



HAL
open science

Exploration of food preferences after bariatric surgery : the role of sensory and reward domains

Erika Guyot

► **To cite this version:**

Erika Guyot. Exploration of food preferences after bariatric surgery : the role of sensory and reward domains. Human health and pathology. Université de Lyon, 2021. English. NNT : 2021LYSE1139 . tel-03544724

HAL Id: tel-03544724

<https://theses.hal.science/tel-03544724>

Submitted on 26 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



N° d'ordre NNT : 2021LYSE1139

THESE de DOCTORAT DE L'UNIVERSITE DE LYON

opérée au sein de

l'Université Claude Bernard Lyon 1

Ecole Doctorale N° 205

Ecole Doctorale Interdisciplinaire Science et Santé

Spécialité de doctorat : Biologie, Médecine et Santé

Discipline : Recherche Clinique

Soutenue publiquement le 09/07/2021, par :

Erika GUYOT

Exploration of food preferences after bariatric surgery: the role of sensory and reward domains

Devant le jury composé de :

Pr Barbara LIVINGSTONE	PU	Ulster University - Irlande	Rapporteure
Pr Vickie DRAPEAU	PU	Université Laval - Canada	Rapporteure
Pr Lia BALLY	PU-PH	Université de Bern - Suisse	Rapporteure
Pr Catherine DACREMONT	PU	Université de Bourgogne - France	Examinatrice
Pr Martine LAVILLE	PU-PH	Université Lyon 1 - France	Examinatrice
Dr Sylvain ICETA	PH	Université Laval - Canada	Examineur
Pr Emmanuel DISSE	PU-PH	Université Lyon 1 - France	Directeur de thèse
Dr Anestis DOUGKAS	Chercheur	Institut Paul Bocuse - France	Co-directeur de thèse
Dr Julie-Anne NAZARE	MCU	Université Lyon 1 - France	Co-directrice de thèse

Université Claude Bernard – LYON 1

Administrateur provisoire de l'Université	M. Frédéric FLEURY
Président du Conseil Académique	M. Hamda BEN HADID
Vice-Président du Conseil d'Administration	M. Didier REVEL
Vice-Président du Conseil des Etudes et de la Vie Universitaire	M. Philippe CHEVALLIER
Vice-Président de la Commission de Recherche	M. Jean-François MORNEX
Directeur Général des Services	M. Pierre ROLLAND

COMPOSANTES SANTE

Département de Formation et Centre de Recherche en Biologie Humaine	Directrice : Mme Anne-Marie SCHOTT
Faculté d'Odontologie	Doyenne : Mme Dominique SEUX
Faculté de Médecine et Maïeutique Lyon Sud - Charles Mérieux	Doyenne : Mme Carole BURILLON
Faculté de Médecine Lyon-Est	Doyen : M. Gilles RODE
Institut des Sciences et Techniques de la Réadaptation (ISTR)	Directeur : M. Xavier PERROT
Institut des Sciences Pharmaceutiques et Biologiques (ISBP)	Directrice : Mme Christine VINCIGUERRA

COMPOSANTES & DEPARTEMENTS DE SCIENCES & TECHNOLOGIE

Département Génie Electrique et des Procédés (GEP)	Directrice : Mme Rosaria FERRIGNO
Département Informatique	Directeur : M. Behzad SHARIAT
Département Mécanique	Directeur M. Marc BUFFAT
Ecole Supérieure de Chimie, Physique, Electronique (CPE Lyon)	Directeur : Gérard PIGNAULT
Institut de Science Financière et d'Assurances (ISFA)	Directeur : M. Nicolas LEBOISNE
Institut National du Professorat et de l'Education	Administrateur Provisoire : M. Pierre CHAREYRON
Institut Universitaire de Technologie de Lyon 1	Directeur : M. Christophe VITON
Observatoire de Lyon	Directrice : Mme Isabelle DANIEL
Polytechnique Lyon	Directeur : Emmanuel PERRIN
UFR Biosciences	Administratrice provisoire : Mme Kathrin GIESELER
UFR des Sciences et Techniques des Activités Physiques et Sportives (STAPS)	Directeur : M. Yannick VANPOULLE
UFR Faculté des Sciences	Directeur : M. Bruno ANDRIOLETTI

Leonardo De Vinci.
Celui qui s'est fixé un but n'en change pas.
" Tout obstacle renforce la détermination.
Pour réussir.

TRAVAUX DE RECHERCHES



Acknowledgements

I would like to express a special thanks to **Barbara Livingstone, Vickie Drapeau, Lia Bally, Catherine Dacremont and Martine Laville** for having accepted to assess my PhD dissertation and for the insightful discussions to come, which will help improve and nourish my current and future work.

Je remercie les membres de mon Comité de Suivi de Thèse, **Sandrine Péneau, Moustafa Bensafi et Maud Robert** pour les échanges constructifs et bienveillants que nous avons eus. J'adresse un remerciement tout particulier à **Sandrine Péneau**, pour son accompagnement depuis mon stage de master 2 sous sa direction et pour son soutien depuis lors.

Je tiens à remercier mon directeur de thèse **Emmanuel Disse**, et mes co-directeurs **Anestis Dougkas, Julie-Anne Nazare et Sylvain Iceta** pour m'avoir fait confiance au début de cette aventure et pour m'avoir aidé à la mener à bien.

Je remercie l'Institut Paul Bocuse en la personne d'**Agnès Giboreau**, directrice de la recherche, pour les conditions de travail exceptionnelles qui m'ont été offertes pour réaliser ce travail de thèse.

Je remercie le laboratoire **CarMeN** et son directeur **Hubert Vidal**, ainsi que le **Centre de Recherche en Nutrition humaine Rhône-Alpes (CRNH-RA)** et sa directrice **Julie-Anne Nazare**, pour votre accueil et pour les valeurs d'excellence que vous véhiculez.

