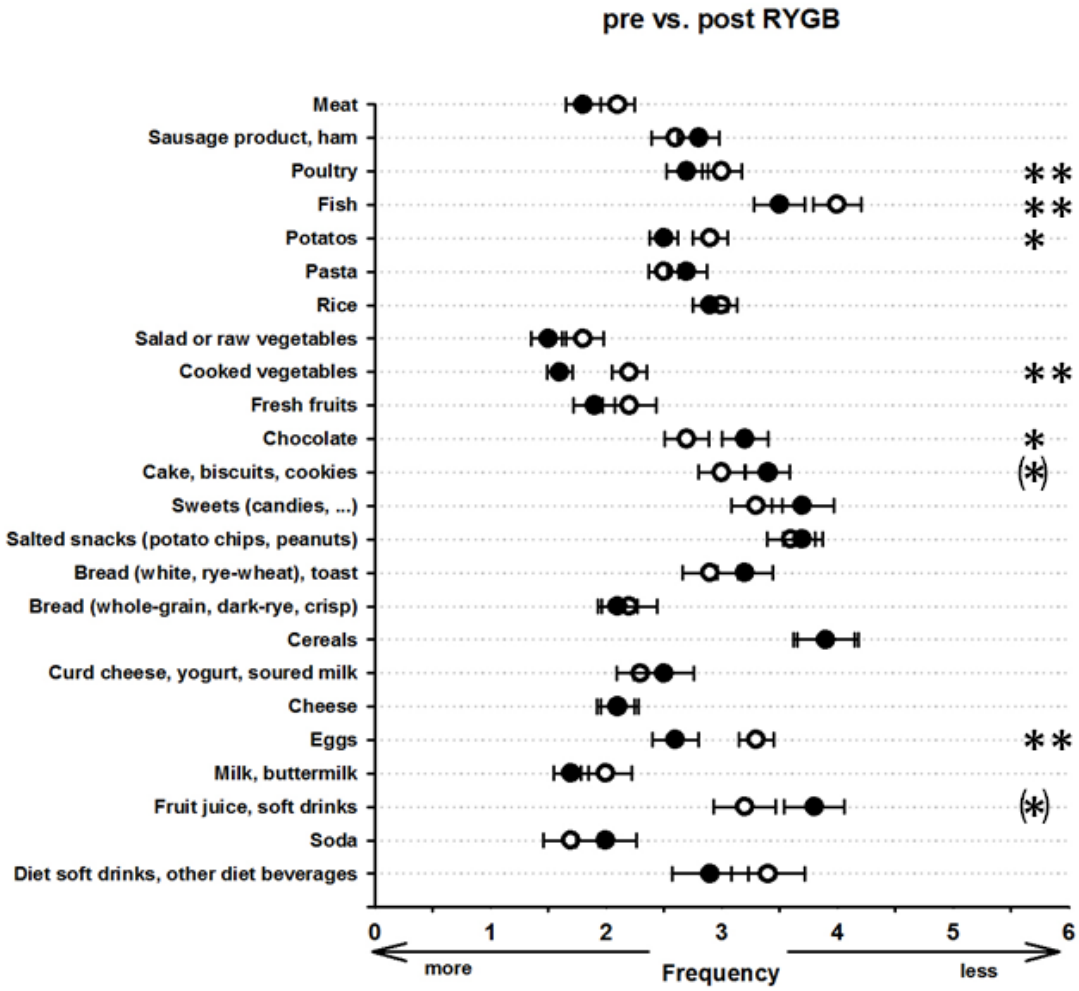

Figure 7 Food Frequency Questionnaire (FFQ) in 44 patients before (open circle) and on average 15.9 ± 0.9 (11-39) months after Roux-en Y gastric bypass (RYGB) surgery *(black circle)*. $^{(*)}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$, p-value by Wilcoxon signed-rank test [evaluation: high value corresponds less frequent consumption].

3.3 Taste Study – Case Control: Patients after RYGB Surgery, Obese & Non-Obese Subjects

3.3.1 Subjects' Characteristics

Clinical, anthropemetric, and BIA data of the 3 study groups are provided in **Table 4**. The sex distribution and age of the 3 study groups was similar (all $p > 0.09$), whereas, as expected, the OB group was heavier, had a greater waist and hip circumference, and displayed a greater fat and also fat free mass than the non-OB group (all $p < 0.001$). Respective values were intermediate in the RYGB group with all showing significant differences compared with the OB group (all $p < 0.01$) and also compared with the non-OB group (all $p < 0.05$).

Table 4 Clinical, anthropemetric, and bioelectrical impedance analysis data of 51 non-obese (non-OB), 59 obese (OB) and 44 subjects after Roux en-Y gastric bypass (RYGB).

characteristics	**non-OB** n = 51	**OB** n = 59	**RYGB** n = 44	***p* overall**
female/male	46/5	46/13	39/5	-
age (years)	39.6 ± 1.8 (20 – 69)	44.1 ± 1.5 (22 – 68)	42.9 ± 1.2 (23 – 61)	0.096
weight (kg)	61.7 ± 1.2 (48.2 – 81.4)	120.7 ± 2.3[e] (76.0 – 168.3)	76.6 ± 1.7[e,f] (61.6 – 102.1)	< 0.001
height (m)	1.66 ± 0.01 (1.50 – 1.88)	1.67 ± 0.01 (1.52 – 1.87)	1.64 ± 0.01 (1.52 – 1.87)	0.34
BMI (kg/m^2)	22.3 ± 0.3 (18.6 – 27.2)	43.4 ± 0.7[e] (26.4 – 53.8)	28.3 ± 0.5[e,f] (21.7 –37.7)	< 0.001
waist (cm)	75.5 ± 1.2 (60 – 98)	123.1 ± 1.8[e] (89 – 157)	87.8 ± 1.5[e,f] (73 – 124)	< 0.001
hip (cm)	96.8 ± 0.8 (86 – 112)	136.6 ± 1.4[e] (104 – 157)	106.6 ±1.4[e,f] (84 – 125)	< 0.001
waste-hip ratio	0.78 ± 0.01 (0.65 – 0.97)	0.90 ± 0.01[e] (0.74 – 1.16)	0.83 ± 0.02[a,d] (0.65 – 1.48)	< 0.001
fat mass (kg)	15.1 ± 0.8 (4.9 – 33.6)	56.1 ± 1.5[e] (21.4 – 84.8)	23.5 ± 1.3[e,f] (7.8 – 46.9)	< 0.001
fat mass (%)	23.9 ± 0.9 (9.5 – 41.3)	46.4 ± 0.9 [e] (28.0 – 57.7)	30.5 ± 1.2[e,f] (11.4 – 45.8)	< 0.001
fat free mass (kg)	46.4 ± 0.8 (35.5 – 64.0)	64.8 ± 2.0[e] (31.0 – 111.2)	52.7 ± 1.5[a,f] (42.4 – 85.6)	< 0.001
phase angle (°)	6.2 ± 0.1 (4.9 – 8.0)	6.0 ± 0.1 (4.4 – 7.4)	5.3 ± 0.1[e,f] (2.5 – 6.8)	< 0.001

Data is mean ± SEM and ranges. [a]$p < 0.05$ vs. non-OB; [b]$p < 0.05$ vs. OB; [c]$p < 0.01$ vs. non-OB; [d]$p < 0.01$ vs. OB; [e]$p < 0.001$ vs. non-OB [f]$p < 0.001$ vs. OB, *p*-value by One-Way ANOVA, post hoc Tukey.

3.3.2 Eating Behavior Questionnaires

Results of the TFEQ and the PFS are summarized in **Table 5**. While there were no differences on the cognitive restraint domain in the TFEQ between the 3 study groups ($p = 0.21$), there were significant differences in the disinhibition and hunger domain (both $p < 0.001$). Specifically, the OB group displayed markedly higher disinhibition and hunger scores than the two other groups ($p < 0.001$ for all comparisons). There was also a difference in disinhibition between the RYGB and the non-OB groups with subjects of the RYGB group showing slightly higher scores ($p = 0.027$).

On the PFS, the OB group displayed significantly higher scores of the 'food available' and 'food present' score as well as on the aggregated domain score than the subjects of the non-OB and RYGB group ($p < 0.001$ for all comparisons). No differences between groups were found in the 'food tasted' domain score ($p > 0.14$).

Table 5 Three Factor Eating Questionnaire (TFEQ) and Power of Food Scale (PFS) of 51 non-obese (non-OB), 59 obese (OB) and 44 subjects after Roux-en Y gastric bypass surgery (RYGB).

	non-OB	OB	RYGB	*p* overall
TFEQ				
cognitive restraint	8.1 ± 0.5	8.2 ± 0.5	9.4 ± 0.6	0.21
disinhibition	3.6 ± 0.4	9.2 ± 0.4[c]	5.0 ± 0.4[a,d]	< 0.001
hunger	3.8 ± 0.4	7.2 ± 0.5[c]	4.2 ± 0.5[d]	< 0.001
PFS				
aggregated score	2.4 ± 0.1	3.1 ± 0.1[c]	2.5 ± 0.1[b]	< 0.001
food available	1.8 ± 0.1	2.8 ± 0.1[c]	2.1 ± 0.1[d]	< 0.001
food present	2.2 ± 0.1	3.2 ± 0.2[c]	2.4 ± 0.1[b]	< 0.001
food tasted	3.1 ± 0.1	3.4 ± 0.1	3.0 ± 0.1	0.15

Mean ± SEM of the TFEQ with scores 'cognitive restraint eating', 'disinhibition' and 'subjective feelings of hunger' as well as of the aggregated PFS score and mean ± SEM scores of the PFS sub-domains 'food available' (regarding food readily available in the environment but not physically present) 'food present' (regarding food present but not tasted), and 'food tasted' (regarding food when first tasted but not consumed). [a]$p < 0.05$ vs. non-OB, [b]$p < 0.01$ vs. OB, [c]$p < 0.001$ vs. non-OB, [d]$p < 0.001$ vs. OB, p-value by One-Way ANOVA, post hoc: Tukey.

Results of the FFQ are summarized in **Table 6**. OB subjects reported a more frequent consumption of meat ($p = 0.005$), sausages/ham ($p = 0.001$), poultry ($p = 0.005$), salted snacks ($p = 0.008$), sweets ($p = 0.011$), and diet soft drinks ($p = 0.001$), while they consumed distinctly less chocolate ($p = 0.017$), cooked vegetables ($p = 0.034$) and cereals ($p < 0.001$) than the non-OB subject group.

RYGB patients consumed more frequently meat ($p = 0.001$), sausages/ham ($p = 0.019$), poultry ($p < 0.001$), eggs ($p = 0.002$), salted snacks ($p < 0.001$), and diet soft drinks ($p < 0.001$), while they distinctly less frequently consumed chocolate ($p = 0.001$), salad/raw vegetables ($p = 0.015$) and cereals ($p = 0.001$) than the non-OB subject group. RYGB patients consumed diet soft drinks even more often than subjects of the OB group ($p = 0.046$).

The 3 study groups showed no difference in the frequency of carbohydrate rich food consumption such as potatoes ($p > 0.38$), pasta ($p > 0.41$), rice ($p > 0.51$), any kind of bread ($p > 0.39$), cake/biscuits/cookies ($p > 0.37$) and fruit juice/soft drinks ($p > 0.60$), and also not in other protein rich foods such as fish ($p > 0.12$), yoghurt/curd cheese ($p > 0.12$), milk/buttermilk ($p > 0.46$) and cheese ($p > 0.92$), as well as soda ($p > 0.42$).

Table 6 Food Frequency Questionnaire (FFQ) of 50 non-obese (non-OB), 59 obese (OB) and 43 subjects after Roux-en Y gastric bypass surgery (RYGB).

FFQ	non-OB	OB	RYGB	*p* overall
meat	2.5 ± 0.16	2.0 ± 0.15[c]	1.8 ± 0.13[c]	0.002
sausage, ham	3.4 ± 0.18	2.7 ± 0.15[c]	2.8 ± 0.14[a]	0.001
poultry	3.3 ± 0.14	2.8 ± 0.16[c]	2.4 ± 0.09[d]	<0.001
fish	4.2 ± 0.12	4.2 ± 0.18	3.7 ± 0.21	0.13
potatoes	2.9 ± 0.14	2.7 ± 0.13	2.6 ± 0.12	0.39
pasta	2.3 ± 0.10	2.5 ± 0.13	2.5 ± 0.13	0.42
rice	2.8 ± 0.13	2.9 ± 0.12	2.8 ± 0.13	0.52
salad, raw vegetables	1.2 ± 0.11	1.4 ± 0.11	1.6 ± 0.15[a]	0.050
cooked vegetables	1.5 ± 0.09	1.9 ± 0.12[a]	1.8 ± 0.14	0.098
fresh fruits	1.3 ± 0.11	1.6 ± 0.13	1.7 ± 0.18	0.17
chocolate	2.4 ± 0.18	3.0 ± 0.19[a]	3.3 ± 0.21[c]	0.003
cake, biscuits, cookies	3.1 ± 0.18	3.1 ± 0.18	3.4 ± 0.20	0.38
sweets (candies, etc.)	4.2 ± 0.16	3.4 ± 0.21[a]	3.7 ± 0.22	0.032
salted snacks	4.3 ± 0.14	3.7 ± 0.17[c]	3.4 ± 0.18[d]	0.001
bread (white, rye-wheat), toast	3.4 ± 0.22	3.1 ± 0.19	3.0 ± 0.22	0.40
bread (whole grain, dark, rye)	1.5 ± 0.11	1.9 ± 0.18	1.7 ± 0.16	0.49
cereals	2.4 ± 0.20	3.4 ± 0.19[d]	3.6 ± 0.27[c]	<0.001
yoghurt, curd cheese	1.8 ± 0.15	2.3 ± 0.20	2.5 ± 0.24	0.13
cheese	2.0 ± 0.15	2.1 ± 0.16	1.9 ± 0.13	0.93
eggs	3.1 ± 0.13	2.8 ± 0.13	2.5 ± 0.16[c]	0.007
milk, buttermilk	1.9 ± 0.21	2.2 ± 0.21	1.8 ± 0.20	0.47
fruit juice, soft drinks	3.8 ± 0.22	3.9 ± 0.21	3.6 ± 0.27	0.61
soda	1.3 ± 0.15	1.2 ± 0.11	1.5 ± 0.21	0.43
diet soft drinks, other diet beverages	5.4 ± 0.14	4.2 ± 0.23[c]	3.5 ± 0.30[b,d]	<0.001

Data is mean ± SEM. [a]$p < 0.05$ vs. non-OB; [b]$p < 0.05$ vs. OB; [c]$p < 0.01$ vs. non-OB; [d]$p < 0.001$ vs. non-OB subjects; *p*-value by Mann-Whitney U-test, overall *p*-value by Kruskal-Wallis test [evaluation: high value corresponds less frequent consumption].

3.3.3 Appetite, Hunger, Wanting and Liking Ratings

Results of the VAS rating scales on hunger, satiety, fullness, prospective consumption, the desire to eat something sweet, salty, savory and fatty assessed at 08:45 and 09:15 a.m. are provided in **Table 7**. Overall, there were marked differences in hunger, satiety, fullness, and prospective consumption ratings between the 3 groups (all $p < 0.012$), but not in the desire to eat food of different tastes (all $p > 0.63$), with exception of the sweet desire ($p = 0.032$).

