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Title page

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Weight loss decreases self-reported appetite and alters food preferences in overweight and obese adults: observational data from the DiOGenes study

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Abbreviations: AUC, Area Under the Curve; CCK, cholecystokinin; CID, Clinical Investigation Day; d-AUC, delta Area Under the Curve; DiOGenes, Diet, Obesity and Genes; E%, Percent of Energy; FCPQ, Forced Choice Photographic Questionnaire; FCQ, Food Choice Questionnaire; FPC, Food Preference Checklist; LCD, Low Calorie Diet; LMM, Linear Mixed Model; VAS, Visual Analogue Scale; WHO, World Health Organization

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Abstract

People with obesity often struggle to maintain their weight loss after a weight loss period. Furthermore, the effect of weight loss on appetite and food preferences remains unclear. Hence this study investigated the effect of weight loss on subjective appetite and food preferences in healthy, overweight and obese volunteers. A subgroup of adult participants (n = 123) from the Diet Obesity and Genes (DiOGenes) study (subgroup A) was recruited from across six European countries. Participants lost ≥ 8% of initial body weight during an 8-week low calorie diet (LCD). Subjective appetite and food preferences were measured before and after the LCD, in response to a standardized meal test, using visual analogue rating scales (VAS) and the Leeds Food Choice Questionnaire (FCQ). After the LCD, participants reported increased fullness ($p < 0.05$), decreased desire to eat ($p < 0.05$) and decreased prospective consumption ($p < 0.05$) after consuming the test meal. An interaction effect (visit x time) was found for hunger ratings ($p < 0.05$). Area under the curve (AUC) for hunger, desire to eat and prospective consumption was decreased by 18.1%, 20.2% and 21.1% respectively whereas AUC for fullness increased by 13.9%. Preference for low-energy products measured by the Food Preference Checklist (FPC) decreased by 1.9% before the test meal and by 13.5% after the test meal ($p < 0.05$). High-carbohydrate and high-fat preference decreased by 11.4% and 16.2% before the test meal and by 17.4% and 22.7% after the meal ($p < 0.05$). No other effects were observed. These results suggest that LCD induced weight loss decreases the appetite perceptions of overweight volunteers whilst decreasing their preference for high-fat-, high-carbohydrate-, and low-energy products.

Keywords: LCD; weight loss; body weight maintenance; hunger; Leeds Food Choice Questionnaire; Visual Analogue Scale

Introduction

According to the World Health Organization, the prevalence of obesity more than doubled between 1980 and 2014, rising to over 600 billion adults with obesity worldwide (1). This increase is often attributed to an increasingly obesogenic environment, characterized by a sedentary lifestyle and by easily available, energy-dense foods (2). Losing weight seems to be a logical solution for the obesity epidemic. However, losing weight and, in particular, maintaining this weight loss proves difficult. A study conducted in the US showed that less than 20% of people who attempted to lose weight could maintain a 10% weight reduction for over a year (3). Since diet plays an important role in weight regain, a better understanding of the effect of weight loss on subjective appetite and food choice is required.

Subjective appetite is generated, in part, by physiological mechanisms occurring before and after a meal. In turn, these mechanisms respond to, and are modulated by, long-term energy intake and expenditure (4, 5). Weight loss is typically caused by a long-term energy deficit and might, therefore, influence physiological appetite mechanisms (6). Indeed, previous studies have shown that a period of weight loss increases self-reported perceptions of hunger and the drive to eat (7).

The hedonic value of food also plays a role in eating behaviours. In essence, people are able to eat foods they find palatable in the absence of hunger (8). Obese people generally report a higher preference for high-fat and high-sugar products than lean people, which has been hypothesized to stem from a decreased sensitivity to sweet and fatty tastes (9). However, to date it is unclear if obesity is the cause or the consequence of this decreased sensitivity (9). Studies in obese participants who have undergone Roux-en-y gastric bypass surgery have shown that high-fat and high-sugar products are preferred before surgery whereas fruit and vegetable products are preferred after surgery (10). It is currently unknown if this shift in food preference is caused by physiological changes due to the surgery or by the weight loss

resulting from the surgery (11). Weight loss has, however, been shown to alter food preferences in previous studies (12, 13).

The findings of previous studies examining changes in post weight loss appetite and food preferences are inconsistent (7, 12-17). Understanding the factors that influence eating behaviours at the end of a weight loss period is, however, essential to develop strategies to prevent subsequent weight regain. Hence, this study focuses on the effect of substantial weight loss induced by an 8-week LCD on self-reported appetite and food preferences in overweight and obese adults (18).