Je remercie mes financeurs, l'**Association Nationale pour la Recherche et la technologie (ANRT)**, **Apicil** et l'**Institut Benjamin Delessert**, sans qui tout ce travail n'aurait pu être mené.

I thank **Wender Bredie** and **Armando Perez-Cueto**, for welcoming me to the **Department of Food Sciences at the University of Copenhagen**. A special thank you to **Camilla** for hosting me and for sharing of the Danish way of life and beautiful places.

Many thanks to **Graham Finlayson** for the help in adapting the LFPQ and for the insightful comments and discussions. Je remercie tout particulièrement **Pauline**, pour ton aide dans l'utilisation du LFPQ, qui a été le point de départ d'une belle amitié. Merci pour nos échanges constructifs, ton énergie communicative, ton soutien, ton écoute et ta gentillesse.

Merci aux équipes du **service d'endocrinologie de Lyon Sud** pour votre accueil et votre gentillesse.

Je remercie les **associations de patients**, notamment **VASF, LIO et Equibr'Emoi**, avec une mention spéciale pour **Aurélie Quillet** et **Nadjette Guidoum** pour les échanges constructifs que nous avons eus.

Merci à **tous ceux qui ont relayé les appels à participations** à mes recherches sur les réseaux sociaux, par mail, dans les unités de soins et les cabinets.

Merci aux **patients** qui ont pris part à mes travaux de recherche et à tous ceux qui les ont nourris par leurs retours d'expériences depuis mes débuts en tant que diététicienne.

Je remercie **l'AFDN**, son bureau et tout particulièrement son président, **Ghislain Grodard**, pour m'avoir cooptée dans la Commission Scientifique et Recherche, qui contribue à faire vivre mes deux vocations : nutrition et recherche.

Merci à mes **collègues du CRNH, Tatiana, Zohra, Maud, Audrey, Eloïse, Nathalie, et Stéphanie**, avec une mention spéciale pour **Laurie et Monique** pour votre aide dans l'adaptation du LFPQ. Un merci tout particulier à **Hari** pour nos discussions, ton soutien et aide. Un grand merci à **Anne-Esther** pour tous les bons moments que nous avons passé au travail et en dehors entre Dublin et le Doubs, merci pour ta bonne humeur et ta zénitude.

Je remercie la **Team Lyon Sud : Maël, Mathilde, Sarah et Stéphanie** pour nos rigolades et tous les bons moments partagés au bureau et en dehors.

Merci à tous mes **collègues de l'IPB**, notamment **Bénédicte, Olga et Raphaëlle**, parce que sans votre aide précieuse, ce travail ne serait pas ce qu'il est aujourd'hui. Merci à l'équipe Recherche et Innovation et Consumer Insight : **Estelle, Laura, Julien et Céline** pour votre regard toujours pertinent et concret et pour votre efficacité lors de la conception et de la mise en œuvre de BT2. Merci beaucoup aux chefs de pôles, **Maxime M, Jérémie et Maxime S** dont

les remarques pertinentes ont fait avancer ce travail. Merci aussi à **Jad, Marine et Nicolas** pour votre gentillesse et les bons moments partagés.

Anestis, je te remercie tout particulièrement pour ta bienveillance et ta disponibilité au quotidien, pour ta gentillesse et les bons moments partagés, professionnellement et personnellement tout au long de ces années de thèse.

Merci infiniment à la Team des **doctorants et docteurs de l'IPB, Anastasia, Jeremy, Sonia, Adriana, Kenza, Camille, Marie, Rafaël, Abigaïl, Clara, Morgane, Fairley, Reisja, Arnaud, Damien**. L'aventure n'aurait pas été aussi belle sans vous. J'ai adoré travailler à vos côtés et partager ces moments si particuliers que sont ceux de faire une thèse. Je remercie tout particulièrement **Camille**, tu as été un soutien sans faille par tes conseils et ta perspicacité dans les moments de doutes. Un grand merci à **Kenza**, tu as été ma grande sœur de thèse pendant ces trois ans. Le chemin aurait été bien plus compliqué sans toi, ton sourire, ta bienveillance et tes conseils. Un merci tout particulier à **Rafaël**. Comme tu le dis si bien, lorsqu'on fait une thèse, on peut voir le verre à moitié vide ou à moitié plein, mais l'essentiel c'est qu'au moins on a verre ! Merci pour ton soutien, ton aide, ta force mentale, les bons repas partagés des barbecues aux raclettes. Un merci tout particulier à **Marie**, mon binôme de thèse, j'ai adoré passer ces 3 années à avancer à tes côtés sur ce chemin sinueux qu'est celui de la mais aussi partager des moments plus légers des murs d'escalade aux terrasses des cafés.

Merci à **Brice, Julie et Mathilde**. Un remerciement tout particulier pour **Sonia et Sarah**, vous êtes brillantes, j'ai eu beaucoup de chance de vous avoir à mes côtés dans la réalisation de ce travail.

Merci à mes **anciennes collègues diététiciennes des Hospices Civils de Lyon**, notamment **Véronique, Edmée, Aline, Karine, Karin, Dominique, et de l'hôpital de Mercy, Julie, Mireille et Isabelle** ; vous m'avez tant appris. Je remercie tout particulièrement **Brigitte Boniteau** pour avoir toujours cru en moi et mes projets. J'adresse un remerciement spécial pour mon amie **Marie** pour tous les bons moments partagés depuis plusieurs années déjà, ton aide et ton soutien.

Merci à vous **Valérie Estève et Marie-France Vaillant**, passionnées et inspirantes qui ont nourri mon envie de poursuivre mes études et d'allier nutrition et recherche.

Merci à mes **collègues et amis de Master**, avec une mention spéciale pour **Hélène, Ariane et Florian** et ceux de l'IUT, en particulier **Charlotte, Camille et Ariane**. Merci également aux **enseignants** qui nous ont poussé à nous dépasser.