Specifically, the non-OB group rated an increased prospective food consumption compared to the RYGB group ($p = 0.006$) as well as more hunger (both $p < 0.033$) and less satiety (both $p < 0.014$) and fullness (both $p < 0.002$) than the OB and the RYGB group, whereas the latter two groups showed no differences in the respective ratings (all $p > 0.096$).

Table 7 Results of Hunger Ratings of 51 non-obese (non-OB), 59 obese (OB) and 44 subjects after Roux-en Y gastric bypass surgery (RYGB).

Hunger Rating	**time** [a.m.]	**non-OB**	**OB**	**RYGB**	***p* group**	***p* time**	***p* group x time**
hunger	8:45 9:15	45.7 ± 4.1 56.0 ± 4.2	31.6 ± 3.7[a] 42.4 ± 4.0	33.1 ± 3.5 40.7 ± 4.9[b]	0.011[a,b]	<0.001	0.80
satiety	8:45 9:15	25.7 ± 3.2 20.8 ± 3.2	41.8 ± 3.8[c] 32.3 ± 3.8	45.2 ± 4.5[d] 44.9 ± 4.9[e]	<0.001[a,e]	0.014	0.17
fullness	8:45 9:15	13.5 ± 2.3 12.3 ± 2.1	31.0 ± 3.3[c] 26.8 ± 3.4[c]	30.2 ± 4.6[d] 31.6 ± 4.8[d]	<0.001[c,e]	0.46	0.47
consumption	8:45 9:15	50.2 ± 2.4 54.7 ± 3.1	44.4 ± 3.3 50.4 ± 3.4	36.9 ± 3.3[b] 40.1 ± 3.7[b]	0.008[d]	0.002	0.72
desire to eat sweet*	8:45 9:15	64.7 ± 4.3 52.2 ± 4.4	74.5 ± 4.3 68.7 ± 4.3[a]	74.6 ± 4.8 68.8 ± 4.9[b]	0.032	0.001	0.38
desire to eat salty*	8:45 9:15	60.8 ± 4.1 55.6 ± 4.5	62.5 ± 4.3 58.5 ± 4.2	56.3 ± 5.3 53.2 ± 5.5	0.64	0.044	0.93
desire to eat savory*	8:45 9:15	66.3 ± 4.0 62.1 ± 4.6	68.4 ± 4.5 68.6 ± 4.0	70.7 ± 4.3 63.5 ± 4.8	0.73	0.078	0.33
desire to eat fatty*	8:45 9:15	85.3 ± 2.7 81.9 ± 3.4	81.0 ± 3.2 80.1 ± 3.1	82.8 ± 3.8 83.7 ± 3.3	0.71	0.47	0.57

Mean ± SEM: Hunger Rating on Visual Analogue Scale (VAS, 0-100 mm) with scores 'hunger', 'satiation', 'fullness', and 'consumption' and 'the desire to eat sweet salty, savory and fatty'. [a]$p < 0.05$ OB vs. non-OB, [b]$p < 0.05$ RYGB vs. non-OB, [c]$p < 0.01$ OB vs. non-OB, [d]$p < 0.01$ RYGB vs. non-OB, [e]$p < 0.001$ RYGB vs. non-OB, p-value by One-Way ANOVA resp. ANOVA with repeated measures (group x time), post hoc: Tukey. [*interpretation: higher score corresponds less desire.]

Ratings of wanting and liking on the presented food pictures are provided in **Table 8**. While there were no differences in liking and wanting on high-calorie non-sweet and low-calorie food pictures between the 3 study groups (all $p > 0.16$), ratings on the high-calorie sweet food pictures significantly differed between groups (both $p < 0.020$). Specifically, the RYGB group rated significantly lower liking and wanting scores on high-calorie sweet food pictures than the other 2 groups (both $p < 0.015$).

Table 8 Wanting & Liking of 39 non-obese (non-OB), 56 obese (OB) and 43 subjects after Roux-en Y gastric bypass surgery (RYGB).

	time [a.m.]	**non-OB**	**OB**	**RYGB**	***p* group**	***p* time**	***p* group x time**
high-calorie non-sweet food							
wanting	8:50	2.2 ± 0.1	2.7 ± 0.1	2.3 ± 0.1	0.19	0.010	0.102
	9:20	2.5 ± 0.1	2.7 ± 0.1	2.5 ± 0.1			
liking	8:50	2.8 ± 0.1	3.1 ± 0.1	2.9 ± 0.1	0.17	0.001	0.10
	9:20	2.7 ± 0.1	3.0 ± 0.1	2.6 ± 0.1			
high-calorie sweet food							
wanting	8:50	2.5 ± 0.2	2.4 ± 0.1	2.0 ± 0.1	0.017[a]	< 0.001	0.073
	9:20	2.9 ± 0.2	2.4 ± 0.1	2.1 ± 0.1[b]			
liking	8:50	3.3 ± 0.1	3.1 ± 0.1	2.8 ± 0.1[a]	0.019[a]	0.001	0.20
	9:20	3.2 ± 0.1	3.0 ± 0.1	2.6 ± 0.1[b]			
low-calorie food							
wanting	8:50	2.9 ± 0.1	3.1 ± 0.1	2.9 ± 0.1	0.44	0.003	0.31
	9:20	3.2 ± 0.1	3.2 ± 0.1	3.0 ± 0.1			
liking	8:50	3.7 ± 0.1	3.5 ± 0.1	3.5 ± 0.1	0.46	0.003	0.25
	9:20	3.6 ± 0.1	3.5 ± 0.1	3.4 ± 0.1			

Mean ± SEM: Rating of wanting ('How much do you want this food?') and liking ('How pleasant is the taste of this food?') of high-calorie non-sweet, high-calorie sweet and low-calorie food pictures. [a]$p < 0.05$ RYGB vs. non-OB , [b]$p < 0.01$ RYGB vs. non-OB, *p*-value by One-Way ANOVA resp. ANOVA with repeated measures (group x time), post hoc: Tukey.

3.3.4 Taste Recognition Thresholds

Results of the taste recognition task are illustrated in **Figure 8**. Overall Kruskal-Wallis-H test indicated significant group differences in recognition thresholds for the salty (p = 0.026), sour (p = 0.001), bitter (p = 0.003), and umami (p < 0.001) taste but not for sweet taste (p = 0.48). Pairwise comparison indicated that the subjects of the OB groups recognized the salty taste on average at higher concentrations than subjects of the non-OB group (3.7 ± 0.2 vs. 3.0 ± 0.2; respectively, p = 0.013) and the same was true for sour (3.4 ± 0.1 vs. 2.8 ± 0.1; respectively, p < 0.001), bitter (4.9 ± 0.1 vs. 4.2 ± 0.2; respectively, p = 0.001), and umami (4.7 ± 0.2 vs. 3.2 ± 0.2; respectively, p < 0.001) recognition. Subjects of the RYGB group recognized salty (3.6 ± 0.2; p = 0.035), sour (3.4 ± 0.2; p = 0.003), and umami (4.0 ± 0.3; p = 0.020) taste at a higher concentration than the subjects of the non-OB group and also the recognition threshold for bitter taste (4.5 ± 0.2) showed in this direction but the group difference did not reach significance (p = 0.14). The RYGB group recognized umami at lower concentrations than the OB group (p = 0.038) and tended to recognize bitter taste at lower concentration, but the group difference did not reach significance (p = 0.089).

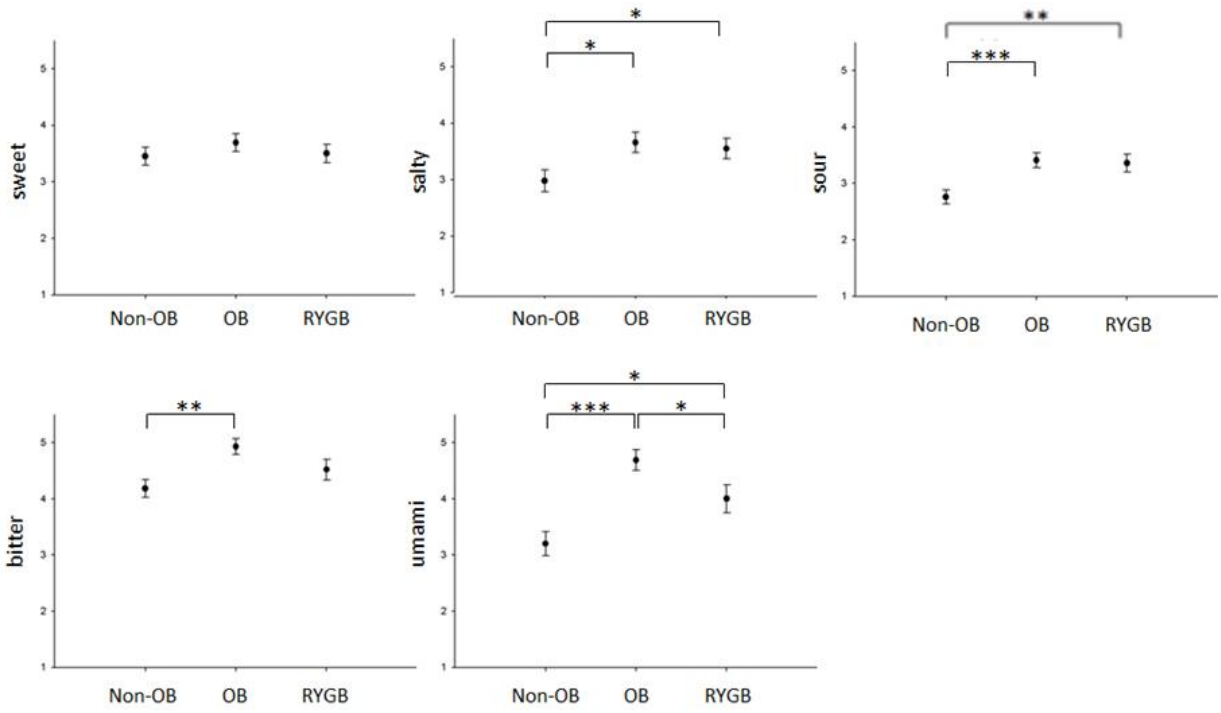

Figure 8 Mean ± SEM Taste thresholds of sweet, salty, sour, bitter and umami in 51 non-obese (non-OB), 58 obese (OB) and 44 subjects after Roux-en Y gastric bypass (RYGB) surgery. *p < 0.05, **p < 0.01, ***p < 0.001; p-value by Mann-Whitney U test.

3.3.5 Hedonic Sweet Creamy Test

Results of the Hedonic Sweet Creamy Test are summarized in **Table 9 - Table 13** and illustrated in **Figure 9** and **Figure 10**.

Non-OB, OB and RYGB subjects did not differ in the rating ‘How sweet is it?’ ($p > 0.64$ for group main effect) and in the rating ‘How creamy is it?’ ($p > 0.72$ for the group main effect). Study group showed no interaction with sugar concentration and/or fat content ($p > 0.23$). Study group only interacted with sugar concentration and fat content in the rating ‘How creamy is it?’ ($p = 0.015$).

Non-OB, OB and RYGB subjects did not differ in the hedonic rating ‘How pleasant is it?’ ($p > 0.087$ for group main effect). Study group showed no interaction with sugar concentration and/or fat content in the rating of ‘How pleasant is it?’ ($p > 0.31$).

Non-OB, OB and RYGB subjects differed in the rating of ‘How much would you like to have more?’ ($p = 0.030$ for group main effect). RYGB subjects rated lesser values for ‘How much would you like to have more?’ than OB subjects ($p = 0.025$), while non-OB and OB ($p > 0.74$) as well as non-OB and RYGB subjects ($p > 0.13$) did not differ. Study group showed no interaction with sugar concentration and/or fat content in the rating of ‘How much would you like to have more?’ ($p > 0.068$).

The rated value of ‘How sweet is it?’ increased with increasing sugar concentration ($p < 0.001$), the rated value of ‘How creamy is it?’ with increasing fat content ($p < 0.001$) of the test solution. An interaction in the ratings of ‘How sweet is it?’ and ‘How creamy is it?’ between fat content and sugar concentration (both $p < 0.001$) of the test solution was found.

The rated value of ‘How pleasant is it?’ increased with increasing fat content ($p < 0.001$) of the test solution, but decreased with sugar concentation ($p < 0.001$). No interaction in the rating ‘How pleasant is it?’ between fat content and sugar concentration was found ($p > 0.33$).

The rated value of ‘How much would you like to have more?’ increased with fat content ($p = 0.027$) and sugar concentration ($p < 0.001$). An interaction in the rating ‘How much would you like to have more?’ between fat content and sugar concentration was found ($p = 0.003$).

Table 9 Hedonic Sweet Creamy Test of 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB)

effect	**sweet**	**creamy**	**pleasant**	**wanting more**
group	0.65	0.73	0.088	0.030[a]
sugar concentration	< 0.001	0.15	< 0.001	< 0.001
sugar concentration x group	0.24	0.60	0.49	0.39
fat content	0.14	< 0.001	< 0.001	0.027
fat content x group	0.73	0.45	0.32	0.069
sugar concentration x fat content	< 0.001	< 0.001	0.34	0.003
sugar concentration x fat content x group	0.31	0.015	0.71	0.72

Data is *p*-value by ANOVA with repeated measures group, 4 (sugar content) x 4 (fat content); [a]OB vs. RYGB $p < 0.05$, post hoc: Tukey.