Participants and Methods

Study design

Participants included in the reported study were a sub-group of participants (subgroup A) from the overarching Diet Obesity and Genes (DiOGenes) study (http://www.diogenes-eu.org/) (18). The DiOGenes study was a pan-European, randomized intervention study that examined the long-term effect of five different intervention diets on body weight maintenance after a weight loss period (18, 19). Enrolment onto one of the intervention diets, was dependent upon participants losing at least 8% of their initial body weight by means of an 8-week low-calorie diet (LCD) (Modifast; Nutrition et Santé, Revel, France, **Table 1**). The diet provided participants with 3.6 MJ energy per day, which they could supplement with up to 400 g of raw vegetables, resulting in a maximal energy intake of 4.5 MJ per day. This sub-study reports on the effect of substantial weight loss induced by a LCD on subjective appetite and food preferences in response to a standardized meal test administered before and on the last day of the weight loss period, with participants still in negative energy balance. These outcome n variables represent secondary outcomes of the overarching DiOGenes study upon

which a priori analyses were performed to identify psychological predictors of weight regain. The DiOGenes study has previously been described in more detail by Larsen et al. and Moore et al. (18, 19). The present results have not previously been published.

Participants

Both male and female participants were recruited from November 2005 to April 2007. Participants were either overweight or obese (body mass index [BMI] between 27-45 kg/m^2) and were between 18 and 65 years old. Only participants who completed the meal test before and at the end of the weight loss period are included in the statistical analyses of this sub-study. An extensive overview of the inclusion and exclusion criteria for the DiOGenes study is provided by Larsen et al. (18). Procedures followed in the DiOGenes study were in accordance with the Declaration of Helsinki and approved by local ethics committees in all participating countries. Written informed consent was obtained from all participants.

Standard meal test

A homogeneous test meal consisting of 220 g pasta served with 75 g of an oven roasted vegetables sauce (Dolmio express! Fusili Pasta and Dolmio 'Stir-in' sauce - Oven Roasted Vegetables, MarsFoods, Dublin, Ireland) was provided to all participants before (Clinical Investigation Day [CID] 1) and at the end of the LCD (CID2) at lunchtime. The test meal provided a total weight of 295 g (total energy: 1.6 MJ, macronutrient content: 13 g, 13 percent of energy (E %) protein, 11 g, 26 E% fat and 63.7 g, 61 E% carbohydrates). Participants were requested to fast overnight before each test meal and were allowed to drink a maximum of 1 dl water before the test. Participants were instructed to consume all of the test meal and were free to drink as much water as they wanted during the test. Visual analogue rating scales (VAS) and the Leeds Food Choice Questionnaire (FCQ) were used to

assess appetite perceptions and food preferences, respectively (15, 20-24). The FCQ was completed 15 minutes before and after consumption of the test meal. The VAS appetite ratings were obtained at 15 minutes before and then at 15, 30, 60, 90, 120, 150, and 180 minutes after the start of the test meal.

Appetite questionnaires

The VAS for appetite measurement consisted of a series of 100 mm horizontal lines anchored with extreme appetite perceptions on both ends of each line (e.g. not at all hungry – very hungry). They were used to answer each of the following 4 questions: How hungry are you? (not at all hungry – very hungry), How full do you feel? (not at all full – very full), How strong is your desire to eat? (not at all strong – very strong), How much food do you think you can eat? (none at all – a large amount). Participants from all research centres received the same instructions on how to fill out the VAS (15). VAS were digitally presented to the participants and were available in the languages of all participating countries. In case of computer problems, paper and pencil VAS were provided.

Leeds Food Choice Questionnaire

Food preferences were measured using the FCQ. The FCQ consisted of the Food Preference Checklist (FPC) and the Forced Choice Photographic Questionnaire (FCPQ) which were adapted to fit with the eating habits of the participating countries as necessary (20-24). These questionnaires were digitally presented to the participants and were available in the languages of all participating countries. Paper and pencil questionnaires were provided to participants in case of computer problems.