Merci à **Gaël et Laure** pour tous les bons moments, les soirées et rigolades partagées.

Un grand merci à **Jenny** pour ton amitié et ta bienveillance.

Merci aux plus belles diététiciennes que je connaisse **Margot, Aurore, Marine, Marie, Elodie, Pauline, Mégane et Barbara**. Merci pour nos fou-rires, nos voyages, nos soirées, et plus encore depuis 11 ans maintenant. Vous êtes tellement géniales <3

Merci à mes anciennes collègues de libéral, particulièrement **Sandra et Émilie**. Merci aussi à mes partenaires, notamment **Virginie** qui m'a ouvert les portes d'une belle aventure à la **Ligue Contre le Cancer**. Merci à toutes les belles personnes que j'ai rencontrées là-bas, en particulier **Monique**.

Merci à tous qui me témoignez régulièrement votre soutien, particulièrement **Paul et Lalie**.

Merci à mes amis de longue date, maintenant aux quatre coins du monde mais pour toujours dans mon cœur : **Maëlle, Morgane, Jany, Claire, William et Emilien**.

Je remercie ma **belle-famille, Delphine, Kevin, Lyana, Damian et Danielle**, et tout particulièrement **Nathalie et Jean-Luc** mes **beaux-parents**, pour leur soutien, leur gentillesse et leur aide.

Je remercie ma **famille**, tout spécialement mes **tontons** et **tatas** que j'adore ! mes **cousins** et **cousines**, avec une mention spéciale pour **Anne-Lise** avec qui je partage tant depuis toujours.

Merci infiniment à **Papi et Mamie de Madagascar** qui de loin, puis de près m'ont toujours soutenu et suivi dans mes aventures.

Un grand merci à **Mémère** qui m'inspire depuis toujours par sa force et sa sagesse. Une pensée pour **Pépère** qui j'espère serait fier de ce que j'ai pu réaliser jusqu'à présent. Merci à mes **parents**, vous m'avez aidé à devenir la personne que je suis aujourd'hui, et votre soutien

sans faille permis de repousser mes limites. Un remerciement spécial à **Anthony**, mon **frère**, pour tout inconditionnellement, sans oublier **Marine** pour ta gentillesse et ton grand cœur.

Merci à **Freyja, Kitkat et Ferrero**, pour mettre un peu de douceur et beaucoup d'animation dans ma vie.

Je remercie particulièrement mon meilleur ami et mon amour **Emeric** pour ton soutien dans les bons et les mauvais moments, pour ton amour, ta gentillesse, notre complicité et nos projets.

Merci à mon petit cœur **Priam** pour faire de ma vie un océan de bonheur. Je t'aime tellement.

Merci à tous ceux que j'ai peut-être oublié, qui ont de près ou de loin participé à la réalisation de ce travail.

The present thesis is part of the 'BariaTaste' project resulting from the collaboration between the Institut Paul Bocuse research Center (IPBR), and the Center for Research in Human Nutrition Rhône-Alpes (CRNH-RA), with the financial support of APICIL, the National Association of Research and Technology (ARNT) and the Benjamin Delessert Institute.

Summary

The hedonic regulation of eating behavior has been shown to be altered in case of obesity, notably the chemo-sensory functions and the reward system. Although bariatric surgery is the most effective treatment for obesity, patients do not all respond the same way to this treatment and some of them might regain weight after a certain time. It is essential to promote an adapted balanced diet for the long-term weight maintenance of bariatric surgery patients. A better understanding of the postoperative modifications of food choices and preferences will enable clinicians to give personalized nutritional advice in the context of a precision bariatric medicine. This doctoral work aims to advance this knowledge, by responding to four objectives.

The first objective was to synthesize the evidence for the link between bariatric surgery in relation to changes in food preferences by a systematic and meta-analytical approach. With an original approach considering various methods to assess food preferences our systemic analysis of the evidence showed a change in food preferences in patients with obesity who undergo bariatric surgery at specific times during their weight loss trajectory.

The second objective was to study the links between food preferences, taste, smell and the weight loss success of bariatric surgery. To this aim, we used an online questionnaire in a cohort of bariatric surgery patients. We found that food preferences were different between patients with and without sensory alterations. For those who experienced sensory alterations, there was a decreased preference for unhealthy foods. We also found that food preferences were different between patients in a weight loss success and failure. Of importance, a higher appreciation for green vegetables was associated with a weight loss success.

The third objective of this thesis was to adapt and use a behavioral computerized task in a clinical setting, to compare food reward (i.e., ‘liking’ and ‘wanting’) between patients with unoperated obesity, a sleeve gastrectomy, and a Roux-en-Y gastric bypass. Our results showed that the Leeds Food Preference Questionnaire could be clinically relevant to identify post-operative alterations in food reward and to guide caregivers to give personalized advice in patients. Especially, we found that ‘liking’ for a large range of food categories was lower among post-operative patients compared to non-operative patients with obesity while ‘wanting’ was lower among post-operative patients for certain food categories only, including highly palatable foods.

The fourth objective of this thesis was to develop a protocol to study food preferences after bariatric surgery in a more realistic environment. We designed a study using a buffet meal in an experimental restaurant, which will be used to study differences in terms of diet quality, food intake and microstructure of the meal between patients with obesity, with and without a bariatric surgery.

This doctoral work is original as it used a multidisciplinary approach and a diversity of methods to move forward knowledge about the issue of modifications of food preferences in

the context of bariatric surgery. It also highlighted the importance of a personalized nutritional strategy for the bariatric surgery patients.