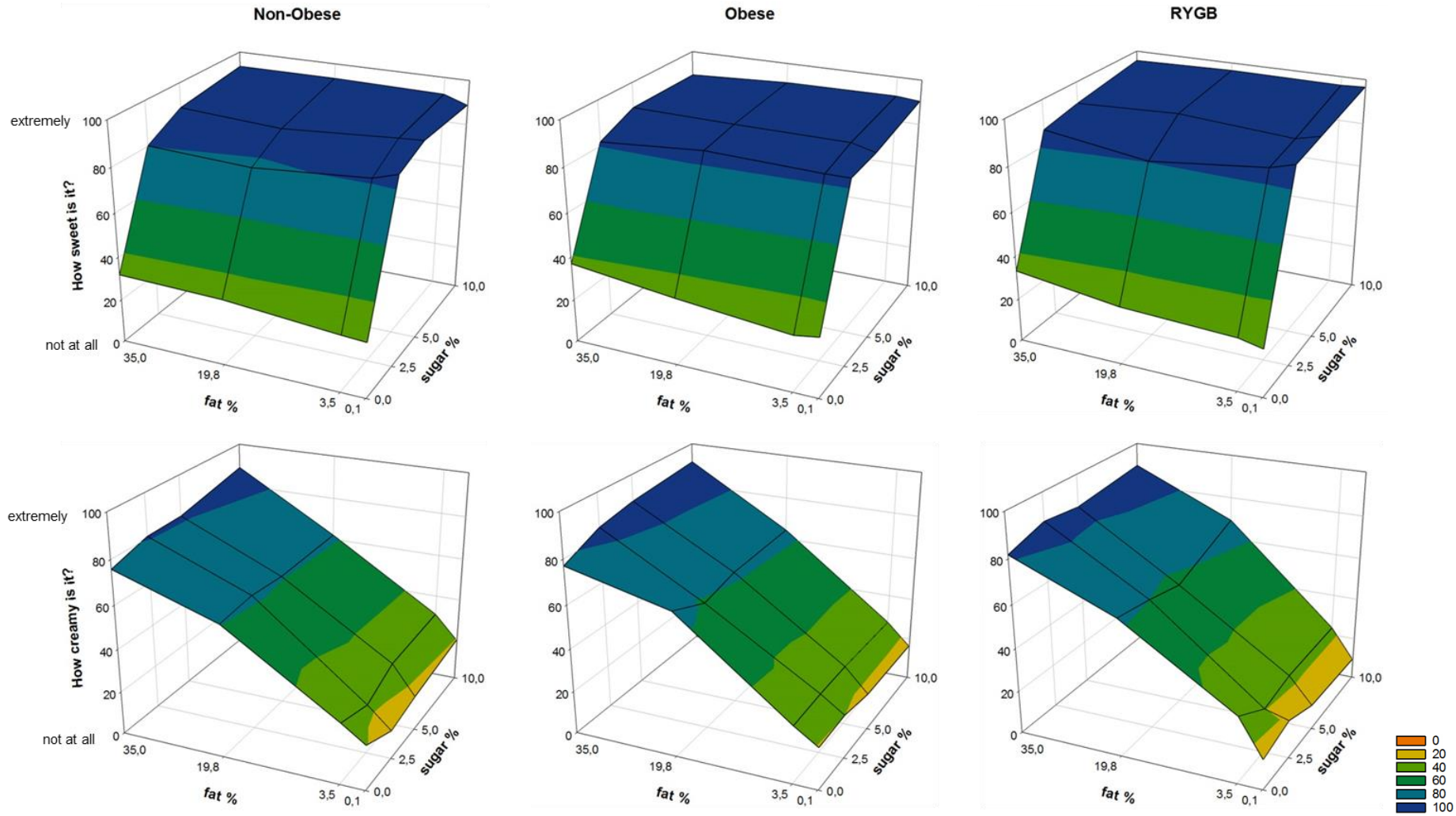

Figure 9 Response surface area mapping the mean values of the sweet and creamy response (Hedonic Sweet Creamy Test) in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB)

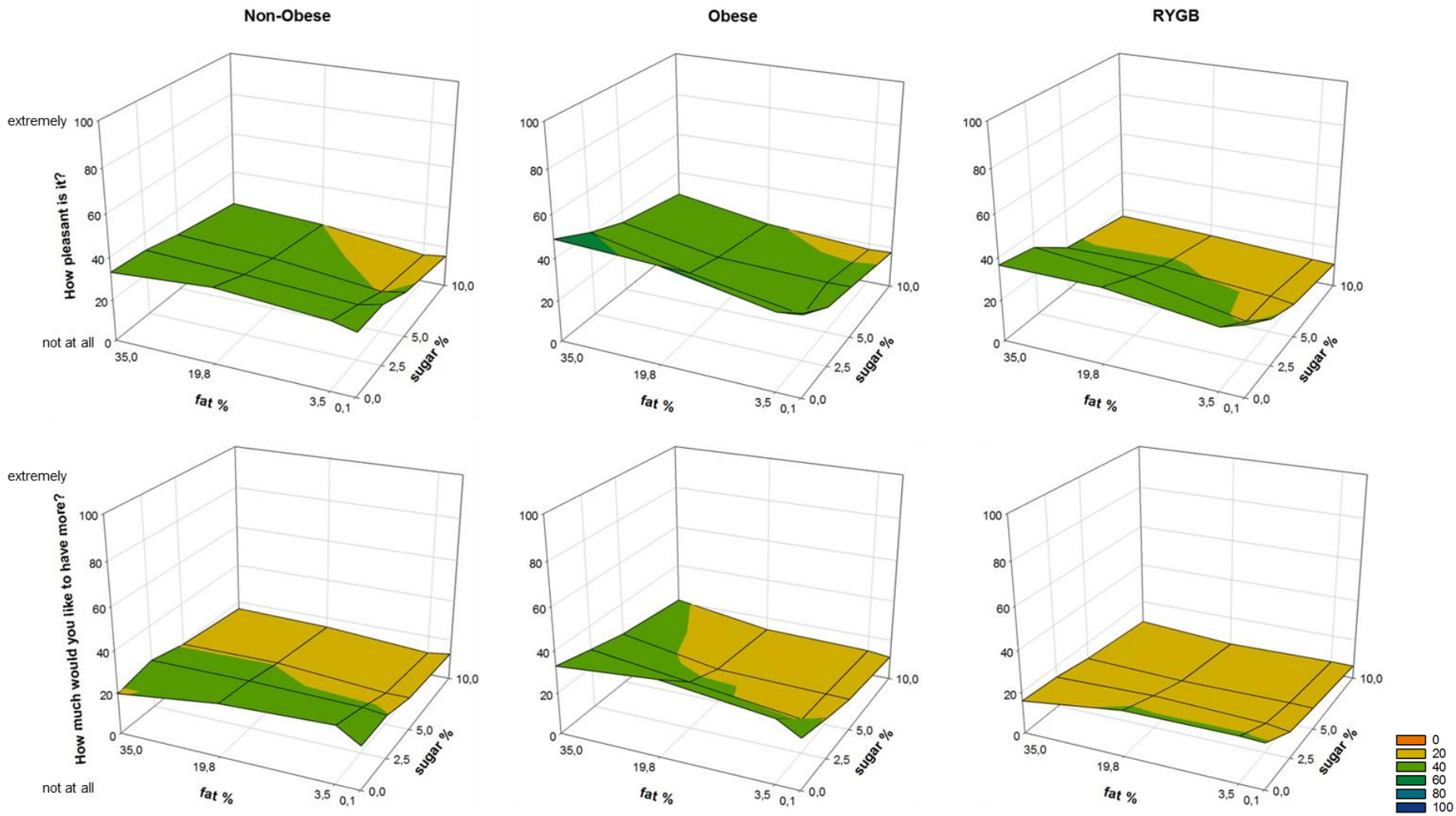

Figure 10 Response surface area mapping the mean values of the hedonic response (Hedonic Sweet Creamy Test) in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB)

Table 10 Rating 'How sweet is it?' in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
non-OB	25.5 ± 3.0	26.2 ± 2.8	30.6 ± 3.3	31.9 ± 3.6
OB	27.8 ± 3.7	26.1 ± 3.1	31.2 ± 3.4	37.0 ± 3.8
RYGB	22.2 ± 4.2	24.6 ± 4.4	26.9 ± 4.3	33.3 ± 5.5
2.5%	No.5	No.6	No.7	No.8
non-OB	85.3 ± 2.6	82.0 ± 2.8	78.1 ± 2.8	80.2 ± 2.8
OB	83.7 ± 2.9	83.7 ± 3.1	85.3 ± 2.7	81.8 ± 3.0
RYGB	89.0 ± 2.6	86.0 ± 3.4	80.5 ± 3.9	86.9 ± 2.5
5%	No.9	No.10	No.11	No.12
non-OB	90.1 ± 1.9	89.5 ± 2.0	86.1 ± 2.4	88.8 ± 1.9
OB	84.8 ± 2.9	87.5 ± 2.3	87.9 ± 2.4	88.7 ± 2.1
RYGB	91.5 ± 2.1	88.9 ± 2.6	92.3 ± 1.8	90.4 ± 2.3
10%	No.13	No.14	No.15	No.16
non-OB	88.8 ± 2.9	92.4 ± 1.8	93.2 ± 1.5	93.1 ± 1.6
OB	90.4 ± 2.6	91.4 ± 2.3	91.0 ± 2.4	88.8 ± 2.9
RYGB	96.6 ± 1.2	96.1 ± 1.1	96.5 ± 1.1	95.5 ± 1.5

Table 11 Rating 'How creamy is it?' in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB) [mean ± SEM]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
non-OB	20.7 ± 3.3	28.1 ± 3.2	60.6 ± 4.1	75.8 ± 3.9
OB	19.5 ± 2.8	26.7 ± 2.7	66.0 ± 3.7	77.1 ± 3.4
RYGB	13.9 ± 3.5	30.8 ± 4.9	62.9 ± 4.7	81.7 ± 4.1
2.5%	No.5	No.6	No.7	No.8
non-OB	13.1 ± 1.9	22.8 ± 2.9	62.4 ± 3.3	80.9 ± 2.8
OB	20.2 ± 2.7	27.7 ± 3.1	58.8 ± 3.9	84.7 ± 2.7
RYGB	17.6 ± 3.5	20.6 ± 2.7	60.2 ± 4.2	87.2 ± 2.8
5%	No.9	No.10	No.11	No.12
non-OB	15.9 ± 2.7	29.5 ± 3.4	60.9 ± 3.4	81.4 ± 2.9
OB	16.9 ± 2.8	27.9 ± 2.7	62.6 ± 3.3	88.0 ± 2.3
RYGB	11.3 ± 2.6	23.4 ± 3.4	56.6 ± 4.6	85.3 ± 3.5
10%	No.13	No.14	No.15	No.16
non-OB	19.6 ± 3.3	30.8 ± 3.6	62.0 ± 3.4	88.7 ± 2.3
OB	16.3 ± 2.8	26.5 ± 2.8	64.3 ± 3.6	91.3 ± 2.1
RYGB	9.3 ± 1.7	23.5 ± 2.8	69.0 ± 4.5	89.4 ± 3.3

Table 12 Rating 'How pleasant is it?' in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM]*

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
non-OB	29.8 ± 3.9	32.4 ± 3.8	36.1 ± 3.9	33.0 ± 3.8
OB	38.4 ± 4.0	36.5 ± 3.8	46.4 ± 3.9	48.7 ± 4.3
RYGB	33.3 ± 5.1	29.7 ± 4.3	36.3 ± 4.8	36.5 ± 5.0
2.5%	No.5	No.6	No.7	No.8
non-OB	28.9 ± 4.3	26.4 ± 3.9	29.6 ± 3.8	31.7 ± 3.9
OB	28.0 ± 3.7	22.0 ± 3.4	30.6 ± 3.9	40.6 ± 4.1
RYGB	22.3 ± 3.5	18.7 ± 3.0	28.7 ± 3.8	33.2 ± 3.6
5%	No.9	No.10	No.11	No.12
non-OB	21.7 ± 3.4	19.8 ± 3.1	25.5 ± 3.7	28.0 ± 4.1
OB	24.6 ± 3.3	24.5 ± 3.4	26.3 ± 3.2	34.5 ± 4.1
RYGB	16.0 ± 2.7	17.6 ± 2.9	21.8 ± 3.9	21.5 ± 3.3
10%	No.13	No.14	No.15	No.16
non-OB	15.3 ± 3.1	13.9 ± 3.1	20.1 ± 3.6	22.9 ± 4.2
OB	17.5 ± 3.0	17.1 ± 2.9	20.8 ± 3.3	28.3 ± 4.1
RYGB	11.2 ± 2.2	11.6 ± 2.4	14.3 ± 2.6	16.1 ± 3.5

Table 13 Rating 'How much would you like to have more?' in 47 non-obese (non-OB), 56 obese (OB) and 38 subjects after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
non-OB	20.5 ± 3.6	27.3 ± 4.0	25.4 ± 3.6	19.5 ± 3.1
OB	24.1 ± 3.6	30.3 ± 3.8	36.6 ± 4.0	32.7 ± 4.1
RYGB	21.7 ± 4.5	22.2 ± 4.5	22.0 ± 4.1	15.8 ± 3.8
2.5%	No.5	No.6	No.7	No.8
non-OB	20.5 ± 3.9	21.9 ± 3.7	23.2 ± 3.6	23.3 ± 3.9
OB	19.2 ± 3.2	16.3 ± 3.1	22.7 ± 3.8	28.7 ± 4.4
RYGB	12.6 ± 3.1	14.1 ± 3.0	15.8 ± 2.9	14.7 ± 2.7
5%	No.9	No.10	No.11	No.12
non-OB	15.6 ± 3.0	15.6 ± 2.7	19.7 ± 3.3	19.6 ± 3.8
OB	14.9 ± 2.6	15.2 ± 2.8	16.6 ± 2.8	24.9 ± 3.9
RYGB	10.3 ± 2.4	10.6 ± 2.7	10.4 ± 2.8	12.0 ± 2.6
10%	No.13	No.14	No.15	No.16
non-OB	12.8 ± 2.8	11.3 ± 2.5	15.1 ± 3.0	16.3 ± 3.7
OB	11.2 ± 2.6	12.5 ± 2.8	13.8 ± 2.8	21.1 ± 3.8
RYGB	6.3 ± 1.4	6.4 ± 1.9	5.7 ± 1.6	8.9 ± 2.0

3.4 Taste Study – Follow-up: Patients pre vs. post RYGB Surgery

3.4.1 Subjects' Characteristics

Clinical, anthropemetric, and BIA data of the 28 patients before, 3 months and 1 year after RYGB surgery are provided in **Table 14**. As expected, patients lost weight and displayed a decreased fat mass (all $p < 0.001$) and fat free mass (p *overall* = 0.047) after the surgery.

Table 14 Body weight measures of 28 patients (9 men) before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

characteristics	**pre RYGB**	**3 months**	**1 year**	***p* overall**
age (years)	42.6 ± 2.0	42.9 ± 2.0	44.0 ± 2.1	-
weight (kg)	124.6 ± 3.9	101.9 ± 3.0[d]	82.0 ± 2.5[d,e]	< 0.001
BMI (kg/m^2)	43.9 ± 0.9	35.8 ± 0.7[d]	28.9 ± 0.7[d,e]	< 0.001
waist (cm)	125.7 ± 3.3	108.7 ± 2.2[d]	96.0 ± 2.0[c,d]	< 0.001
hip (cm)	137.4 ± 2.1	121.4 ± 1.9[d]	107.9 ±1.4[d,e]	< 0.001
waist-hip ratio	0.92 ± 0.02	0.90 ± 0.02	0.89 ± 0.02	0.59
fat mass (kg)	56.1 ± 2.1	39.2 ± 1.7[e]	20.6 ± 1.7[d,e]	< 0.001
fat mass (%)	45.3 ± 1.4	38.5 ± 1.5[a]	25.2 ± 2.0[d,e]	< 0.001
fat free mass (kg)	68.6 ± 3.3	61.8 ± 2.7	58.7 ± 2.50[a]	0.047
phase angle (°)	6.0 ± 0.2	5.3 ± 0.1[b]	5.2 ± 0.2[b]	0.001

Data is mean ± SEM and ranges. [a]$p < 0.05$ vs. pre RYGB, [b]$p < 0.01$ vs. pre RYGB, [c]$p < 0.01$ vs. 3 months post RYGB, [d]$p < 0.001$ vs. pre RYGB, [e]$p < 0.001$ vs. 3 months post RYGB, p-value by One-Way ANOVA; post hoc: Tukey.

3.4.2 Eating Behavior Questionnaires

Results of the TFEQ and the PFS are summarized in **Table 15**. While cognitive restraint increased, disinhibition and hunger decreased 3 months (all $p < 0.003$) and 1 year (all $p < 0.025$) after RYGB surgery compared to the presurgical assessment. There were no differences between the two postsurgical assessments ($p > 0.63$).