Food Preference Checklist

The FPC is composed of a list of written descriptions of 32 common food items. Participants were asked to examine each individual food item (e.g. a roast chicken breast) in turn and to make an assessment as to whether or not they would like to eat it at that particular moment in time by responding "yes" or "no". Participants were instructed to consider food items independently from each other, and to limit their thinking time for any one of the food items. The foods that were described could be divided into one of four different categories: high-fat, high-carbohydrate, high-protein (each food contained at least 50 % of total energy as the macronutrient by which it was categorised and foods were presented in portions corresponding to approximately equal energy content [180-220 kcal]), with the exception of low-energy foods (averaging 25 kcal per portion). There were 8 food descriptions per category. Within the high-fat, high-carbohydrate and low energy categories, 4 foods were savoury and 4 were sweet. In the high-protein category all foods were savoury. Hence, the minimal score for each category was 0 ("no" for each question) and the maximal score was 8 ("yes" for each question). In addition, the total frequency of chosen food items was calculated (score ranged between 0 and 32).

Forced Choice Photographic Questionnaire

During the FCPQ, participants were presented with photographs of two different foods and instructed to indicate which one they preferred more. Participants were instructed to imagine they could eat as little or as much of the chosen food as desired. In total, 30 pairs of food photographs were shown and the foods (20 in total) could be divided into one of the following categories: high-fat/savoury, high-fat/sweet, low-fat/savoury, and low-fat/sweet. For example, participants could choose between a picture of a doughnut (high-fat/sweet) or a jelly pudding (low-fat/sweet). Each preference category was presented 5 times in 3 different combinations, providing 15 presentations in total. Thus, the total score for each category ranged from 0 to

15. From these scores, separate scores for the sub-categories high-fat (sweet plus savoury), low-fat (sweet plus savoury), savoury (low-fat plus high-fat), and sweet (low-fat plus high-fat) were calculated. The minimal score for the sub-categories was 5, since there was always one combination in which a sub-category was inevitably chosen (e.g. high-fat/sweet vs high-fat/savoury would always give a high-fat preference), and this combination occurred 5 times in the questionnaire. There were 4 combinations in which a sub-category could be chosen over the other sub-categories, and these combinations occurred 5 times. Including the minimal score of 5 (above), the maximal score was, therefore, 25 for each sub-category.

Statistical methods

Linear mixed models (LMM) were used to assess differences in subjective appetite and food preferences before and at the end of the weight loss period. All LMMs included visit (before [CID1] or at the end of the weight loss period [CID2]), time (time points at which the questionnaires were filled out) and their interaction as well as adjustment for age and sex. Random effects for centre and subjects were also included in all models. For appetite ratings, the baseline value (CID1, at 15 minutes before the meal test) of the appetite rating was also included as a covariate. If a significant time-visit interaction effect was found, pairwise comparisons between CID1 and CID2 were performed for each time point. Tukey's test was used to correct for multiple comparisons. In an additional analysis, centres were treated as fixed effects to allow comparisons between centres. In case a centre effect was present, pairwise comparisons with a Tukey correction were performed to identify differences between centres.

To assess if the change in appetite perception from CID1 to CID2 was affected by the weight loss period, a linear regression model was fitted with delta area under the curve ([d-AUC], defined as AUC at CID1 minus CID2) of the VAS appetite rating as the outcome variable,

and absolute weight loss as the independent variable. Total AUC was calculated using the trapezoid method (25). Age and sex were included in this model as covariates. Furthermore, Pearson's correlation coefficients between weight loss percentage and d-AUC of appetite were calculated. Statistical analyses were performed with the software programme R (26). Data were not transformed prior to analysis. Results were considered significant when $p < 0.05$. Graphs were constructed using GraphPad Prism 7.

Results

In total, 151 participants from across 6 European intervention sites (i.e. the Netherlands, Denmark, United Kingdom, Germany, Spain, and Czech Republic) were included in this sub-study of which 123 (48 males and 75 females) participants participated in the meal test both before and at the end of the LCD. Drop-out rates were highest in Spain (32.3 %) and lowest in Denmark (6.3 %).

Participants were on average (mean ± SD) 41.2 ± 5.2 years of age with an average (mean ± SD) body weight of 100.0 ± 16.8 kg at baseline. They had a mean weight loss of 11.1kg (± 0.2) during the LCD. Due to missing values, data from 11 participants could not be included in any of the AUC analysis of appetite ratings. For 1 additional participant, only AUC for prospective consumption could not be calculated because of missing values.