Keywords: bariatric surgery; food preferences; food reward; liking; wanting; taste; smell; sensory alterations

Résumé

Des études ont montré que la régulation hédonique du comportement alimentaire est altérée en cas d'obésité, notamment les fonctions chimio-sensorielles et le système de récompense. Bien que la chirurgie bariatrique soit le traitement le plus efficace de l'obésité, les patients ne répondent pas tous de la même manière à ce traitement et certains d'entre eux reprennent du poids après un certain temps. Il est essentiel de promouvoir une alimentation équilibrée adaptée pour le maintien du poids à long terme des patients en chirurgie bariatrique. Une meilleure compréhension des modifications postopératoires des choix et préférences alimentaires permettra aux cliniciens de donner des conseils nutritionnels adaptés et personnalisés dans le cadre d'une médecine bariatrique de précision. Ce travail doctoral vise à faire progresser ces connaissances, en répondant à quatre objectifs.

Le premier objectif était de faire l'état de l'art du lien entre la chirurgie bariatrique et l'évolution des préférences alimentaires par une approche systématique et méta-analytique. Avec une approche originale prenant en compte diverses méthodes pour évaluer les préférences alimentaires, notre analyse systémique a montré un changement des préférences alimentaires chez les patients obèses qui subissent une chirurgie bariatrique à des moments précis de leur trajectoire de perte de poids.

Le deuxième objectif était d'étudier les liens entre les préférences alimentaires, le goût, l'odorat et le succès pondéral de la chirurgie bariatrique. Pour ce faire, nous avons utilisé un questionnaire en ligne dans une cohorte de patients opérés d'une chirurgie bariatrique. Nous avons constaté que les préférences alimentaires étaient différentes entre les patients avec et sans altérations sensorielles. Pour ceux qui ont subi des altérations sensorielles, la préférence pour les aliments malsains a diminué. Nous avons également constaté que les préférences alimentaires étaient différentes entre les patients en succès et en échec pondéral. De manière importante, une plus grande appréciation des légumes verts était associée au succès pondéral.

Le troisième objectif de cette thèse était d'adapter et d'utiliser une tâche informatisée comportementale dans un contexte clinique afin de comparer la récompense alimentaire (c'est-à-dire le « liking » et le « wanting ») entre des patients atteints d'obésité non opérée, ceux opérés d'une sleeve gastrectomie et ceux opérés d'un bypass gastrique avec Roux-en-Y. Nos résultats ont montré que le Leeds Food Preference Questionnaire pouvait être cliniquement pertinent

pour identifier les altérations postopératoires de la récompense alimentaire et pour guider les soignants à donner des conseils personnalisés aux patients. Plus particulièrement, nous avons constaté que le « liking » était plus faible chez les patients postopératoires que chez les patients obèses non opérés pour un large éventail de catégories d'aliments, tandis que le « wanting » était plus faible chez les patients postopératoires pour certaines catégories d'aliments uniquement, y compris les aliments très appétissants.

Le quatrième objectif de cette thèse était de développer un protocole pour étudier les préférences alimentaires après une chirurgie bariatrique dans un environnement plus réaliste. Nous avons conçu une étude utilisant un repas sous forme de buffet dans un restaurant expérimental, qui sera utilisée pour étudier les différences en termes de qualité de l'alimentation, de prise alimentaire et de microstructure du repas entre les patients atteints d'obésité, avec et sans chirurgie bariatrique.

Ce travail doctoral est original car il utilise une approche pluridisciplinaire et une diversité de méthodes pour faire avancer les connaissances sur la question des modifications des préférences alimentaires dans le cadre de la chirurgie bariatrique. Il a également souligné l'importance d'une stratégie nutritionnelle personnalisée pour les patients en chirurgie bariatrique.

Mots-clés : chirurgie bariatrique; préférences alimentaires; récompense alimentaire; liking; wanting; goût; odeur; altérations sensorielles

Table of contents

Acknowledgements	ix
Summary.....	xvii
Résumé.....	xix
Table of contents	xxi
Abbreviations	xxvi
List of figures.....	xxix
List of tables.....	xxxii
Chapter I. Introduction	1
1.1 The global burden of obesity.....	3
1.2 Obesity and the regulation of food intake.....	6
1.2.1. Obesity and the homeostatic model of appetite control.....	6
<i>Appetite and the “Psychobiological” system.....</i>	<i>6</i>
<i>Obesity alterations of the psychobiological system</i>	<i>8</i>
1.2.2. Obesity and the hedonic model of appetite regulation.....	9
<i>Sensory domain</i>	<i>10</i>
<i>Reward domain</i>	<i>11</i>
<i>Alteration of the hedonic regulation of appetite in the case of obesity.....</i>	<i>12</i>
<i>Obesity and food preferences.....</i>	<i>13</i>
1.3 Bariatric surgery as a treatment for obesity	15
1.3.1. Bariatric surgery: insight on its effectiveness and associated challenges	15
1.3.2. Bariatric surgery, appetite control and food preferences	18
1.4 Aim and objective of the thesis	22
1.5 References	24
Chapter II. A systematic review of food preference modifications after bariatric surgery	37

Abstract	39
3.1 Introduction.....	41
3.2 Methods and procedures	42
2.2.1. Protocol and registration	42
2.2.2. Literature search strategy	43
2.2.3. Inclusion and exclusion criteria	43
2.2.4. Study selection and data extraction.....	43
2.2.5. Quality assessment.....	44
2.2.6. Statistical analysis.....	44
3.3 Results	46
2.3.1. Study selection	46
2.3.2. Studies and patients' characteristics.....	47
2.3.3. Relative choice between macronutrients, foods and food groups.....	54
<i>Relative choice between macronutrients.....</i>	<i>54</i>
<i>Relative choice between foods or food categories</i>	<i>55</i>
2.3.4. Choices related to hedonics.....	59
2.3.5. Quality of the total body of evidence.....	63
<i>Quality.....</i>	<i>63</i>
<i>Publication bias</i>	<i>64</i>
3.4 Discussion.....	64
2.4.1. Main findings	64
2.4.2. Comparison with other studies.....	64
<i>Clinical studies and reviews</i>	<i>64</i>
<i>Pre-clinical animal studies</i>	<i>65</i>
2.4.3. Strengths and limitations.....	66
2.4.4. Implications of findings and future research.....	67
3.5 Conclusion.....	68
3.6 References.....	69