Table 15 Three Factor Eating Questionnaire (TFEQ) and Power of Food Scale (PFS) in 28 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

	pre RYGB	3 months post RYGB	1 year post RYGB	*p* overall
TFEQ				
cognitive restraint	8.8 ± 0.8	12.6 ± 0.7[b]	11.6 ± 0.8[a]	0.002
disinhibition	9.3 ± 0.6	3.2 ± 0.3[c]	3.4 ± 0.4[c]	< 0.001
hunger	7.6 ± 0.7	1.4 ± 0.3[c]	1.4 ± 0.4[c]	< 0.001
PFS				
aggregated domain score	3.2 ± 0.2	2.2 ± 0.1[c]	2.3 ± 0.1[c]	< 0.001
food available	2.9 ± 0.2	1.8 ± 0.1[c]	2.1 ± 0.1[c]	< 0.001
food present	3.4 ± 0.2	1.7 ± 0.1[c]	1.9 ± 0.2[c]	< 0.001
food tasted	3.5 ± 0.2	2.9 ± 0.2	3.0 ± 0.2	0.045

Mean ± SEM of the TFEQ with scores 'cognitive restraint eating', 'disinhibition', and 'subjective feelings of hunger' & of the aggregated PFS score and mean ± SEM scores of the PFS sub-domains 'food available' (regarding food readily available in the environment but not physically present) 'food present' (regarding food present but not tasted), and 'food tasted' (regarding food when first tasted but not consumed) in 28 patients before, 3 months and 1 year after RYGB surgery. [a]$p < 0.05$ vs. pre RYGB, [b]$p < 0.01$ vs. pre RYGB, [c]$p < 0.001$ vs. pre RYGB, *p*-value by One-Way ANOVA, post hoc: Tukey.

Three months after the surgery patients show markedly lower aggregated PFS domain scores ($p < 0.001$) than before the surgery and also the subdomains 'food available' and 'food present' were found to be markedly reduced (both $p < 0.001$). This pattern was still present 1 year after RYGB surgery (all $p < 0.001$), whereas no difference of these items between the postsurgical assessments was observed ($p > 0.52$). Of note, the subdomain 'food tasted' was not significantly altered by RYGB surgery (all $p > 0.059$).

Results of the FFQ are summarized in **Table 16**. Compared to presurgical state, patients 3 months after the surgery reported less frequent consumption of protein rich food such as meat ($p = 0.005$) and sausages/ham ($p < 0.001$) as well as carbohydrate rich food (chocolate: $p < 0.001$; cake/biscuits/cookies: $p < 0.001$; sweets: $p = 0.005$; white bread: $p = 0.014$; pasta: $p = 0.038$) than before the surgery, while the consumption of eggs ($p = 0.009$) and cooked vegetables ($p = 0.029$) increased. Compared to presurgical, the reported changes 1 year after surgery were still current for sausages/ham ($p = 0.018$) as well as for cooked vegetables ($p = 0.013$) and carbohydrate rich food such as chocolate ($p = 0.017$),

cake/biscuits/cookies (p = 0.001), pasta (p = 0.007), but not for sweets (p > 0.091), white bread (p > 0.95), meat (p > 0.18), eggs (p > 0.49). From 3 months to 1 year postsurgically the consumption of sausages/ham (p =0.019) and carbohydrate rich food (chocolate: p = 0.004; cake/biscuits/cookies: p = 0.005; sweets: p = 0.014; white bread: p = 0.002) as well as fruit (p = 0.024) increased, while the consumption of eggs (p =0.014) decreased.

Table 16 Food Frequency Questionnaire of 28 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

Food Category	pre RYGB	3 months post RYGB	1 year post RYGB	*p* overall
meat	1.9 ± 0.21	2.6 ± 0.32[c]	2.2 ± 0.24	0.033
sausage/ham	2.7 ± 0.23	4.0 ± 0.27[e]	3.3 ± 0.25[a,b]	<0.001
poultry	2.8 ± 0.23	2.8 ± 0.26	2.7 ± 0.20	0.96
fish	3.9 ± 0.29	3.5 ± 0.29	3.7 ± 0.27	0.20
potatoes	2.7 ± 0.19	2.6 ± 0.17	2.6 ± 0.12	0.90
pasta	2.4 ± 0.16	2.9 ± 0.25[a]	3.0 ± 0.24[c]	0.038
rice	3.0 ± 0.16	3.1 ± 0.27	3.2 ± 0.21	0.37
salad/raw vegetables	1.3 ± 0.10	1.4 ± 0.19	1.2 ± 0.08	0.70
cooked vegetables	1.9 ± 0.17	1.5 ± 0.20[a]	1.5 ± 0.14[a]	0.006
fresh fruit	1.5 ± 0.14	1.8 ± 0.27	1.4 ± 0.12[b]	0.21
chocolate	3.1 ± 0.26	4.4 ± 0.24[e]	3.6 ± 0.24[a,d]	< 0.001
cake/biscuits/cookies	3.1 ± 0.26	4.5 ± 0.21[e]	3.8 ± 0.23[c,d]	< 0.001
sweets/candies	3.6 ± 0.28	4.6 ± 0.28[c]	4.0 ± 0.27[b]	0.001
salted snacks	3.9 ± 0.24	4.3 ± 0.19	3.8 ± 0.20	0.12
bread (white, rye-wheat), toast	3.0 ± 0.27	4.0 ± 0.31[a]	3.0 ± 0.25[d]	0.011
bread (whole grain, dark rye)	2.1 ± 0.26	2.0 ± 0.22	1.8 ± 0.19	0.25
cereals	3.6 ± 0.27	4.1 ± 0.25	4.1 ± 0.26	0.59
yoghurt/curd cheese	2.4 ± 0.31	1.9 ± 0.25	2.4 ± 0.26[b]	0.21
cheese	2.3 ± 0.27	2.1 ± 0.23	2.2 ± 0.23	0.94
eggs	2.8 ± 0.17	2.3 ± 0.20[c]	2.7 ± 0.22[b]	0.004
milk/buttermilk	2.3 ± 0.32	1.8 ± 0.23	2.2 ± 0.26	0.23
fruit juice/soft drinks	4.5 ± 0.23	4.3 ± 0.34	4.2 ± 0.31	0.56
soda	1.2 ± 0.15	1.1 ± 0.14	1.1 ± 0.06	0.65
diet soft drinks/diet beverages	4.1 ± 0.38	3.9 ± 0.35	3.6 ± 0.44	0.76

Data is mean ± SEM. [a]p < 0.05 vs. pre RYGB, [b]p < 0.05 vs. 3 months post RYGB, [c]p < 0.01 vs. pre RYGB, [d]p < 0.01 vs. 3 months post RYGB, [e]p < 0.001vs. pre RYGB, p value by Wilcoxon-Wilcox test; overall p-value by Friedman test [evaluation: high value corresponds less frequent consumption].

3.4.3 Appetite, Hunger, Wanting and Liking Ratings

Results of the VAS rating scales on hunger, satiety, fullness, prospective consumption, and desire to eat something sweet, salty, savory or fatty assessed at 08:45 and 09:15 a.m. are provided in **Table 17**. Overall, there were marked differences in hunger, satiety, fullness, prospective consumption ratings between the surgery states (all $p < 0.043$), also in the desire to eat food of different tastes (all $p < 0.005$), in exception of the desire to eat salty ($p < 0.12$). Specifically, 3 months after RYGB surgery subjects rated less hunger and prospective food consumption, but instead more satiety and fullness and a reduced desire to eat sweet, fatty and savory food than before the surgery. This pattern appeared to be less pronounced 1 year after surgery, but the comparisons of the two postsurgical assessments showed no differences in respective ratings.

Table 17 Hunger Rating of 28 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

Hunger Rating	**Time [a.m.]**	**pre RYGB**	**3 months post RYGB**	**1 year post RYGB**	***p* surgery**	***p* time**	***p* surgery x time**
hunger	08:45 09:15	38.0 ± 5.4 47.5 ± 5.8	14.2 ± 3.0[c] 20.7 ± 4.0[c]	24.0 ± 5.6 31.7 ± 4.5	0.001[e]	0.001	0.86
satiation	08:45 09:15	29.0 ± 4.7 24.3 ± 4.8	58.2 ± 5.2[c] 48.8 ± 6.1[c]	51.8 ± 6.1[b] 42.0 ± 5.2	< 0.001[b,e]	0.006	0.71
fullness	08:45 09:15	26.9 ± 4.7 20.2 ± 3.6	42.2 ± 5.9 38.3 ± 6.4[a]	31.8 ± 5.3 31.3 ± 4.8	< 0.001[d,a]	0.033	0.64
consumption	08:45 09:15	48.6 ± 4.5 52.2 ± 5.1	23.1 ± 3.4[e] 27.3 ± 3.4[e]	32.1 ± 4.0[b] 36.3 ± 3.2[b]	0.042[e]	0.16	0.99
desire to eat sweet*	08:45 09:15	68.0 ± 7.5 62.1 ± 6.5	93.9 ± 1.4[c] 81.4 ± 4.9	84.2 ± 4.1 73.2 ± 5.4	0.004[c]	0.033	0.65
desire to eat salty*	08:45 09:15	64.0 ± 6.6 59.1 ± 6.1	78.4 ± 4.8 72.3 ± 5.7	63.4 ± 6.3 57.6 ± 6.2	0.11	0.045	0.98
desire to eat savory*	08:45 09:15	62.4 ± 6.8 67.6 ± 5.8	89.8 ± 2.8[e] 85.8 ± 3.5[a]	87.9 ± 3.6[d] 74.4 ± 5.6	0.001[b,e]	0.14	0.026
desire to eat fatty*	08:45 09:15	75.5 ± 4.9 77.5 ± 4.7	92.9 ± 2.4 92.8 ± 2.0	92.1 ± 3.5 88.5 ± 3.4	0.002 [b,c]	0.73	0.37

Mean ± SEM of Hunger Rating on Visual Analogue Scale (VAS, 0-100 mm) with scores 'hunger', 'fullness', and 'prospective food consumption' and 'the desire to eat sweet salty, savory and fatty'. [a]*p < 0.05* pre vs. 3 mths post RYGB, [b]*p < 0.05* pre vs. 1 y post RYGB, [c]*p < 0.01* pre vs. 3 mths post RYGB, [d]*p < 0.01* pre vs. 1 y post RYGB, [e]*p < 0.001* pre vs. 3 mths post RYGB, *p*-value by One-Way ANOVA, post hoc Tukey resp. by ANOVA with repeated measures (time x surgery state) [*interpretation: higher score corresponds to less desire.]

Rating of wanting and liking on the presented food pictures are provided in **Table 18**. While subjects after RYGB surgery reported no differences in liking and wanting ratings on low-calorie food pictures (all $p > 0.13$), wanting ratings on the high-calorie sweet and non-sweet food pictures showed (partly only by trend) a reduced score. Specifically, 1 year after surgery patients rated a significant lower wanting on high-calorie non-sweet food pictures than before (both $p < 0.047$). Subjects 3 months up to 1 year after RYGB surgery reported a significant reduced liking of high-calorie non-sweet food only at 8:50 a.m. (both $p < 0.033$), not at 9:20 a.m. ($p > 0.90$) as well as in liking ratings of high-calorie sweet food at both times (all $p > 0.15$).

Table 18 Wanting and Liking of food in 26 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

	Time [a.m.]	**pre RYGB**	**3 mths post RYGB**	**1 year post RYGB**	***p* surgery**	***p* time**	***p* surgery x time**
high-calorie non-sweet food							
wanting	8:50 9:20	2.8 ± 0.2 2.8 ± 0.2	2.2 ± 0.2 2.2 ± 0.2	2.1 ± 0.2[b] 2.3 ± 0.2	0.030[b]	0.15	0.37
liking	8:50 9:20	3.3 ± 0.2 3.1 ± 0.2	2.8 ± 0.2[a] 2.5 ± 0.2	2.7 ± 0.2[b] 2.6 ± 0.2	0.030	< 0.001	0.11
high-calorie sweet food							
wanting	8:50 9:20	2.4 ± 0.2 2.5 ± 0.2	1.8 ± 0.2[a] 1.9 ± 0.2	1.8 ± 0.1[b] 2.1 ± 0.2	0.038[a]	0.006	0.30
liking	8:50 9:20	3.2 ± 0.2 3.1 ± 0.2	2.8 ± 0.2 2.6 ± 0.2	3.1 ± 0.2 2.9 ± 0.2	0.23	< 0.001	0.63
low-calorie food							
wanting	8:50 9:20	3.1 ± 0.2 3.2 ± 0.1	2.9 ± 0.2 3.0 ± 0.2	2.9 ± 0.2 3.2 ± 0.2	0.65	0.063	0.46
liking	8:50 9:20	3.7 ± 0.1 3.6 ± 0.1	3.4 ± 0.1 3.4 ± 0.1	3.7 ± 0.1 3.5 ± 0.1	0.35	0.037	0.21

Mean ± SEM: Rating of wanting ('How much do you want this food?') and liking ('How pleasant is the taste of this food?') high-calorie non-sweet, high-calorie sweet and low-calorie food by pictures. [a]$p < 0.05$ pre vs. 3 months post RYGB, [b]$p < 0.05$ pre vs. 1 year post RYGB, *p*-value by One-Way ANOVA, post hoc Tukey resp. ANOVA repeated measures (time x surgery state).

3.5 Taste Recognition Thresholds

Results of the taste recognition task are summarized in **Table 19** and **Figure 11**. The overall Friedman test indicated a significant difference in recognition thresholds for salty (p = 0.005) and umami (p = 0.003), but not for sweet (p > 0.87), sour (p > 0.53) and bitter taste (p > 0.052) after RYGB surgery. Pairwise comparison by Wilcoxon-Wilcox test indicated that 3 months after surgery patients recognized bitter at lower concentrations than before (p = 0.046). This change was still present 1 year after surgery as compared to presurgical (p = 0.047); in addition umami was recognized at lower (p = 0.005) and salty at higher concentrations (p = 0.001).

Table 19 Taste Recognition Thresholds of 28 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

Taste Recognition	**pre RYGB**	**3 months post RYGB**	**1 year post RYGB**	***P* overall**
sweet	3.8 ± 0.3	3.7 ± 0.3	3.7 ± 0.3	0.88
salty	3.6 ± 0.3	3.8 ± 0.3	4.6 ± 0.3[b,c]	0.005
sour	3.5 ± 0.2	3.3 ± 0.2	3.5 ± 0.3	0.54
bitter	5.3 ± 0.2	4.8 ± 0.2[a]	4.6 ± 0.3[a]	0.053
umami	4.8 ± 0.3	4.3 ± 0.3	3.9 ± 0.3[c]	0.003

Mean ± SEM of taste recognition thresholds. [a]$p < 0.05$ vs. pre RYGB, [b]$p < 0.05$ vs. 3 months post RYGB, [c]$p < 0.01$ vs. pre RYGB, p-value by Wilcoxon-Wilcox test, overall value by Friedman test.