Appetite

Mean VAS rating scores for the different appetite perceptions are presented in **Figure 1**. The before meal rating of prospective consumption was significantly lower (χ^2 (1) = 4.20, $p < 0.05$) at the end of the LCD period than before this period (62.5 ± 1.7 before the LCD compared with 58.6 ± 1.6 at the end of the LCD). The before meal ratings of hunger, fullness and desire to eat were not significantly altered by the LCD period ($p > 0.05$). For hunger there

was a significant time-visit interaction (χ^2 (1) = 6.26, p < 0.05), corresponding to significant decreases in hunger at CID2 relative to CID1 at 120, 150, and 180 minutes after consumption of the test meal. Fullness was generally increased at the end of the weight loss period (χ^2 (1) = 91.93, p < 0.05), whilst desire to eat (χ^2 (1) = 111.93, p < 0.05) and prospective consumption (χ^2 (1) = 153.63, p < 0.05) were decreased. There were a number of differences in appetite ratings between the countries involved in the research, but no systematic differences were observed.

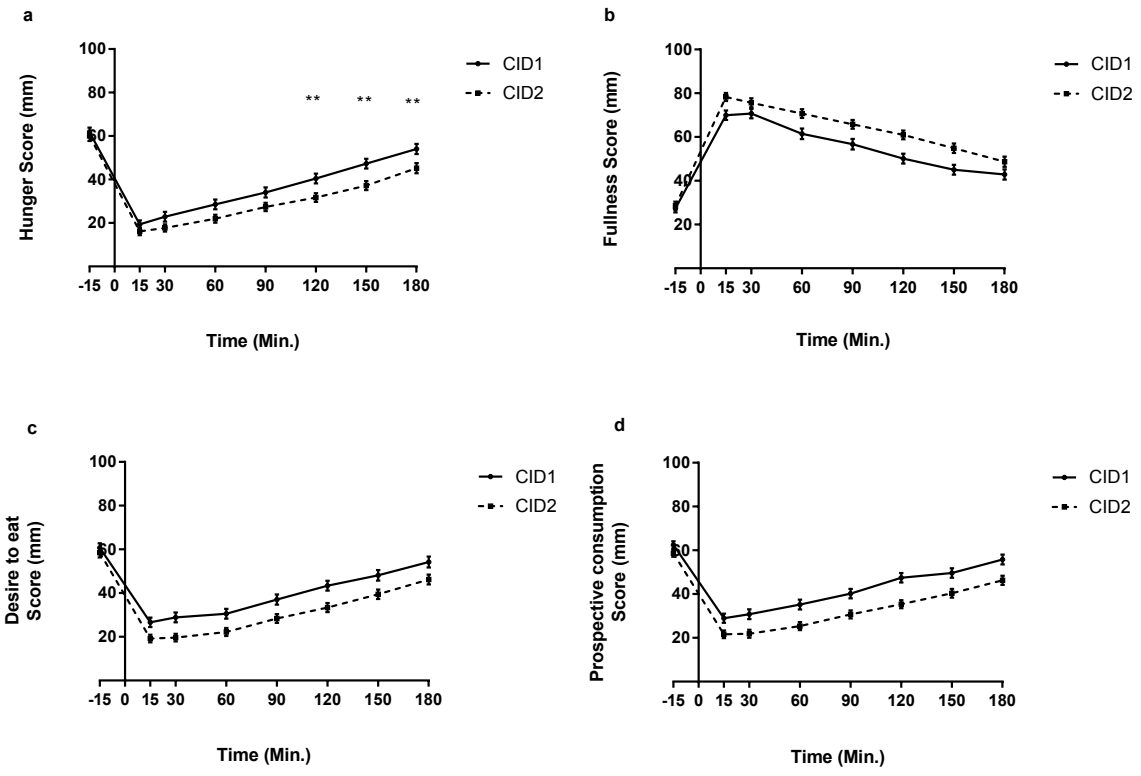

FIGURE 1

Mean ± SEM visual analogue scale appetite scores (0 – 100 mm) before (t = -15) and after a test meal (at t = 0) before (CID1) and at the end of (CID2) a weight loss period. Appetite measurements included (a) hunger, (b) fullness, (c) desire to eat, and (d) prospective consumption. Appetite scores over time were analysed using a linear mixed model procedure. ** Significantly differences in appetite after weight loss: ** P < 0.01.

CID, Clinical Investigation Day.

There was an 18 % decrease in AUC for hunger at the end of the LCD period compared to before this period. AUC for desire to eat decreased by 20 %, AUC for prospective consumption decreased by 21 %, and AUC for fullness increased by 14 % at the end of the LCD. Regression analysis of the d-AUC appetite scores showed significant correlations between absolute weight loss (kg) and hunger [$F(1, 217) = 9.20$, $p < 0.05$], fullness [$F(1, 217) = 3.89$, $p < 0.05$], desire to eat [$F(1, 217) = 9.95$, $p < 0.05$], and prospective consumption [$F(1, 215) = 4.89p < 0.05$]. No significant correlations were found between weight loss percentage and delta AUC of hunger, fullness, desire to eat, and prospective consumption ($p > 0.05$).