Chapter III. Food preferences and their perceived modifications before and after bariatric surgery: a cross sectional study 79

Abstract	81
3.1 Introduction.....	82
3.2 Material and methods.....	83
3.2.1 Study population	83
3.2.2 Data collection and calculations.....	83

3.2.3	Statistical analysis	84
3.3	Results	85
3.3.1	Sample characteristics and surgery outcomes.....	85
3.3.2	Food preferences following bariatric surgery and perceived post-operative modifications	86
3.3.3	Food preferences between participants with and without taste or smell alterations 88	
3.3.4	Food preferences according to the postoperative follow-up duration.....	90
3.3.5	Food preferences between patients in success and failure of bariatric surgery ..	90
3.3.6	Food rejections	90
3.4	Discussion.....	90
3.5	Conclusion.....	93
3.6	References	94

Chapter IV. Alterations in food reward following bariatric surgery 97

Abstract	99	
3.7 Introduction.....	100	
3.8 Material and Methods	101	
3.8.1	Subjects	101
3.8.2	Data collection and calculations.....	101
	<i>Food reward.....</i>	<i>101</i>
	<i>Behavioral assessment</i>	<i>104</i>
	<i>Other covariates.....</i>	<i>105</i>
3.8.3	Sample size calculation	105
3.8.4	Statistical analyses	105
3.9 Results	106	
3.9.1	Characteristics of the subjects.....	106
3.9.2	Relationship between explicit liking for foods and bariatric surgery	108
3.9.3	Relationship between explicit wanting for foods and bariatric surgery.....	111
3.9.4	Relationship between implicit wanting for foods and bariatric surgery	111
3.9.5	Relationship between food choices and bariatric surgery.....	113
3.9.6	Relationship between fat and sweet appeal bias and behavioral traits.....	115
3.9.7	Relationship between food preference for ‘high-fat – sweet’ foods and behavioral traits	115
3.9.8	Comparison of food reward according to the follow-up periods	117
3.10 Discussion	117	
3.11 Conclusion	120	

3.12	References.....	121
------	-----------------	-----

Chapter V. Study of food preferences and eating behavior after bariatric surgery in a real context eating environment: conception and settings of the study 125

Abstract	127
5.1. Introduction	128
5.2. Subjects and methods	130
5.2.1. Study design	130
5.2.2. Sample size.....	130
5.2.3. Subjects	131
5.2.4. Recruitment.....	131
5.2.5. Primary and secondary endpoints	132
5.2.6. General organization of the study	133
5.2.7. Data collection	135
<i>Anthropometric data and medical history</i>	<i>135</i>
<i>Gustatory function</i>	<i>135</i>
<i>Olfactory function</i>	<i>136</i>
<i>Eating behaviors assessment using TFEQ</i>	<i>137</i>
<i>Assessment of levels of hunger, desire to eat, prospective consumption and satiation</i>	<i>138</i>
<i>Assessment of food preferences</i>	<i>138</i>
5.2.1. Summary of the course of the experiment (see Figure 5.8)	142
5.2.2. Statistical analyses	144
<i>Treatment of missing subjects</i>	<i>144</i>
<i>Descriptive statistics</i>	<i>144</i>
<i>Analytical statistics</i>	<i>144</i>
5.3. Expected results	145
5.4. Conclusion	145
5.5. References	146

Chapter VI. General discussion and conclusion 153

8.1 Main results	155
8.2 Reflection about the model of homeostatic and hedonic regulation of appetite following bariatric surgery	156
8.3 Methodological considerations related to the measure of food preferences in the context of bariatric surgery	158

8.4	Strengths and limitation	160
8.5	Perspectives and recommendations.....	162
2.4.5.	Direction for future research	162
	<i>Study food preferences in an ecological setting.....</i>	<i>162</i>
	<i>Study other determinants of food preferences.....</i>	<i>162</i>
	<i>Build a predictive model of weight loss success and failure.....</i>	<i>163</i>
	<i>A consumer study to improve acceptance of healthy products</i>	<i>164</i>
2.4.6.	Recommendations for clinical practice and public health	164
	<i>Prevent protein energy malnutrition after bariatric surgery.....</i>	<i>164</i>
	<i>Adherence to nutritional recommendations, barriers and facilitators for the longer-term follow-up</i>	<i>165</i>
8.6	Conclusion.....	166
8.7	References	167
Thesis valorisation		I
List of appendices.....		III

Abbreviations

AGB	Adjustable gastric banding
ANOVA	Analysis of variance
ANRT	National Association of Research and Technology
BES	Binge eating scale
BMI	Body mass index
BOLD	Blood oxygenation level dependent
CCK	Cholecystokinin
CHO	Carbohydrates
CI	Confidence interval
CIQUAL	Centre d'information sur la qualité des aliments
CNAM	Caisse Nationale d'Assurance Maladie
CO	Color
CRNH-RA	Center for Research in Human Nutrition Rhône-Alpes
CSO	Centre Spécialisé de l'Obésité
d	Day
DA	Dairy
DS	Duodenal switch
EL	Explicit likin
EPPHP	Effective Public Health Practice Project
ETOC	European test of olfactory capabilities
EW	Explicit wanting
EWL	Excess weight loss
FFA	Free fatty acids
FFA	Food anticipatory activity
FFQ	Food frequency questionnaires
FI	Fiber
FIFO	First in first out
FL	Fluid
fMRI	Functional magnetic resonance imaging
FORCE	French Obesity Research Center of Excellence
GEMRCN	Groupement d'étude des marchés en restauration collective et de nutrition
GLP-1	Glucagon-like peptide-1
HAS	Haute Autorité de Santé
HC	High carbohydrate
HF	High fat
HGP	Horizontal gastropasty
HP	High protein
HR	Hazard ratio
IFSO	International Federation for the Surgery of Obesity and Metabolic Disorders