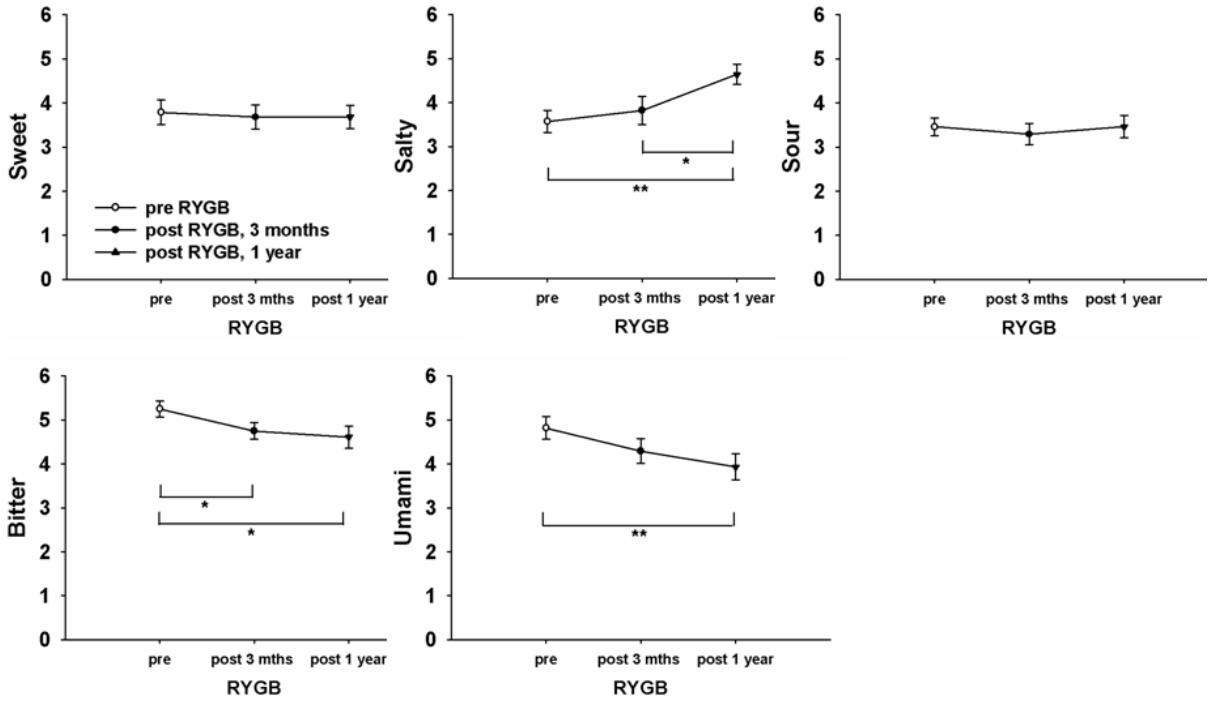

Figure 11 Mean ± SEM of taste recognition thresholds of sweet, salty, sour, bitter and umami in 28 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB); *p < 0.05, **p < 0.01 by post hoc Wilcoxon-Wilcox test.

3.6 Hedonic Sweet Creamy Test

Results of the Hedonic Sweet Creamy Test are summarized in **Table 20** - **Table 24** and are illustrated in **Figure 12** and **Figure 13**.

The rating ‘How sweet is it?’ did not differ in subjects after RYGB surgery as compared to the baseline ($p > 0.062$ for surgery state main effect). Surgery state only interacted with sugar concentration in the rating ‘How sweet is it?’ ($p = 0.016$).

The rating ‘How creamy is it?’ was not altered after RYGB surgery as compared to the baseline ($p > 0.24$ for the surgery state main effect). Surgery state showed no interaction with sugar concentration and/or fat content in the rating ‘How creamy is it?’ (all $p > 0.069$).

The rating ‘How pleasant is it?’ was altered after RYGB surgery as compared to before ($p = 0.030$ for surgery state main effect). RYGB subjects rated 3 months after surgery reduced values in the rating ‘How pleasant is it?’ as compared to the baseline ($p = 0.027$). Surgery state showed no interaction with sugar concentration and/or fat content in the rating ‘How pleasant is it?’ (all $p > 0.62$).

The rating ‘How much would you like to have more?’ was not altered after RYGB surgery as compared to the baseline ($p > 0.14$ for surgery state main effect). Surgery state showed no interaction with sugar concentration and/or fat content in the rating ‘How much would you like to have more?’ (all $p > 0.31$).

The rated value of ‘How sweet is it?’ increased with increasing sugar concentration ($p < 0.001$) and the rated value of ‘How creamy is it?’ increased with increasing fat content ($p < 0.001$). The rated value of ‘How sweet is it?’ increased with the fat content ($p = 0.036$) and the rated value of ‘How creamy is it?’ increased with the sugar concentration ($p = 0.002$) of the test solution. An interaction between sugar concentration and fat content was found in the rating ‘How sweet is it?’ ($p = 0.012$) and ‘How creamy is it?’ ($p < 0.001$).

The rated value of ‘How pleasant is it?’ increased with increasing fat content ($p = 0.003$) of the test solution, but decreased with sugar concentation ($p < 0.001$). An interaction between fat content and sugar concentration on the rating ‘How pleasant is it?’ was observed ($p = 0.021$).

The rated value of ‘How much would you like to have more?’ increased with sugar concentration ($p < 0.001$), but not with fat content ($p > 0.16$). No interaction in the rating ‘How much would you like to have more?’ between sugar content and fat content was found ($p > 0.16$).

Table 20 Hedonic Sweet Creamy Test of 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

effect	**sweet**	**creamy**	**pleasant**	**wanting more**
surgery state	0.063	0.25	0.030[a]	0.15
sugar concentration	< 0.001	0.002	< 0.001	< 0.001
sugar concentration x surgery state	0.016	0.070	0.85	0.84
fat content	0.036	< 0.001	0.003	0.17
fat content x surgery state	0.19	0.90	0.63	0.71
sugar concentration x fat content	0.012	< 0.001	0.021	0.17
sugar concentration x fat content x surgery state	0.74	0.73	0.83	0.32

Data is *p*-value by ANOVA with repeated measures group, 4 (sugar content) x 4 (fat content). [a]pre vs. 3 mths post RYGB $p < 0.05$, post hoc: Tukey.

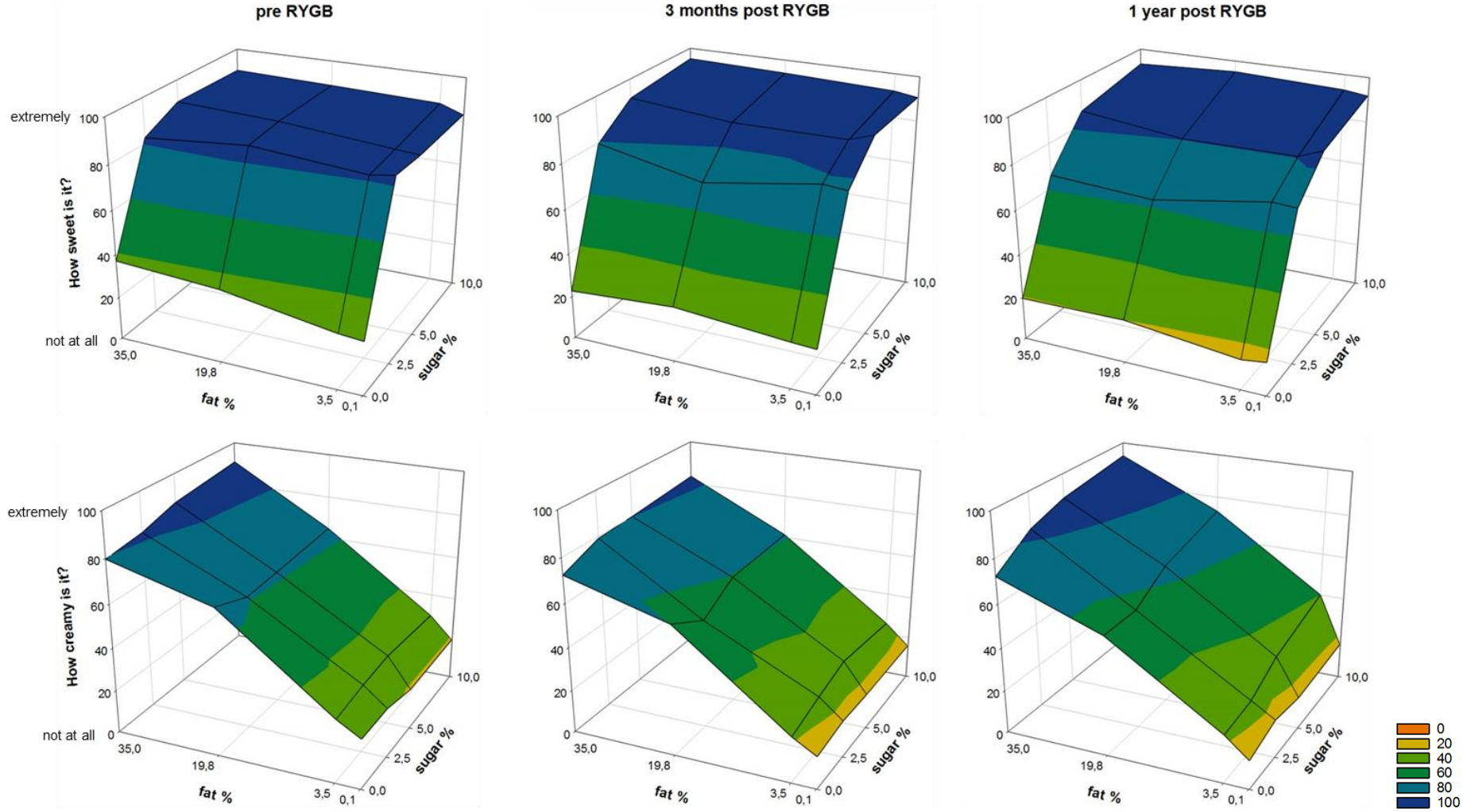

Figure 12 Response surface area mapping the mean values of the sweet and creamy response (Hedonic Sweet Creamy Test) in 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

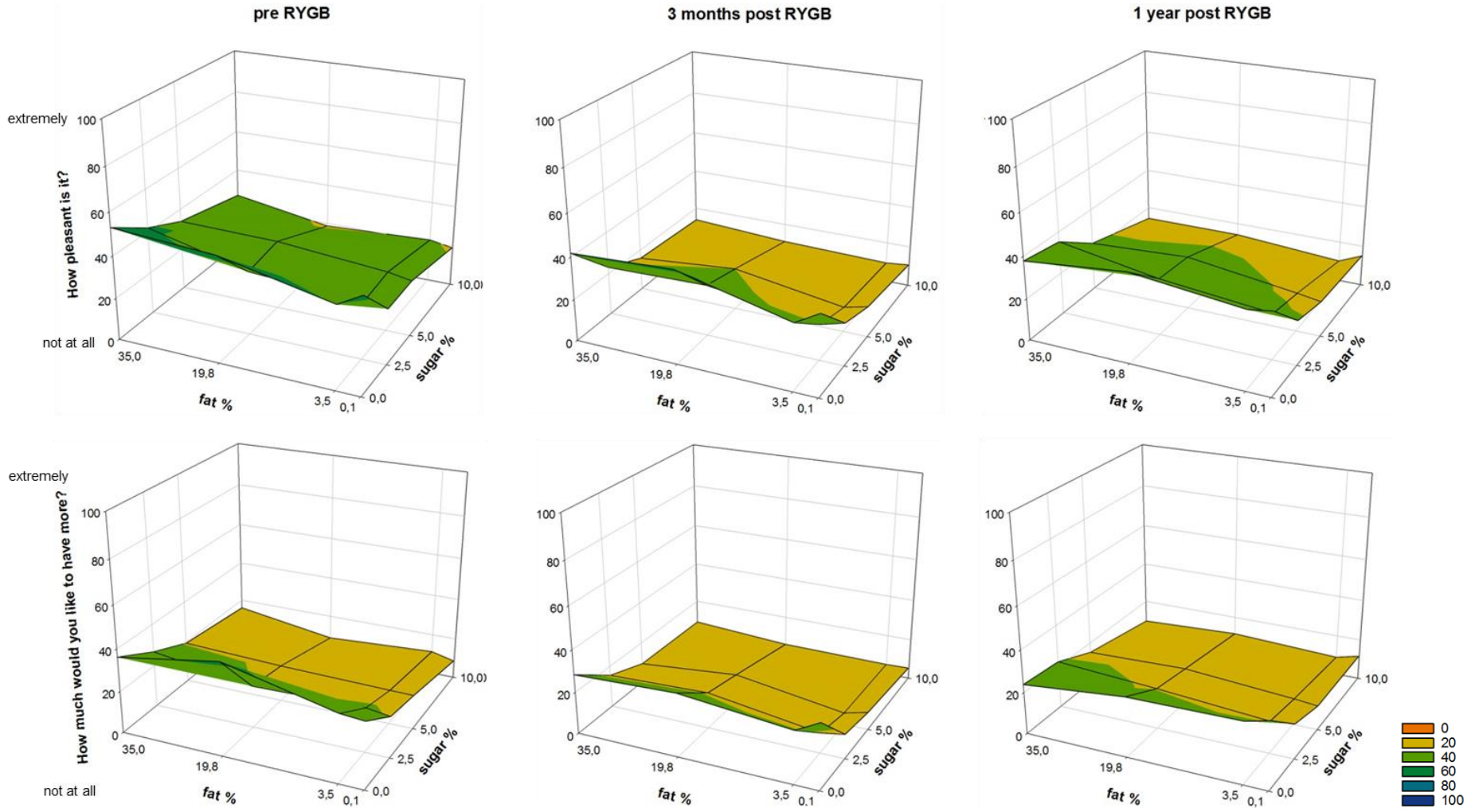

Figure 13 Response surface area mapping the mean values of the hedonic response (Hedonic Sweet Creamy Test) in 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB).