Leeds Food Choice Questionnaire

Food Preference Checklist

Significant decreases in preference were found for low-energy foods ($\chi^2(1) = 4.82$, $p < 0.05$), high-carbohydrate foods ($\chi^2(1) = 11.52$, $p < 0.05$) and high-fat foods ($\chi^2(1) = 22.46$, $p < 0.05$) at the end of the LCD period (**Table 2)**. Before the test meal, a decrease in preference for low-energy foods (1.9 %), high-carbohydrate foods (11.4 %), and high fat foods (16.2 %) was observed after the LCD compared to before this period. After the test meal, decreases in preference were found for low-energy foods (13.5 %), high-carbohydrate foods (17.4 %), and high-fat foods (22.7 %) in response to the LCD. The total frequency of chosen foods decreased both before (6.3 %) and after the test meal (15.2 %), as a result from the LCD ($p < 0.05$). Preference for high-protein foods remained unaltered at the end of the weight loss period ($p > 0.05$).

In response to the test meal, preference for low-energy foods (χ^2 (1) = 116.45, $p < 0.05$), high-protein foods (χ^2 (1) = 232.74, $p < 0.05$), high-fat foods (χ^2 (1) = 107.72, $p < 0.05$), and high-carbohydrate foods (χ^2 (1) = 187.08, $p < 0.05$) was decreased (table 2). Hence, the total frequency of chosen foods was also significantly lower after the test meal compared to before this meal (χ^2 (1) = 239.09, $p < 0.05$). There were no differences between centres in food choice measured by the FPC ($p > 0.05$).

Forced Choice Photographic Questionnaire

No significant differences in food preferences assessed before and after the weight loss period were found (**Table 3**, $p > 0.05$). There were, however, significant differences in preferences assessed before and after the test meal. After the test meal, participants reported a higher preference for sweet (χ^2 (1) = 184.34, $p < 0.05$) and high-fat products (χ^2 (1) = 17.64, $p < 0.05$) compared to before the meal. Preference for low-fat (χ^2 (1) = 17.64, $p < 0.05$) and savoury products (χ^2 (1) = 184.34, $p < 0.05$) decreased after the test meal. Differences in preferences between the centres were also observed, but these differences were not systematic.

Discussion

Our study showed that substantial LCD-induced weight loss generally decreased postprandial appetite perceptions, when measured while the participants were still in negative energy balance. Fullness was increased, whilst hunger, desire to eat and prospective consumption were all decreased in response to weight loss. Furthermore, the overall number of foods selected from the Food Preference Checklist (FPC) was also decreased in response to the LCD. Hence, the FPC showed a decreased preference for low-energy-, high-carbohydrate-, and high-fat foods. In the fasted state, prospective consumption was significantly lower after the LCD compared to before the LCD. No other significant findings were observed.

Both the changes found in subjective appetite and food preferences support a reduced interest in food after weight loss. Therefore, our findings cannot explain the weight regain people with obesity often experience after a weight loss period (3). From our results, it appears that subjective appetite is influenced by body weight, which has also been shown in previous studies (16, 27). However, a cohort study by Gregersen et al. did not show a relationship between BMI and subjective appetite (28). These investigators compared lean with obese participants, without a weight loss intervention. In contrast, we assessed subjective appetite in overweight and obese participants before and immediately after a weight loss period. At the end of this period, participants were still in negative energy balance. It might, therefore, be that the state of negative energy balance influenced the appetite sensations we measured. Indeed, the study of Sumithran et al. showed that different physiological processes occur during an energy depleted state and during refeeding. This study found the VAS appetite ratings from their overweight and obese male and female participants remained unchanged after an 8-week very low-calorie diet (17). They hypothesized that this response might have resulted from the ketogenic state participants were experiencing due to the low carbohydrate content of the weight loss diet. This hypothesis was also supported by the observation that, after 2 weeks of refeeding, appetite ratings were significantly increased compared with those assessed immediately after the weight loss period. This increase in appetite after 2 weeks might also indicate that different physiological processes occur immediately after a weight loss period compared to those occurring during a subsequent period of weight maintenance. It is likely that the LCD used in our study did not lead to a ketogenic state in all our participants. However, it is possible that the LCD induced a ketogenic state in men, since men generally have a higher energy expenditure than women. Unfortunately, we do not have measurements to support this theory.