ILI	Subjects with a lifestyle intervention
IPBR	Institut Paul Bocuse Research Center
IQR	Interquartile range
IW	Implicit wanting
LABS-2	Longitudinal Assessment of Bariatric Surgery-2
LASSO	Least absolute shrinkage and selection operator
LC	Low carbohydrate
LFPQ	Leeds Food Preferences Questionnaire
LFPQ	Low fat
LP	Low protein
ME	Meat
mo	Month
MV	With multivitamin supplement
NC	No color
ND	Non-dairy
NF	No fiber
NMV	Without multivitamin supplement.
NMV	No meat
NO	Subjects without obesity
NR-RYGB	Roux-en-Y gastric bypass without resected stomach
NS	No sauce
NTS	Nucleus of the tractus solitarius
NV	No variation
OB	Subjects with obesity
OR	Odds ratio
PCA	Principal component analysis
PRISMA	preferred reporting items for systematic reviews and meta-analysis
PROSPERO	International Prospective Register of Systematic Reviews
PVN	Paraventricular nucleus
PYY	Peptide YY
R-RYGB	Roux-en-Y gastric bypass with resected stomach
RYGB	Roux-en-Y gastric bypass
SA	Savory
SC	Sauce
SD	Standard deviation
SEM	Standard error of the mean
SG	Sleeve gastrectomy
SMD	Standardized mean difference
SO	Solid
SOS	Swedish Obese Subjects
SW	Stable weight
SW	Sweet
T: LNAA	Tryptophan: large neutral amino acids

TFEQ	Three-factor eating questionnaire
TWL	Total weight loss
UPPS-P	Urgency, premeditation, perseverance, sensation seeking, and positive urgency
USA	United States of America
VA	Variation
VAS	Visual Analog Scales
VGB	Vertical banded gastroplasty
VTA	Ventral tegmental area
WHO	World Health Organization
WL	Weight loss
WR	Weight regain
YFAS	Yale food addiction scale
yr	Year

List of figures

Chapter I. Introduction

Figure 1.1. Obesity system map with thematic clusters of determinants of obesity.....	4
Figure 1.2. Factors, which influence accumulation of energy within the cluster ‘food consumption’ of the obesity system map.....	5
Figure 1.3. Expression of appetite from the 3-stage Psychobiological System.....	7
Figure 1.4. Interactions between hedonic and homeostatic system in the brain depend on the palatability of the food.....	12
Figure 1.5. Number of bariatric surgeries performed in one year worldwide (panel A) and in France (panel B).....	16
Figure 1.6. Bariatric surgery procedures.....	17
Figure 1.7. By modifying the gastrointestinal tract, bariatric surgery might induce a series of modification in homeostatic and hedonic processes of appetite regulation.....	21

Chapter II. A systematic review of food preference modifications after bariatric surgery

Figure 2.1. Study selection flow diagram.....	46
Figure 2.2. Pooled effect sizes for the weighted mean differences, and 95% confidence intervals (CI), in total energy intake from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.....	54
Figure 2.3. Weighted summary bar-plot representing the proportion of information with a given level of bias for each sub-domain of the ‘Quality assessment tool for quantitative studies’...	63

Chapter III. Food preferences and their perceived modifications before and after a bariatric surgery: a cross sectional study

Figure 3.1. Description of food preferences and their postoperative perceived modifications among 220 participants with bariatric surgery.....	87
Figure 3.2. Comparison of liking scores between the patients with and without taste alterations (panel A, N=220), with and without smell alterations (panel B, N=220), in a short- and long-term follow-up (panel C, N=220) and in failure or success of bariatric surgery (panel D, N=81).	89

Chapter IV. Alterations in food reward following bariatric surgery

Figure 4.1. Leeds Food Preference Questionnaire.....	102
Figure 4.2. Comparison of explicit liking scores between OB, SG and RYGB patients.....	110
Figure 4.3. Comparison of implicit wanting scores between OB, SG and RYGB patients...	112

Chapter V. Study of food preferences and eating behavior after bariatric surgery in a real context environment: conception and settings of the study

Figure 5.1. Study design. Abbreviation: M, Month..... 133

Figure 5.2. A domestic-type kitchen at the Institut Paul Bocuse restaurant..... 134

Figure 5.3. Use of the Taste Strips..... 136

Figure 5.4. Use of the ETOC..... 137

Figure 5.5. Use of the olfactory cards to assess the identification smell capacity of the patients.
..... 137

Figure 5.6. Ad-libitum buffet meal..... 140

Figure 5.7. Video recordings will be performed to study the microstructure of the meal..... 141

Figure 5.8. Summary of the course of the experiment..... 143

List of tables

Chapter I. Introduction

Table 1.1. Modifications of the major appetite-related signals after bariatric surgery.....	19
---	----

Chapter II. A systematic review of food preference modifications after bariatric surgery

Table 2.1. Characteristics of the studies included by study design.	48
--	----

Table 2.2. Relative choices between foods or food categories in comparison with preoperative measures (prospective studies, N=19) or with measures on control groups of patients with obesity (cross-sectional studies, N=3).	57
--	----

Table 2.3. Hedonic ratings for foods or food categories in comparison with preoperative measures (prospective studies, N=10) or with measures on control groups of patients with obesity (cross-sectional studies, N=6).	61
---	----

Chapter III. Food preferences and their perceived modifications before and after a bariatric surgery: a cross sectional study

Table 3.1. Characteristics of the patients.	85
--	----

Chapter IV. Alterations in food reward following bariatric surgery

Table 4.1. Dichotomous food categories tested with the LFPQ.	103
---	-----

Table 4.2. Socioeconomic and behavioral characteristics of the 86 included patients according to their operative status.	106
---	-----