Table 21 Rating 'How sweet is it?' of 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
pre RYGB	24.8 ± 5.4	25.7 ± 4.6	34.0 ± 5.7	37.1 ± 6.4
3 months post	20.8 ± 3.9	21.4 ± 4.1	25.6 ± 4.9	22.6 ± 3.8
1 year post RYGB	15.4 ± 3.4	14.0 ± 3.3	20.0 ± 3.7	19.5 ± 4.3
2.5%	No.5	No.6	No.7	No.8
pre RYGB	83.8 ± 4.5	82.2 ± 4.4	86.4 ± 3.3	82.5 ± 4.2
3 months post	77.1 ± 4.5	78.0 ± 4.7	70.0 ± 6.1	79.5 ± 5.3
1 year post RYGB	70.2 ± 4.3	70.9 ± 4.5	62.8 ± 5.5	65.8 ± 4.7
5%	No.9	No.10	No.11	No.12
pre RYGB	82.7 ± 4.4	83.6 ± 3.0	88.1 ± 2.7	90.2 ± 2.7
3 months post	90.9 ± 2.2	87.3 ± 4.3	87.2 ± 3.9	91.5 ± 2.2
1 year post RYGB	84.6 ± 3.1	80.5 ± 3.2	80.4 ± 3.6	86.0 ± 2.8
10%	No.13	No.14	No.15	No.16
pre RYGB	83.1 ± 5.4	86.9 ± 4.2	88.5 ± 4.3	89.8 ± 4.0
3 months post	90.6 ± 3.8	92.2 ± 2.8	93.9 ± 2.6	95.0 ± 2.0
1 year post RYGB	91.7 ± 2.5	93.1 ± 2.3	95.0 ± 1.5	92.9 ± 2.5

Table 22 Rating 'How creamy is it?' of 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
pre RYGB	22.9 ± 4.7	29.2 ± 4.3	67.3 ± 5.9	79.6 ± 5.5
3 months post	14.9 ± 3.3	21.2 ± 3.8	59.8 ± 5.3	72.4 ± 4.5
1 year post RYGB	13.2 ± 3.6	22.2 ± 4.3	55.1 ± 5.4	72.1 ± 4.6
2.5%	No.5	No.6	No.7	No.8
pre RYGB	22.9 ± 4.3	31.4 ± 4.9	61.1 ± 6.0	82.0 ± 4.9
3 months post	17.0 ± 3.0	25.8 ± 4.8	50.3 ± 4.2	79.1 ± 4.6
1 year post RYGB	17.6 ± 3.3	24.2 ± 3.6	55.3 ± 3.8	83.6 ± 2.6
5%	No.9	No.10	No.11	No.12
pre RYGB	18.8 ± 4.6	32.6 ± 4.2	62.2 ± 5.1	87.0 ± 4.2
3 months post	16.1 ± 3.0	29.8 ± 5.2	59.6 ± 5.0	80.2 ± 5.4
1 year post RYGB	14.8 ± 2.9	32.2 ± 4.8	65.1 ± 3.8	89.1 ± 2.0
10%	No.13	No.14	No.15	No.16
pre RYGB	19.1 ± 4.9	29.5 ± 3.9	64.6 ± 5.7	90.8 ± 3.9
3 months post	15.7 ± 4.1	25.2 ± 4.8	61.2 ± 6.3	83.3 ± 5.9
1 year post RYGB	16.7 ± 3.5	40.0 ± 5.5	73.1 ± 3.6	93.8 ± 1.9

Table 23 Rating 'How pleasant is it?' of 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
pre RYGB	45.5 ± 5.6	39.2 ± 5.6	50.0 ± 6.7	53.0 ± 7.4
3 months post	38.2 ± 6.0	31.6 ± 4.9	44.1 ± 4.6	41.8 ± 5.3
1 year post RYGB	38.9 ± 6.2	37.2 ± 5.2	42.8 ± 4.3	37.9 ± 5.1
2.5%	No.5	No.6	No.7	No.8
pre RYGB	26.4 ± 5.1	27.0 ± 5.3	30.4 ± 4.9	41.8 ± 6.3
3 months post	20.3 ± 3.9	17.2 ± 3.3	24.4 ± 4.7	23.2 ± 4.9
1 year post RYGB	21.2 ± 4.6	22.1 ± 4.5	27.2 ± 4.9	35.3 ± 6.0
5%	No.9	No.10	No.11	No.12
pre RYGB	26.6 ± 4.8	28.6 ± 4.4	33.1 ± 4.5	34.0 ± 5.5
3 months post	14.7 ± 3.4	12.0 ± 3.1	20.1 ± 4.5	15.8 ± 4.5
1 year post RYGB	16.8 ± 4.3	18.6 ± 4.4	25.6 ± 4.8	23.1 ± 5.7
10%	No.13	No.14	No.15	No.16
pre RYGB	19.0 ± 4.0	21.0 ± 4.5	18.6 ± 4.0	26.5 ± 5.5
3 months post	10.6 ± 3.1	9.5 ± 3.3	10.8 ± 3.6	13.7 ± 5.1
1 year post RYGB	15.0 ± 4.9	10.2 ± 2.9	14.1 ± 4.4	14.1 ± 5.0

Table 24 Rating 'How much would you like to have more?' of 25 patients before, 3 months and 1 year after Roux-en Y gastric bypass surgery (RYGB) [*mean ± SEM*]

	fat content			
sugar content	**0.1 %**	**3.5%**	**19.8%**	**35.0 %**
0%	No.1	No.2	No.3	No.4
pre RYGB	31.2 ± 5.9	32.1 ± 6.1	44.0 ± 6.8	36.2 ± 6.7
3 months post	31.0 ± 6.1	25.0 ± 4.9	30.2 ± 4.6	28.4 ± 5.2
1 year post RYGB	32.0 ± 6.1	29.2 ± 5.3	28.5 ± 4.4	23.8 ± 5.8
2.5%	No.5	No.6	No.7	No.8
pre RYGB	19.6 ± 5.1	21.2 ± 5.2	20.1 ± 4.5	26.8 ± 6.6
3 months post	11.6 ± 2.6	9.7 ± 2.2	17.3 ± 4.2	15.6 ± 4.2
1 year post RYGB	16.6 ± 4.3	15.4 ± 4.6	19.4 ± 4.9	22.4 ± 5.8
5%	No.9	No.10	No.11	No.12
pre RYGB	16.2 ± 3.9	16.4 ± 3.9	17.5 ± 3.5	19.4 ± 4.6
3 months post	8.4 ± 2.5	5.6 ± 1.6	13.5 ± 3.5	9.2 ± 2.8
1 year post RYGB	11.6 ± 4.1	12.7 ± 4.0	16.6 ± 4.5	15.2 ± 5.2
10%	No.13	No.14	No.15	No.16
pre RYGB	8.5 ± 1.9	11.2 ± 2.5	8.4 ± 2.4	15.8 ± 4.5
3 months post	5.2 ± 1.8	4.9 ± 1.9	5.4 ± 2.2	8.5 ± 3.7
1 year post RYGB	11.5 ± 4.6	8.8 ± 3.2	11.2 ± 4.2	9.1 ± 4.2

4 Discussion

4.1 Comprehensive Summary of Results

In this work comprehensive assessments of eating behavior, hunger/satiety, hedonic drive, taste recognition as well as food preferences were made in non-OB, OB and in subjects after bariatric surgery, i.e. after RYGB surgery and after gastric band implementation.

Data of our cross-sectional Case Control Taste Study revealed differences in dietary habits (FFQ), a distinct eating behavior characterized by a stronger disinhibition and hunger traits (TFEQ) but less current hunger and stronger current satiety (ratings) in OB as compared to non-OB subjects. In addition, OB compared to non-OB subjects showed a reduced sensitivity to recognize salty, sour, bitter and umami taste and, of note, a stronger desire to eat palatable food as indicated by higher aggregated, food available and food present domain scores of the PFS. No difference in wanting and liking of different kinds of food (food pictures) was noted between the OB and non-OB subjects. OB subjects did not differ from non-OB subjects by rating on scores ‘How sweet is it?’, ‘How creamy is it?’, ‘How pleasant is it?’ and ‘How much would you like to have more?’ while tasting sugar/fat solutions (Hedonic Sweet Creamy Test).

Furthermore, data of our cross-sectional Case Control Taste Study indicates that RYGB patients compared to OB subjects do not differ in dietary habits (FFQ) and current measures of hunger and taste desires (ratings), but in eating behavior (TFEQ) characterized by less disinhibition and hunger as well as in a reduced desire to eat palatable food as indicated by higher aggregated, food available and food present domain scores on the PFS. No differences were found in wanting and liking of different kinds of food (food pictures). Of note, RYGB patients compared to OB subjects showed an increased sensitivity to recognize umami taste. RYGB subjects did not differ from OB subjects by rating the scores ‘How sweet is it?’, ‘How creamy is it?’ and ‘How pleasant is it?’, while tasting sugar/fat solutions (Hedonic Sweet Creamy Test), whereas RYGB subjects showed a reduced score for ‘How much would you like to have more?’ with an increasing fat and sugar content of the test solution compared to OB subjects (Hedonic Sweet Creamy Test).

The data of our Case Control Taste Study revealed that RYGB subjects compared to non-OB subjects differ in their dietary habits (FFQ) and in their eating behavior characterized by a stronger disinhibition (TFEQ). RYGB subjects also rated a reduced hunger and prospective food consumption and an increased satiety and feeling of fullness (rating). In addition, RYGB patients showed a reduced sensitivity to recognize salty, sour and umami taste compared to non-OB subjects. While the desire to eat palatable food assessed by the PFS showed no difference between RYGB and non-OB subjects, RYGB patients rated a reduced wanting and liking of high-calorie sweet food (food pictures). RYGB subjects did not differ from non-OB subjects by rating the scores 'How sweet is it?', 'How creamy is it?', 'How pleasant is it?' and 'How much would you like to have more?', while tasting sugar/fat solutions (Hedonic Sweet Creamy Test).

Data of our Follow-up Taste Study shows changes in dietary habits (FFQ) and eating behavior characterized by a reduced disinhibition and hunger and by a stronger cognitive restraint (TFEQ) after RYGB surgery. Current measures (state rating) of hunger and prospective food consumption were reduced postsurgically and satiety and feeling of fullness increased postsurgically. The desire to eat palatable food reported in the aggregated, food available and food present domain score of the PFS was reduced in patients 3 months postsurgically and was still reduced 1 year after RYGB surgery. Three months after RYGB surgery patients reported a reduced hunger and prospective food consumption, an increased satiety and feeling of fullness, a reduced desire to eat sweet, savory and fatty foods in the hunger ratings during the testing sessions compared to before the surgery. One year after RYGB surgery satiety and the feeling of fullness remained at an increased level, the desire to eat savory and fatty foods remained at a reduced level. Patients reported a reduced wanting of high-calorie sweet food only 3 months after surgery and a reduced wanting of high-calorie non-sweet food 1 year after surgery. In contrast, changes in liking of respective food categories in the Follow-up Taste Study were not significant. Furthermore, compared to presurgical testing, the sensitivity to recognize bitter taste increased 3 months and 1 year after the surgery. The sensitivity to taste umami increased, whereas the sensitivity to recognize salty taste decreased 1 year after the surgery. The rating of the scores 'How sweet is it?', 'How creamy is it?' and 'How much would you like to

have more?' while tasting sugar/fat solutions did not alter 3 months and 1 year after surery, whereas 3 months after surgery RYGB subjects showed a reduced score for 'How pleasant is it?' with an increasing sugar and fat content of the test solution compared to the baseline (Hedonic Sweet Creamy Test).

Data of the Follow-up Taste Study is in line with results of our more long-term Follow-up Eating Behavior Study, which also revealed altered dietary habits (FFQ) as well as a reduced desire to eat palatable food reported in all domain scores of the PFS, in contrast to the data of the Follow-up Taste Study, which showed no reduced food tasted domain score. The food tasted domain score was reduced for patients on average ~16 months after RYGB surgery.

Collectively, our cross-sectional Case Control Eating Behavior and cross-sectional Case Control Taste Study shows a stronger desire to eat palatable food reported in the aggregated, food available and food present domain score of the PFS in OB compared to non-OB subjects. In addition, the Case Control Eating Behavior Study showed that compared to OB subjects, gastric banding patients as well as previously reported by RYGB patients showed a reduced desire to eat palatable food reported in the aggregated, food available and food present, but not in the food tasted domain score of the PFS. Furthermore, data of the Case Control Eating Behavior Study revealed that gastric banding patients compared to non-OB subjects showed a reduced desire to eat palatable food, but only in the food available domain score.

Results of these different aspects of eating behavior, hunger/satiety, hedonic drive, taste recognition as well as food preferences will be discussed in the following sections in detail and reflected against previous research results.

4.2 Eating Behavior, Hunger, Satiety

Our data showing eating behavior (TFEQ) characterized by an unaltered cognitive restraint in eating and a stronger dietary disinhibition in OB compared to non-OB subjects is in line with one previous study [35], while other studies report a stronger [65, 166] as well as a reduced [82, 120] cognitive restraint in OB subjects.

RYGB patients showed a reduced disinhibition when compared to OB subjects. However, they differed from non-OB subjects with eating behavior characterized by a reduced disinhibition in our study. This is confirmed by our follow-up data and is in line with previous studies [20, 94, 134].

Of note, in contrast to comparable levels of cognitive restraint found between RYGB and OB subjects in the Case Control Taste Study, data of the Follow-up Taste Study also showed an increased cognitive restraint in patients 3 months after RYGB surgery, which was still present 1 year postsurgically. The longer the time period after RYGB surgery - as in the case of the Case Control Taste Study when compared to the Follow-up Taste Study – the weaker the effect of RYGB surgery on cognitive restraint. Previous studies report a stronger cognitive restraint from ~4, ~9, ~15, ~21 months after RYGB surgery [134] as well as an unaltered cognitive restraint 3 days, 2 months, 1 year [20] and 1 and 2 years postsurgically, while it transiently increased 6 weeks postsurgically [94]. Thus, the increase in cognitive control after RYGB surgery might get lost over time.

Our data of the TFEQ in the Case Control Taste Study clearly showed increased feelings of hunger in OB compared to non-OB subjects, which is in line with previous research [166]. Reduced hormone release arising from the gastrointestinal tract resulting in reduced activation of brain areas important for appetite control [73, 131, 162] is suggested as the underlying mechanisms. This reduced activation of brain areas is suggested to result in appetite, larger meal sizes and a more frequent food intake in OB subjects [73, 131].

Our finding of generally stronger feelings of hunger in OB compared to non-OB subjects assessed by the TFEQ is not in line with the rating results reporting a reduced current hunger. Expectation bias might explain these different results.

Also, our trait measures of the TFEQ hunger score, where RYGB subjects showed reduced levels of hunger compared to OB subjects, are not in line with the state measures of hunger in our Case Control Taste Study, which revealed no difference. While state measures of hunger and prospective food consumption (ratings) were reduced 3 months after RYGB surgery, this reduction was no longer present 1 year after RYGB surgery (Follow-up Taste Study). It might be argued that the hunger reducing effect of the surgery gets weaker over time.

Our results of the Follow-up and Case Control Taste Study revealed that RYGB subjects showed stronger satiety and feeling of fullness ratings compared to non-OB subjects. Our finding of reduced hunger feelings after RYGB surgery are in line with previous research [6, 134]. Several mechanisms might account for the reduction of hunger after RYGB surgery. Of note, they seem to be independent of weight loss and leptin levels [86]. Instead increased gut hormone release observed after RYGB surgery is suspected to be the key modulator in suppressing hunger and food intake [30, 129, 131].

4.3 Hedonic Drive

Both of our Case Control Studies revealed a generally stronger desire to eat palatable food reported in the aggregated, food available and food present domain score of the PFS in OB compared to non-OB subjects [173, 174], while no difference in the current ratings of wanting different kind of food (food pictures) was noted.

However, our PFS data of an increased desire to eat highly palatable food in OB subjects as compared to non-OB subjects fits well with previous research [25, 28, 51, 136]. Several, previous functional magnetic resonance imaging (fMRI) studies have shown that pictures of highly palatable food lead to a hyper-response of brain areas involved in attention and reward expectation [74, 181], while eating highly palatable food leads to a reduced response of brain areas involved in reward in OB compared to non-OB subjects [41, 96, 153]. This reward deficiency in obesity is suggested to be physiologically accompanied by a reduced dopamine receptor type D2 availability in the brain [177]. An increased and repeated exposure to highly palatable food might be the root cause for the reward deficiency followed by the excessive desire to eat highly palatable food, resulting again in an excessive food intake in OB subjects [26, 33, 40, 48]. It is suggested that an overriding of the homeostatic control systems by the rewarding aspects of palatable food may contribute to obesity [89]. Data of our Case Control Taste Study showing an increased hunger and disinhibition in OB subjects may support this hypothesis.