In contrast to our study, a study by Seimon et al. found an increase in desire to eat in both lean and obese men after consuming a 30 % energy restricted diet for 4 days (29). However, the hormonal response in this study differed from the response normally associated with an increase in appetite after a period of fasting. Specifically, the anorexic hormones peptide YY (PYY) and cholecystokinin (CCK) were increased in both lean and obese male participants. Normally, decreases in PYY and CCK, together with an increase in hunger, are reported after a period of fasting (30). This finding reflects the complexity of the physiological processes occurring during energy restriction. A possible explanation for this discrepancy could be that physiological processes regulating appetite in the body are influenced by the duration of the energy restriction. Also, it has been hypothesized that the relative fat content of the diet can alter gastrointestinal transit time, and thereby modulate appetite response (14, 31, 32). The genetic profile of obese people may also modulate the effect of dietary fat on the consequent appetite response (33). Moreover, the study by Seimon et al. measured subjective appetite in response to an intraduodenal lipid infusion, whereas our study measured appetite in response to consumption of a test meal (29). Hence, the lipid infusion in the study by Seimon et al. did not pass the stomach. Bypassing of the stomach has major impact on subjective appetite (5). Therefore, it is highly likely that the differences in appetite found in the study by Seimon et al. (increased desire to eat) and our study (decreased appetite) can be attributed to processes in the stomach that influence appetite.

Similarly, patients that undergo Roux-en-Y gastric bypass (RYGB) surgery frequently report increased postprandial satiety after surgery (34-37). The surgery is accompanied by a substantial amount of weight loss (approximately 35 % of initial body weight), which seems to be sustained long term (at least two years) (38, 39). Surgery increases the postprandial levels of the orexigenic hormones glucagon-like peptide 1 (GLP-1) and PYY, which might cause the increased satiety and subsequent weight loss (34-37). However, it is also possible

that the weight loss itself results in altered hormone levels and increased satiety, since the RYGB studies have not been able to draw inferences on causality due to their observational nature (34-37). Our study cannot support the hypothesis that weight loss increases postprandial satiety through increased levels of PYY and GLP-1 response, as we did not measure any biological parameters related to satiety. Previous studies did show an increased level of postprandial GLP-1 and PYY after dietary weight loss, indicating that weight loss might be accountable for the observed changes after RYGB (40, 41). Both GLP-1 and PYY are related to decreased appetite and seem to inhibit gastric emptying, which in turn also affects appetite (5). At present, it is unclear how gastric emptying is affected by RYGB and studies investigating the effect of dietary weight loss on gastric emptying are scarce (42, 43). Interestingly, the decrease in food preference (measured with the FPC) for high-carbohydrate and high-fat foods that we observed at the end of the LCD also corresponds to the decreased food preference for high-energy foods reported after RYGB surgery (10). This finding seems to strengthen the hypothesis that the observed changes in food intake after RYGB can, at least partially, be attributed to weight loss.

However, it is also possible that other mechanisms than the weight loss itself influenced our results. For example, the negative energy balance of the participants might have affected the sympathetic nervous system (SNS). The SNS has a profound role in gastric intestinal processes. In lean people, fasting suppresses the SNS and increases appetite (5, 44). However, obese people appear to have an over-activity of the SNS and therefore their appetite response to a decreased SNS activity might be different (44). It might be that a supressed SNS in obese people leads to a more sensitive response to incoming nutrients which results in decreased postprandial appetite.

Furthermore, appetite is not only influenced by physiological mechanisms but also by psychological mechanisms (45). Habituation to the LCD is a potential psychological mechanism that could have influenced our results. Before the LCD, participants could have been habituated to portion sizes that were bigger than our test meal and thus reported lower feelings of satiety after eating the test meal. Unfortunately, we did not measure eating habits before the LCD. A study by Berg et al. supports habituation to bigger meals before the LCD. This study showed that obese men and women generally choose bigger sized portions than lean people. In contrast, this same study also presented an association between being obese and omitting lunch (46). This association might suggest that most of our (overweight and obese) participants were not habituated to having lunch. Thus, comparing the habitual lunch (nothing) of our participants with the test meal (which was served at lunch time) does not favour a decrease in post-prandial satiety after the test meal (before the LCD). However, it could be possible that participants became habituated to the LCD. The portions during the LCD were smaller compared to the test meal and therefore participants might have experienced a higher postprandial satiety at the end of the weight loss period.