Table 4.3. Comparison of food choices between patients with OB, SG and RYGB.....	114
--	-----

Table 4.4. Comparison of fat and sweat appeal bias between OB, SG and RYGB patients.	115
---	-----

Table 4.5. Correlations between food reward and behavioral traits of bariatric surgery patients.	116
---	-----

Chapter V. Study of food preferences and eating behavior after bariatric surgery in a real context environment: conception and settings of the study

Table 5.1. Steps of the study.....	133
------------------------------------	-----

Table 5.2. Composition of the Taste Strips.....	135
---	-----

Table 5.3. Randomization of the administration of the Taste Strips.	135
--	-----

Table 5.4. Studied food items and composition of the buffet meal.	139
--	-----

Table 5.5. Calculation of the evaporation coefficient.....	142
--	-----

Chapter I. Introduction

1.1 The global burden of obesity

The prevalence of obesity is increasingly rapidly (1) and given its consequences on physical and mental health and more generally on mortality (1–3) is a global public health concern (1) that must be addressed. More precisely, obesity is associated with a higher risk for developing many other conditions, such as cardiovascular diseases, type II diabetes mellitus, cancer or depression (4). Moreover, the costs in terms of prevention and management of obesity represent an economic burden so as the indirect costs, related to the reduced productivity (as a result of absenteeism, early retirement, and premature death) and increased disability (5).

According to the World Health Organization (WHO), obesity is characterized by an *'abnormal or excessive fat accumulation that present a risk to health'* (1). A body mass index (BMI) $\geq 30 \text{ kg.m}^{-2}$ is classically used as an indicator for obesity. Obesity class II (moderate obesity) refers to a BMI $\geq 35 \text{ kg.m}^{-2}$ and obesity class III (severe obesity) corresponds to a BMI $\geq 40 \text{ kg.m}^{-2}$ (6). Moreover, skinfold thickness and waist circumference (7,8) have been shown to reliably measure central fat mass, which is a predictor of mortality (9,10). Obesity is characterized as 'complicated' when accompanied by comorbid conditions (e.g., type II diabetes mellitus, cardiovascular diseases, sleep apnea, etc.) (11).

The core problem underlying obesity is a chronic imbalance between the energy intakes (food consumption) and the energy expenditures (resting energy expenditure, thermic effect of feeding, and physical activity energy expenditure) (12), leading to a storage of excess energy, mostly in the form of triglycerides within the adipose tissue. The cause for this energy imbalance is multifactorial, as both individual, environmental and social factors interact and play a role in the development of obesity (see Figure 1.1) (13).

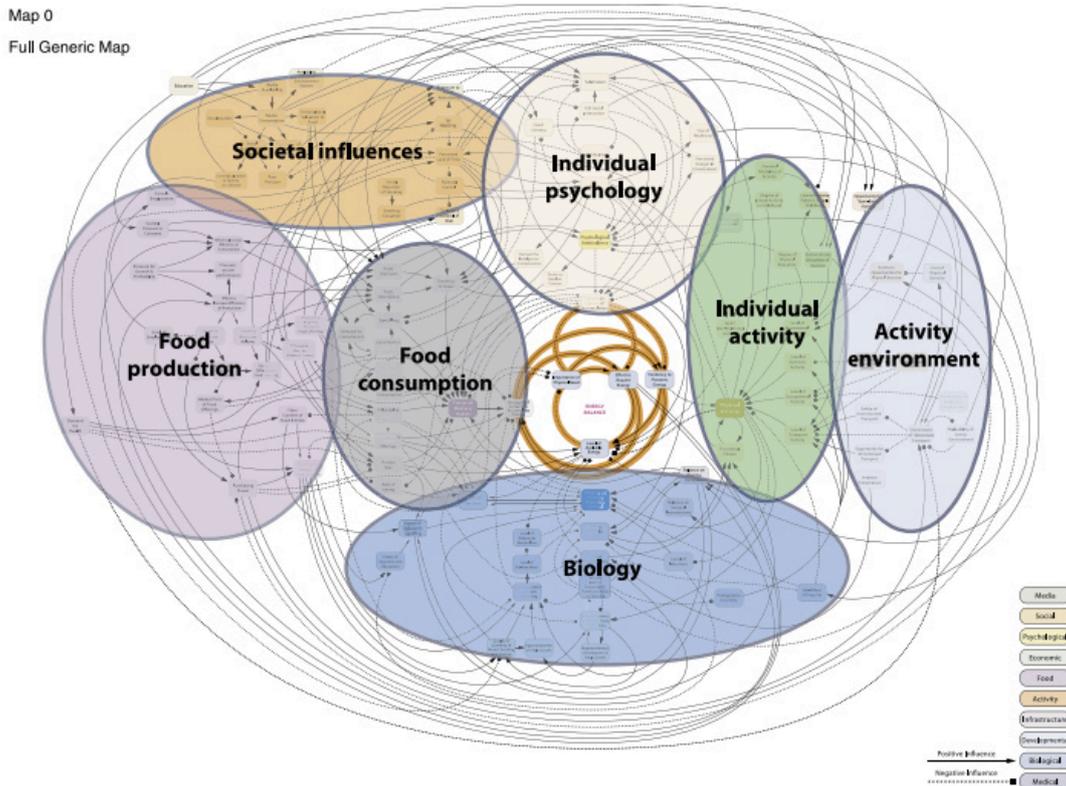


Figure 1.1. Obesity system map with thematic clusters of determinants of obesity.
Source: Foresight report (13).

The food exposure, the food abundance, the energy density, the portion sizes and the palatability of the food offerings are among the factors highly contributing to the excess of food consumption (13) (see Figure 1.2). This is particularly striking in the Westernized countries, which are characterized by an abundance of highly palatable foods (14). This ‘obesogenic environment’ (15), combined with individual susceptibility contribute to a maladaptive response to external stimuli, which could override the homeostatic regulation system (16) and contribute to obesity.