RYGB subjects consistently showed a reduced desire to eat palatable food reported in the aggregated, food available and food present domain score of the PFS compared to OB subjects across all studies and held comparable values to non-OB subjects. In the Follow-up Eating Behavior Study we found in addition a reduced desire to eat palatable food in the food tasted domain score, which might be explained by the passed time after RYGB surgery, on average ~16 months.

While no difference in current wanting ratings of different kind of food (food pictures) between RYGB and OB patients was found in the Case Control Taste Study, data of our Follow-up Taste Study showed a reduced wanting of high-calorie sweet food in patients 3 months after surgery as well as a reduced wanting of high-calorie non-sweet food in patients 1 year after surgery. Thus, the wanting reducing effect of the surgery might get weaker over time.

Data of the wanting state ratings in the Follow-up Taste Study are in line with those of the state ratings on the desire to eat something sweet resp. savory /fatty. Thus, along with a reduced wanting rating of high-calorie sweet food, the desire to eat something sweet rating was also reduced 3 months after RYGB surgery. Both were not reduced 1 year postsurgically. In addition, our finding of a reduced wanting rating of high-calorie non-sweet food is in line with the reduced rating of the desire to eat something savory and fatty 1 year after RYGB surgery. Thus, data provides evidence that the wanting of high-calorie sweet food is reduced shortly after RYGB surgery and wanting of high-calorie non-sweet food is reduced when more time has passed after RYGB surgery. In addition to the rated food pictures, ratings on tasting sugar and fat solutions (Hedonic Sweet Creamy Test) also revealed a reduced overall score ‘How much would you like to have more?’ in RYGB as compared to OB subjects in the Case Control Taste Study, but independent of sugar and fat content. However, in the Follow-up Taste Study no significant changes with surgery were found. It should be noted, that these ratings capture only the current state, whereas the PFS as well as the TFEQ assesses the trait.

Gathered together, the pattern of findings in our studies suggests that the desire to eat highly palatable food (PFS) is reduced in OB subjects after RYGB surgery, which fits well with our [50, 136] and other previous research [34]. Our consistent study results of a reduced food present score (PFS) after RYGB

surgery also fit well with previous neuroimaging studies, that showed a reversed hyper-activation of brain reward by food pictures of the environment after RYGB surgery [59, 110–112]. The reduced desire to eat palatable food, so called hedonic hunger after RYGB surgery is an important observation since it suggests that patients who have undergone this procedure do not only eat less because of the restrictive nature of the operation, but also due to a reduced hedonic drive to consume highly palatable food [174].

The mechanism underlying the reduction in hedonic hunger after RYGB surgery cannot be derived from the obtained data. However, RYGB surgery has repeatedly been shown to enhance the secretion of anorexigenic gut hormones, i.e. GLP-1 and PYY as well as decreasing levels of orexogenic gut hormones, i.e. ghrelin and motilin after RYGB surgery [4, 11, 39]. On the one hand such hormones contribute to the homeostatic regulation of eating behavior by acting peripherally and also on central nervous structures like the brain stem and hypothalamus, thereby affecting hunger and satiety [9, 66]. On the other hand they are also involved in food reward by acting on reward-related brain areas via neural (i.e. vagal afferents) and possibly also via humoral routes [9, 37, 66, 69, 179]. Of note, brain structures involved in the homeostatic control of eating behavior (i.e. the hypothalamus) are highly interlinked with the circuits that control non-homeostatic aspects of eating behavior such as food reward (i.e. OFC) [89, 144]. Evidence suggests that such hormones have a great impact on brain reward, independent of sensory influences such as taste [179]. Of note, there is evidence that changes in those gastrointestinal hormones, released after RYGB surgery also play an important role in the postsurgically reduced hedonic drive [39].

To further explore the putative role of gastrointestinal hormones after RYGB in this context, a comparable study in patients undergoing gastric band implantation, that do not induce similar endocrine changes [4, 135], was carried out [173]. Data of this study indicates that OB subjects who have undergone gastric band implantation on an average of more than 7 years before also show markedly lower values in all PFS scores, except for the ‘food tasted’ domain, than OB subjects. And the scores are comparable to those of non-OB subjects with the exception of elevated values in the ‘food available’ domain. This data suggests that adjustable gastric band implantation also reduces hedonic hunger in severe

OB subjects. This effect may be mediated by other non-gastrointestinal resp. non-homeostatical mechanisms or by weight loss per se.

The mechanism behind the apparent reduction in hedonic hunger after gastric banding surgery cannot be derived from this data. The fact that gastric banding surgery does not induce similar endocrine changes as RYGB surgery [4, 135], non-metabolic factors might explain the reduced hedonic drive. Adverse food reactions like vomiting [160] may reduce the pleasure of eating highly palatable food postsurgically. The observation that gastric banding patients - in contrast to previous findings in RYGB patients [136] - showed a similar 'food present' but a higher 'food available' domain score to non-OB subjects also pointing in this direction. Interestingly and contrary to any suggestions, a fMRI study of Bruce *et al*. provides evidence that adjustable gastric banding also alters brain reward and motivation in response to food pictures assessed in patients before and 12 weeks postsurgically [19]. These surprising results for this restrictive procedure might stem from generally reduced postsurgical food consumption, diminishing the reinforcing effect of food. Nevertheless, OB subjects after gastric band implantation still have higher brain-hedonic responses to high-calorie food than patients after gastric bypass assessed 2 months postsurgically, possibly explaining more long-term weight loss after RYGB surgery, and highlighting the importance of the gut-brain axis in the control of reward-based eating behavior [135]. Prospective studies, especially fMRI studies are needed to ascertain whether or not gastric banding can reduce hedonic hunger over a longer period in severely OB subjects.

4.4 Taste Recognition

Our data revealed a reduced sensitivity to recognize salty, sour, bitter and umami in OB compared to non-OB subjects, as has been found in previous research [116, 121]. Another previous study that included a lower number of subjects and used a distinct test paradigma, reported no alterations in salty, sour and bitter recogntion [140].

Interestingly, we found a reduction in the sensitivity to recognize salty after RYGB surgery in the Follow-up Taste Study, but no differences in our Case Control Taste Study. This finding is in contrast to a previous study using a different testing method reporting an unaltered salty detection [106]. Of note, the sensitivity to recognize salty further decreased between the two postsurgical assessments. It might be argued that the more time that elapsed after surgery, the stronger the decreasing sensitivity effect to taste salty.

Our data revealed an increase in the sensitivity to taste bitter in the Follow-up Taste Study. Of note, the sensitivity to recognize bitter did not decrease between the two postsurgical assessments. In addition, the Case Control Taste Study showed no difference between OB and RYGB subjects in the sensitivity to taste bitter. Again, it might be argued that the more time that passed after surgery, the weaker the increasing sensitivity effect to taste bitter. However, a previous study [140] also found an increased sensitivity to taste bitter 30, 60, and 90 days postsurgically in a case control study design, while another previous study did not find a significant change 6 and 12 weeks after RYGB surgery in a follow-up study design [25]. It should be mentioned that both studies included only small study groups. Increased anorectic gut hormone levels like GLP-1 [4] might explain the ascending sensitivity of bitter taste recognition after RYGB surgery. This hypothesis is based on the fact that both GLP-1 as well as bitter taste [80] are linked to anorectic histaminergic pathways [183].

Across all taste studies we found an increased sensitivity to recognize umami after RYGB surgery, while no previous research has tested this taste quality before. Of note, the sensitivity to recognize umami did not decrease between the two postsurgical assessments. The consistent finding of increased umami sensitivity might be linked to the increased protein preference. This suggestion is based on the finding of a previous study that reported the taste threshold of monosodium glutamate in combination with inosine 5’-monophosphate, which does appear to predict one's liking of as well as preference for high-protein foods [99]. This might also explain the increased intake of protein rich foods after RYGB surgery as observed in our taste studies over time postsurgically.

Data of our Case Control Taste Study revealed that RYGB patients showed a reduced sensitivity to recognize salty and sour taste compared to non-OB subjects. Altered gut hormone levels might also play a role in this context.

The underlying mechanisms behind all these alterations in taste recognition cannot be derived from this data. It is postulated that the observed altered blood levels of hormones regulating feeding status and metabolic states affect taste recognition via taste cells or brain areas [70, 145]. This hypothesis is based on the fact that oral taste cells release GLP-1 [145, 164] and express receptors for such hormones [75, 85]. Thus, it merits further research to clarify the underlying mechanisms.

4.5 Food Preferences, Liking, Dietary Habits

Our data revealed that OB and non-OB subjects did not differ in liking ratings of distinct food categories as well as in ratings on ‘How pleasant is it?’, ‘How sweet is it?’ and ‘How creamy is it?’ by tasting sugar and fat solutions at suprathreshold level (Hedonic Sweet Creamy Test). It should be noted that these ratings measure the current state. Trait measures on liking were not assessed in this work. However, trait measures of dietary habits (FFQ) differed between OB and non-OB subjects in such that the OB subjects less frequently consumed low-calorie food such as cooked vegetables and cereals, and more frequently consumed high-calorie non-sweet food such as salted snacks, meat, sausage/ham and like high-calorie sweet food such as sweets/ candies. Our finding of an increased disinhibition in OB as compared to non-OB subjects (FFQ) as well as an increased desire to eat highly palatable food (PFS) might be the reason for this eating pattern. A questionnaire to measure the trait of liking would be helpful in further studies to clarify if an increased liking of highly palatable food might also lead to such an unhealthy eating pattern in OB subjects.

While RYGB subjects did not differ from OB subjects in the liking ratings of the Case Control Taste Study, data of the Follow-up Taste Study showed a significant reduction of the first liking rating of high-calorie non-sweet food in patients 3 months after RYGB surgery compared to the baseline, which was still present 1 year postsurgically. The liking reducing effect of the surgery on high-

calorie non-sweet food appears to be weaker the more time that passes after surgery.

The liking ratings of high-calorie sweet food (food pictures) did not change after RYGB surgery, while the rating on ‘How pleasant is it?’ by tasting sugar and fat solutions at suprathreshold level (Hedonic Sweet Creamy Test) was reduced in RYGB subjects, but only 3 months after RYGB surgery in the Follow-up Taste Study. On one hand these different study results might be explained by the different test methods watching food pictures versus tasting sweet and creamy test solutions. On the other hand it might be argued again that the more time elapsing after surgery, the weaker the liking reducing effect of the surgery on high-calorie sweet food.

Our data fit with several previous studies reporting a reduced preference of high-calorie sweet and high-calorie non-sweet food intake in rats [70, 102] and in humans [86, 114, 165, 167].

The underlying mechanisms behind these alterations cannot be derived from our data. It can be postulated that the frequency of consuming such foods might play a role here. A recent study [83] showed that the lesser the perceived sweet intensity, the higher the total energy and carbohydrate intake, frequency of sweet food intake and sweet beverage liking. In addition, the sweet hedonic liking increases the higher the total energy and carbohydrate intake. Thus, it can be postulated that a high-frequent intake of high-calorie sweet resp. non-sweet food in OB subjects might decrease the perceived sweet and creamy intensity, and in parallel increase hedonic liking of such food. Indeed, across all Follow-up Studies, subjects after RYGB surgery consumed less frequent simple carbohydrates/high-calorie sweet food and fatty/high-calorie non-sweet food as well as more frequent low-calorie food like cooked vegetables than before. Of note, from 3 months up to 1 year postsurgically, patients more frequently consumed carbohydrate rich/high-calorie sweet food and also high-calorie non-sweet food. Our finding of a decreased disinhibition in subjects after RYGB surgery as observed in the FFQ across all studies might be the reason for this eating pattern. Also previous studies provide evidence that RYGB procedure led to beneficial changes in dietary habits by a more frequent intake of protein-rich foods low in fat [50, 136] and cooked vegetables [50] and a reduced intake of fresh fruits/ raw vegetables [146] as well

as sweet and fatty foods in patients after RYGB surgery [50, 94, 95, 114, 150, 167]. In addition, RYGB surgery reversed the increased rating on ‘How pleasant is it?’ for test solutions high in fat and sugar 3 months after surgery in OB subjects, supporting the connection between the frequent intake and the perceived pleasantness of highly palatable food. Interestingly, no effect of RYGB surgery on the rating ‘How sweet is it?’ and ‘How creamy is it?’ at suprathreshold level was found. This might be explained by sugar concentrations, which may have been set too high to differentiate intensity between the test solutions.

Of note, RYGB subjects rated lesser values for liking high-calorie sweet food than non-OB subjects, even if those two study groups did not differ in the rating on ‘How pleasant is it?’, ‘How sweet is it?’ and ‘How creamy is it?’, by tasting sweet and fatty solutions at suprathreshold level of the Hedonic Sweet Creamy Test. In addition, no difference in the frequency of high-calorie sweet food intake was observed. Thus, an altered frequency of consuming such food seems not to be the key modulator for the reduced liking of highly palatable foods after RYGB surgery.

Aversions to highly palatable food [67, 114, 130, 159], especially observed in the early postsurgical state [142], might explain the reduced liking of high-calorie sweet and non-sweet food after RYGB surgery, because eating such foods often results in intestinal discomfort and diarrhea, collectively called the early dumping syndrome [172]. However, aversions also seem not to be the main cause for the reduced liking after RYGB surgery, because patients without unpleasant gastrointestinal symptoms also reported a reduced liking of such food in previous studies [86, 167]. Next to learning by nutritional councelling [167], it can be postulated that the reduced preference as well as the reduced liking of high-calorie sweet and non-sweet food might also be a result of altered appetite-regulating hormone levels such as GLP-1, insulin, leptin and endocannabinoids [53–55, 115, 182], which affects gustatory sensation [104, 164] and brain reward processing [130]. Further investigation is needed to clarify the pathways, by which RYGB surgery reduces the liking of highly palatable food.

5 Conclusion

In conclusion, we could show in a series of studies that dietary habits in OB subjects are characterized by highly frequent consumption of highly palatable food. The root cause of this unhealthy eating pattern in OB subjects seems to be stronger disinhibition and hunger, but especially an increased desire to eat such palatable food. Whether the observed changes in taste recognition in OB subjects compared to non-OB subjects are the result or root cause of this eating pattern needs to be clarified in further research. The role of liking highly palatable food and its perceived pleasantness in this construct also needs to be established, most likely by trait measures.

Of note, with gastric band implantation it was surprisingly possible to reduce the patients' desire to eat palatable food more likely by dietary advice or food aversions.

RYGB surgery also reduced the desire to eat palatable food as well as disinihibition and hunger thereby leading to a healthier eating pattern. Taste recognition was also affected by RYGB surgery. Whether food liking and the perceived pleasantness is affected in general needs to be clarified in further studies. However, the observed changes after RYGB surgery are most likely to be based on metabolic/endocrine mechanisms such as altered gut hormone levels improving brain reward, satiety control and affecting taste recognition. The time that elapsed after RYGB surgery seems to play an important role here. The underlying mechanisms of this association require further investigation.

6 Summary

Background: The high prevalence of obesity is a worldwide problem. Bariatric surgery is currently the only effective strategy for long-term weight reduction. Patients after Roux-en Y gastric bypass surgery (RYGB) often report an altered desire to eat palatable foods. Here the question arose, how far bariatric surgery, like RYGB surgery and gastric band implantation, affects the hedonic drive, taste and eating behavior in obesity.