In addition, our results might have been affected by the motivation to lose weight. Only participants that lost 8% of their body weight were included in this sub-study, which includes only participants that were very motivated to lose weight. In addition, the 8% weight loss might have served as an additional motivational factor by improving the body image of our participants. This motivation might have resulted in lower appetitive standards. Furthermore, participants were subjected to a 6- or a 12-month weight maintenance diet after the LCD. In anticipation of the weight maintenance period it would be undesirable for participants to feel hungrier, which might have also added to the lower appetitive standards. Results from the FPC showed that participants appeared to have a lower preference for most food types. Hence, the total frequency of chosen products was decreased after the LCD induced weight

loss, reflecting a lower preference for low-energy-, high-carbohydrate-, and high-fat foods. Our findings contradict the majority of studies reporting that the reward value of food is increased after food deprivation (8). The changes in food preferences observed in our study may be partially explained by the study by Anton et al. (12). In this two-year intervention study, overweight participants were assigned to one of four different weight loss diets. Each diet provided participants with a 750 kcal deficit in daily energy intake calculated from the participants' baseline energy expenditure. Regardless of the diet, participants reported reductions in food cravings for high-fat foods, fast-food fats, sweets, and carbohydrates/starches after 6 months, 12 months and 24 months of dieting. It was hypothesized that the participants' association between consumption of the typically unhealthy foods and the feeling of emotional relief became lower after a prolonged period of limited intake of these products. This decreased association was thought to decrease the preference for unhealthy foods (12).

A previous study also showed that a 3-month weight loss period induced an earlier satiation to a sweet stimulus. In this study, participants repeatedly ingested a sweet stimulus until they felt displeased with the stimulus. The time leading up to displeasure was significantly shorter after the weight loss period than before. It was hypothesized that the earlier satiation experienced with the sweet stimulus was indicative of a lowered body weight set-point (47). Hence, homeostatic mechanisms would favour a lower food intake after weight loss to accommodate the decreased body weight. Our study supports this theory since food preference in our study resulted in a decreased preference for food in general. However, the frequently observed regain of body weight after a weight loss period suggests that there are mechanisms that can override the body weight set-point (3).

The Forced Choice Photographic Questionnaire (FCPQ) did not reveal any alterations in food preference. A possible explanation for the discrepancy between the results of the FPC and the FCPQ is that the FCPQ forces the participant to choose between two target food stimuli and thereby measures the relative behavioural preference (48). Furthermore, although the FCPQ has been validated in a wide range of research, the FCPQ is highly dependent on the quality of the pictures (48-50). It is generally assumed that the way food is presented visually can influence people's flavour perception and modify their food choices (51). Despite the fact that each food in the photographs was presented in a standardized fashion (i.e. on a white plate or in a glass bowl), it is possible that the appearance of the food itself might have influenced participants' choices.

Strengths and limitations

Our study has several limitations. Firstly, we examined subjective appetite and food choice in response to a fixed test meal with use of VAS rating scales and food choice questionnaires, rather than assessing objective satiety and food choice via an ad libitum test meal. Although VAS ratings are a validated tool to measure subjective appetite, in some studies subjective appetite does not reflect actual food intake (52, 53). In our study, we found significant reductions in subjective appetite following weight loss. However, the changes observed were rather small. Hence, it is not clear if the differences in appetite would translate to a lower food intake. Often, an ad libitum test meal is offered to participants after a preload to objectively assess the effects of the preload on food choice and energy intake (4). However, an ad libitum test meal is not itself infallible since the variety of foods offered to participants is typically different from their usual eating pattern. This, therefore, acts to stimulate interest in the different foods provided and thus promotes increased food intake from the ad libitum meal (4).

Another limitation of our study is the possibility that the interpretation of the end points of the VAS scales (e.g. not at all hungry – very hungry) was different before compared to after the weight loss period. Hence, this potential difference in interpretation could have influenced the resulting appetite ratings. A method that circumvents the problem of interpretation of the endpoints is the general Labeled Magnitude Scale (gLMS). This method uses a scale with endpoints that are external to the perception measured (i.e. no perception – strongest imaginable perception of any kind). Since these endpoints refer to any kind of perception experienced, the gLMS eliminates difficulties with interpretation of the endpoints (54, 55). In contrast, it has been found that the VAS and gLMS give comparable results when assessing within-subject differences, while they differ when comparing across different subject groups. Since our study only examined within-subject differences, it appears that both methods would have been suitable tools to measure appetite (54, 55). Nevertheless, a validation study that compares appetite perceptions before and after a weight loss period using both the VAS and the gLMS seems to be warranted.