Methods: In a series of studies we tested in two cross-sectional case control studies [Taste Study: 51 non-obese (non-OB), 58 obese (OB), 44 (37.6 months post) RYGB subjects; Eating Behavior Study: 133 non-OB, 138 OB, 116 gastric banding (GB) subjects] as well as in two follow-up studies [Taste Study: baseline, 3 months & 1 year post RYGB; Eating Behavior Study: baseline & ~15.9 months post RYGB] the effect of bariatric surgery (RYGB & partly of GB) on the eating pattern (trait: frequent intake of food; Food Frequency Questionnaire, FFQ), eating behavior (trait: hunger, disinhibition, cognitive restraint by the Three Factor Eating Questionnaire, TFEQ; state: hunger rating on hunger, satiety, feeling of fullness, prospective food consumption), the desire to eat palatable food (trait: the desire to eat if food is available, present or tasted by the PFS; state: rating on wanting low-calorie, high-calorie sweet and non-sweet food; state: hunger rating on the desire to eat s.th. sweet, salty, savory, fatty; state: rating on wanting more by tasting sugar/ fat solutions at suprathreshold level by Hedonic Sweet Creamy Test), food preferences (state: rating on liking low-calorie, high-calorie sweet and non-sweet food; state: rating on pleasantness by tasting sugar/fat solutions at suprathreshold level by Hedonic Sweet Creamy Test) and taste recognition thresholds of sweet, salty, sour, bitter, and umami.

Results: Eating behavior in OB patients compared to non-OB patients were characterized by highly frequent consumption of highly palatable food (FFQ), stronger disinhibition and hunger (TFEQ), an increased desire to eat highly palatable food (PFS), changes in taste recognition, a reduced sensitivity to recognize salty, sour, bitter, and umami taste, while no changes on food liking/pleasantness were observed.

The desire to eat highly palatable food (PFS) decreased in patients after RYGB surgery and also after GB. In patients after RYGB surgery disinihibition and

hunger were reduced. Patients after RYGB surgery showed an increased sensitivity to taste bitter and umami and - only significant in the follow-up study ─ a decreased sensitivity to taste salty. No changes in food liking/pleasantness were observed in patients after RYGB surgery.

Conclusion: Gathered together our results show distinct differences in eating behavior and taste perception in OB compared to non-OB subjects as well as a great impact of bariatric surgery on these measures. The effects of bariatric surgery appear to attenuate the more time that elapses after surgery.

7 Literature

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8 Appendix

EKSG 10/001/1B Datum 19.01.2010 Seite 1 / 4

Ethikkommission
des Kantons St.Gallen

Kantonsspital, Haus 57, 9007 St.Gallen
Telefon 071 494 24 92, Fax 071 494 63 44

A-Post

Herr
Prof. Dr. med. Bernd Schultes
Leiter Adipositas-Zentrum
Heidenerstrasse 11
9400 Rorschach

19. Januar 2010 US/mm
Kontaktperson
Prof. Dr. Ulrico Schmid
Direktwahl 071 494 24 91
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SMTP ulrico.schmid@kssg.ch
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Beschlussmitteilung der Ethikkommission des Kantons St. Gallen

Die Ethikkommission des Kantons St. Gallen hat an ihrer Sitzung vom **13. Januar 2010** in der unten angegebenen Zusammensetzung das folgende Forschungsprojekt eingehend begutachtet.

Titel des Forschungsprojektes Studiencode: Ref. Nr. **EKSG 10/001** *

EKSG 10/001/1B
Reaktion auf nahrungsbezogene Reize und Aktivitätsverhalten: Veränderungen nach bariatrisch-chirurgisch vs. konservativ-therapeutisch induziertem Gewichtsverlust

Zusammensetzung der Ethikkommission
Die Ethikkommission tagte in der nachfolgend erwähnten Zusammensetzung und war damit beschlussfähig (Art. 32 der Verordnung über klinische Versuche mit Heilmitteln vom 17.10.2001).

					am Beschluss beteiligt		
					ja	nein	
	Name, Vorname	Berufliche Stellung / Titel	m	f		abwesend	In Ausstand
Vorsitz	Schmid Ulrico	Prof. Dr. med., Präsident	x	☐	x	☐	☐
Mitglieder	Breuer Markus	Dr. oec.	x	☐	x	☐	☐
	Driessen Susanne	Dr. med.	☐	x	x	☐	☐
	Eigenmann Denise	Pflegedienst KSSG	☐	x	x	☐	☐
	Gehrer-Hug Monika	lic. iur., Richterin	☐	x	x	☐	☐
	Gerig Anna	Dr. med.	☐	x	x	☐	☐
	Gysling Etzel	Dr. med.	x	☐	x	☐	☐
	Jäger Gudrun	Dr. med.	☐	x	x	☐	☐
	Jungi Felix	Dr. med.	x	☐	x	☐	☐
	Pulfer Franziska	Sozialarbeiterin	☐	x	x	☐	☐
	Schilling Dieter	Dr. phil.	x	☐	x	☐	☐
	Schmucki Simone	Rechtsanwältin	☐	x	☐	x	☐
	Schöbi Markus	Spitalseelsorger	x	☐	x	☐	☐
für Biometrie zuständiges Mitglied	Baty Florent	Dr. phil.	x	☐	x	☐	☐

§ = schriftliche Stellungnahme liegt vor

*** Bitte EKSG Nr. in allen zukünftigen Korrespondenzen erwähnen**

Hauptprüfer/in (verantwortliche/r Studienleiter/in am Versuchsstandort)

Name, Vorname, Titel: Schultes, Bernd, Prof. Dr. med.

Funktion: Leiter Adipositas-Zentrum

Adresse: Heidenerstrasse 11, 9400 Rorschach

Die Ethikkommission stützt ihre Beurteilung auf die Unterlagen, wie sie aufgeführt sind:

- x im beiliegenden „Basisformular zur Einreichung eines biomedizinischen Forschungsprojektes" vom 01.12.2009
- ☐ im beiliegenden Begleitbrief vom
- ☐ in der Rubrik „begutachtete Unterlagen" (siehe weiter unten)

Art des Verfahrens:

- x normales Verfahren
- ☐ vereinfachtes Verfahren
- ☐ Nachbegutachtung
- ☐ Neubeurteilung

Die Ethikkommission kommt zu folgendem **Beschluss**:

- ☐ **A positiv**
- ☐ **B positiv mit Empfehlungen**
- x **C positiv mit Auflagen**
  - ☐ Nachbegutachtung durch Ethikkommission notwendig
  - x Schriftliche Mitteilung an Ethikkommission ausreichend
- ☐ **D negativ (mit Begründung und Erläuterung für die Neubeurteilung)**
- ☐ **E Nicht-Eintreten (mit Begründung)**
- ☐ **F Rückstellung (mit Begründung)**

Der Beschluss gilt auch für die namentlich aufgeführten weiteren PrüferInnen im Zuständigkeitsbereich der Ethikkommission (gemäss separater detaillierter Liste)

Auflagen:
Ethisch unbedenkliche Studie mit klarer Fragestellung.
Wie erfolgt die Rekrutierung der Patientinnen und Patienten, sowie der normalgewichtigen Probanden? Bitte beachten Sie, dass freiwillige Probanden möglichst nicht in der eigenen Organisationseinheit rekrutiert werden sollten. Bitte definieren Sie das strukturierte konservative Adipositas-Programm und definieren Sie Ein- und Ausschlusskriterien (nur Milcheiweiss-Allergie oder Medikamente erwähnt).
Bitte geben Sie genauere Hinweise auf die zu bestimmenden genetischen Polymorphismen. Wo werden die molekulargenetischen Untersuchungen durchgeführt? Was passiert mit den DNA-Proben bei Rücktritt von der Studie?
Datenanalyse: Bitte spezifizieren Sie in der Poweranalyse, welche Power erwartet wird (80 %?).
Patienten-/Probandeninformation: Bitte verwenden Sie Briefpapier mit Logo Ihrer Klinik, und versehen Sie die Seiten mit Seitenzahlen, Versionsnummer und Datum. Bitte fügen Sie unter dem Titel den Sponsor (KSSG) ein.
Punkt 2, Wissenschaftlicher Hintergrund und Ziel der Studie: Bitte ersetzen Sie im 1. Satz des 2. Abschnitts den Passus '... ~~bislang die einzige~~ ...' durch '... eine effektive Therapie ...'. Da insbesondere auch adipöse Patientinnen und Patienten unter konservativer Therapie eingeschlossen werden sollen, soll nicht der Eindruck erweckt werden, dass ausschliesslich die bariatrischen Operationen wirksam sind, zumal in der vorliegenden Studie die Auswahl der Therapie (bariatrisch versus konservativ) nicht Gegenstand der Studie ist.
Bitte erklären Sie die Fremdwörter wie z.B. nahrungsbezogene Stimuli, Umami, bioelelektrische Impedanzanalyse, etc. Die Information über die zu bestimmenden Variationen von mit Adipositas zusammenhängenden Genen sollte differenzierter erfolgen. Wo werden die Proben untersucht (genaue Adresse des Laboratoriums)? Was passiert mit den Proben nach der Untersuchung? Was passiert mit den Proben nach Rücktritt aus der Studie (Proben müssen dann vernichtet werden). Bitte fügen Sie einen Abschnitt über Versicherung ein und erwähnen Sie die Haftpflichtversicherung des Kantonsspitals.
Punkt 10, Kosten: Bitte spezifizieren Sie, dass nur die im Rahmen der Studie zusätzlich durchgeführten Untersuchungen kostenlos sind.
Punkt 12, Kontaktpersonen: Bitte geben sie zudem die Adresse der Kontaktpersonen an.
Einverständniserklärung: Bitte fügen Sie den Sponsor (KSSG) ein, sowie Datum und Versionsnummer.
Bitte erwähnen Sie die Haftpflichtversicherung gemäss Template.
Bitte reichen Sie ein CV nach.

Es genügt, wenn Sie die geänderten Dokumente elektronisch der Ethikkommission einreichen.
Sind die Auflagen der Ethikkommission erfüllt, kann die Studie definitiv genehmigt werden.

> Bitte jeweils die Änderungen in den revidierten Dokumenten markieren.

Pro Memoria: **Pflichten des/der Hauptprüfers/in**

- Meldepflicht bei: a) schwerwiegenden unerwünschten Ereignissen unverzüglich (Arzneimittel: nur bei schwerwiegenden unerwarteten Nebenwirkungen)
  b) neuen Erkenntnissen, die während des Versuchs verfügbar werden und die Sicherheit der Versuchspersonen und/oder die Weiterführung des Versuchs beeinflussen können.
  c) Änderung des Protokolls (Versuchsplans)
  d) Ende oder Abbruch der Studie
- Zwischenbericht: einmal pro Jahr
- Meldungs- oder Bewilligungspflicht von Studien bei Swissmedic bzw. anderen Bundes- oder kantonalen Behörden (bei sponsorisierten Studien ist dies die Pflicht des Sponsors)
  Diese Meldepflicht gilt nur für Studien, die dem Heilmittelgesetz unterstehen.
- Schlussbericht

Die Ethikkommission des Kantons St. Gallen bestätigt, dass sie nach den ICH-GCP-Richtlinien arbeitet.

Rechtsmittelbelehrung
Gegen diesen Beschluss kann **innert 14 Tagen**, von der Zustellung an gerechnet, beim Gesundheitsdepartement des Kantons St. Gallen, Rechtsdienst, Davidstrasse 27, 9001 St. Gallen, durch schriftliche Eingabe (in dreifacher Ausfertigung) **Rekurs** erhoben werden.
Die Rekursschrift muss einen Antrag, eine Darstellung des Sachverhalts und eine Begründung enthalten; sie ist zu unterzeichnen. Der angefochtene Beschluss ist dem Rekurs beizulegen.

Gebühr: Fr. 500.00

Haben Sie Ihre Studie schon registriert/registrieren lassen (z.B. www.clinicaltrials.gov)?

ETHIKKOMMISSION DES
KANTONS ST. GALLEN

Prof. Dr. Ulrico Schmid
Präsident

St. Gallen, **19. Januar 2010**

Beilagen
- Formular Jährlicher Zwischenbericht
- Empfangsbestätigung der Unterlagen

9 Acknowledgements

I gratefully thank Prof. Dr. Bernd Schultes and the Cantonal Hospital St. Gallen for their support. I thank Dr. Britta Wilms and Dr. Barbara Ernst for their support in planning and Luzia Krempl-Gnädinger for her support in conducting the study visits. Furthermore I thank Dr. Michael Lowe from the Department of Psychology, Drexel University, Philadelphia, for generously providing us the Power of Food Scale as well as Sabine Frank Podlech from the University Tübingen for providing us the food pictures as well as the test method for assessing wanting and liking. Finally, I gratefully thank all of our patients who participated in the studies.

10 Curriculum vitae

Name: Jennifer Ullrich

Age: 35

Education

PhD student in Human Biology since APR 2010
Cantonal Hospital St. Gallen, Switzerland
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M.Sc. in Nutritional Sciences OCT 2007 – SEP 2009
Justus Liebig University Giessen,
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Master's Thesis (Clinical study) OCT 2008 – SEP 2009
The effect of Chronic Inflammatory Bowel Disease on Body composition, Energy metabolism and Physical activity
Ludwig Maximilians University, Munich,
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B.Sc. in Ökotrophologie: Food economics, APR 2003 – SEP 2007
Household and Nutritional Sciences
Justus Liebig University Giessen,
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Agricultural Sciences FEB 2007 – JUL 2007
Polytechnic University of Valencia
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Professional experience

QA Document & Training System Manager since MAY 2018
Vifor Pharma (International) AG
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Specialist Stability Studies AUG 2013 – APR 2018
Vifor Pharma (International) AG
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Research Assistant/ Study Coordinator APR 2010 – MAY 2013
Interdisciplinary Obesity Center
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Publications

Ullrich J, Ernst B, Wilms B, Thurnheer M, Hallschmid M, Schultes B. The hedonic drive to consume palatable foods appears to be lower in gastric band carriers than in severely obese patients who have not undergone a bariatric surgery. *Obes Surg. 2013;23:474-9.*

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;23:50-5.*

Ullrich J, Wilms B, Ernst B, Thurnheer M, Schultes B Roux-en Y Magen Bypass vermindert die Geschmackserkennungsschwelle für bitter und umami bei stark adipösen Probanden. *Poster-Präsentation am Deutschen Adipostias Kongress, Oktober 2012, Stuttgart, Deutschland.*

Schultes B, Ullrich J, Wilms B, Ernst B, Thurnheer M Roux-En Y Gastric Bypass Surgery Decreases Bitter And Umami Taste Perception Thresholds In Severely Obese Subjects. *ABSTRACT for the Annual Meeting of the Society for the Study of Ingestive Behavior (SSIB) in July 10 - 14, 2012. Zurich, Switzerland*

Werkstetter KJ, Ullrich J, Schatz SB, Prell C, Koletzko B, Koletzko S. Lean body mass, physical activity and quality of life in paediatric patients with inflammatory bowel disease and in healthy controls. *J Crohns Colitis. 2012;6:665-73.*