Finally, we did not control for individual differences in food preferences when using the FCPQ (4). However, these individual differences could be compensated for by the large sample size of our study. This large sample size, in combination with the multi-centred nature of our study, increased the external validity of our study and allowed us to observe small but potentially important changes in food choice and appetite.

Future studies

Future studies are necessary to gain more insight into the mechanisms responsible for the changes in appetite and food preferences observed in our study. Indeed, it might be interesting to examine the effect of weight loss combined with increased exercise on appetite, since fat

free mass has been positively associated with energy intake and self-determined meal size in obese participants (56). Additionally, exercise has been shown to affect food preference (57). Currently, the PREVIEW study investigates how intensity of exercise (and type of diet) might help to improve weight loss maintenance, amongst other study outcomes (58). It might also be interesting for future studies to examine eating behaviour throughout a period of weight maintenance. Measuring appetite in an energy homeostatic state eliminates interference of the effects of a negative energy balance on appetite, and therefore permits conclusions about the effect of weight loss on appetite. Also, the period of weight loss maintenance could provide information on the time it takes for participants to habituate to a diet.

Conclusion

In conclusion, our study showed that postprandial appetite and food preferences were altered in favour of a decreased food intake after the substantial weight loss induced by a LCD. Results from our study show that eating behaviour immediately after a period of LCD-induced weight loss does not seem to explain the weight regain frequently reported in other studies (3). Hence, it is likely that appetite and food preferences observed after a weight loss period are altered during the phase of weight loss maintenance.

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TABLES

TABLE 1

Nutritional composition of the LCD per kg of diet

	LCD
Energy, MJ / kg	16.4
Protein, g / kg	254.6
Carbohydrates, g / kg	545.5
Fat, g / kg	90.9

LCD, Low Calorie Diet

TABLE 2

The frequency of each food type chosen on the Food Preference Checklist before and after test meal consumption at each visit

	Frequency				P-values		
	CID1		CID2				
	Before meal (n=117)	**After meal (n=119)**	**Before meal (n=117)**	**After meal (n=116)**	**Time**	**Visit**	**Visit x Time**
High-fat	3.7 ± 2.2	2.2 ± 0.2	3.1 ± 2.3	1.7 ± 0.2	< 0.001	< 0.001	0.88
High-carbohydrate	4.4 ± 1.9	2.3 ± 0.2	3.9 ± 2.0	1.9 ± 0.2	< 0.001	< 0.001	0.71
High-protein	5.2 ± 2.1	2.3 ± 0.3	5.2 ± 2.1	2.0 ± 0.2	< 0.001	0.86	0.24
Low-energy	5.2 ± 1.7	3.7 ± 0.2	5.1 ± 1.9	3.2 ± 0.2	< 0.001	< 0.05	0.25
Total frequency	18.4 ± 5.6	10.5 ± 0.7	17.3 ± 6.2	8.9 ± 0.7	< 0.001	< 0.001	0.46

Before meal values are represented as mean ± SD; After meal values are presented as mean ± SE. The values indicate how often a certain food type was chosen on the Food Preference Checklist. Time represents before and after the test meal. Visit represents the visits before (CID1) and after (CID2) the 8-week low calorie diet. Results were analysed using a linear mixed model procedure.

CID, Clinical Investigation Day

TABLE 3

The frequency of each food type chosen on the Forced Choice Photographic Questionnaire before and after test meal consumption at each visit

	Frequency				P-values		
	CID1		CID2				
	Before meal (n=114)	**After meal (n=109)**	**Before meal (n=115)**	**After meal (n=112)**	**Time**	**Visit**	**Visit x Time**
High-fat	13.3 ± 3.5	14.1 ± 0.3	13.2 ± 3.4	14.1 ± 0.3	< 0.001	0.26	0.16
Low-fat	16.1 ± 3.5	15.9 ± 0.3	16.8 ± 3.4	15.9 ± 0.3	< 0.001	0.26	0.16
Savoury	18.9 ± 3.6	14.3 ± 0.5	19.6 ± 3.8	14.5 ± 0.5	< 0.001	0.61	0.45
Sweet	11.1 ± 3.6	15.7 ± 0.5	10.4 ± 3.8	15.5 ± 0.5	< 0.001	0.61	0.45

Before meal values are represented as mean ± SD; After meal values are presented as mean ± SE. The values indicate how often a certain food type was chosen on the Forced Choice Photographic Questionnaire. Time represents before and after the test meal. Visit represents the 8-week low calorie diet. Results were analysed using a linear mixed model procedure.

CID, Clinical Investigation Day.