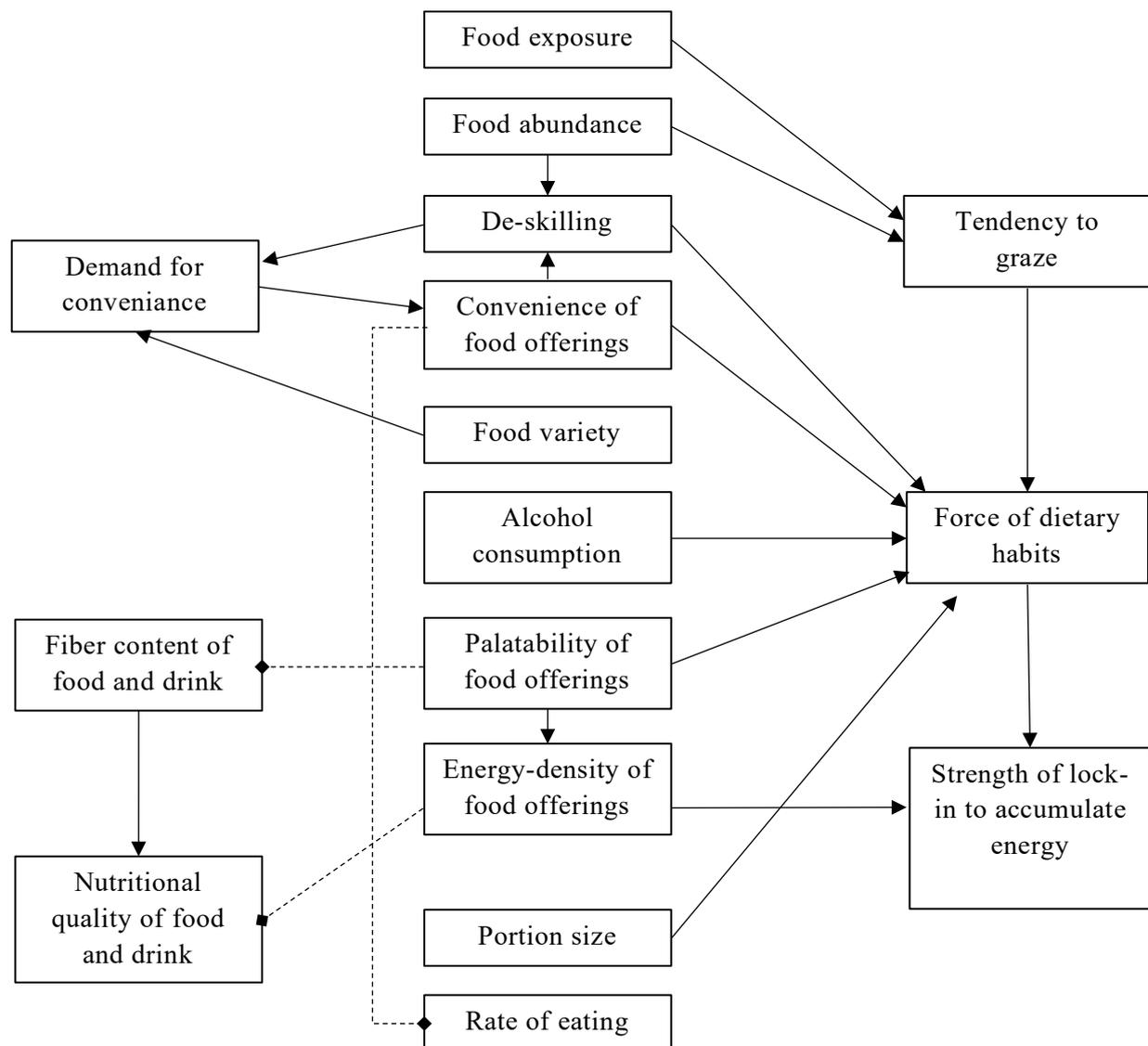


Figure 1.2. Factors, which influence accumulation of energy within the cluster 'food consumption' of the obesity system map. Adapted from the foresight system map (13).

Key message

This complex obesity framework highlights that overconsumption is not solely driven by dysfunction of homeostatic processes (i.e., integration of internal signals, which regulate the energy balance), but it also involves non-homeostatic processes (i.e., integration of external signals, which respond to the hedonic dimension of food intake) (17,18).

1.2 Obesity and the regulation of food intake

Most conceptualizations, consider that the regulation of food intake is the result of an interaction between homeostatic and hedonic processes (18,19), which have been proposed to be altered in the case of obesity. The homeostatic regulation of food intake aims to control energy balance via increased motivation to eat when energy stores are low. On the other hand, hedonic regulation of food intake is based on the concept of food reward. It can override the homeostatic pathways and aims to increase motivation towards highly palatable foods when the energy stores are not depleted (19).

1.2.1. *Obesity and the homeostatic model of appetite control*

Appetite and the “Psychobiological” system

Appetite is defined as a ‘*desire for food intake that may be produced by normal metabolic and energy needs or by other cues that may increase desire for food intake, including appearance, taste, and smell*’ (20). It results from the synchronous functioning of events and processes of a 3-level Psychobiological System conceptualized by Blundell (21), the functioning of which has been described in details by Hopkins et al. (17). The first level of this system corresponds to psychological events (hunger perception, cravings, and hedonic sensations) and behavioral operations (meals, snacks, energy and macronutrients intakes). The second level describes the peripheral physiologic and metabolic events, which involve sensory inputs, hormones and neurotransmitters. The third level refers to the neurotransmitter and metabolic interactions in the brain. Within this framework, eating episodes are stimulated by cognitive and sensory factors, which induce a peripheral physiological response and in turn elicit a neuronal response. Figure 1.3 summarizes the expression of appetite considering the 3-stage Psychobiological System.

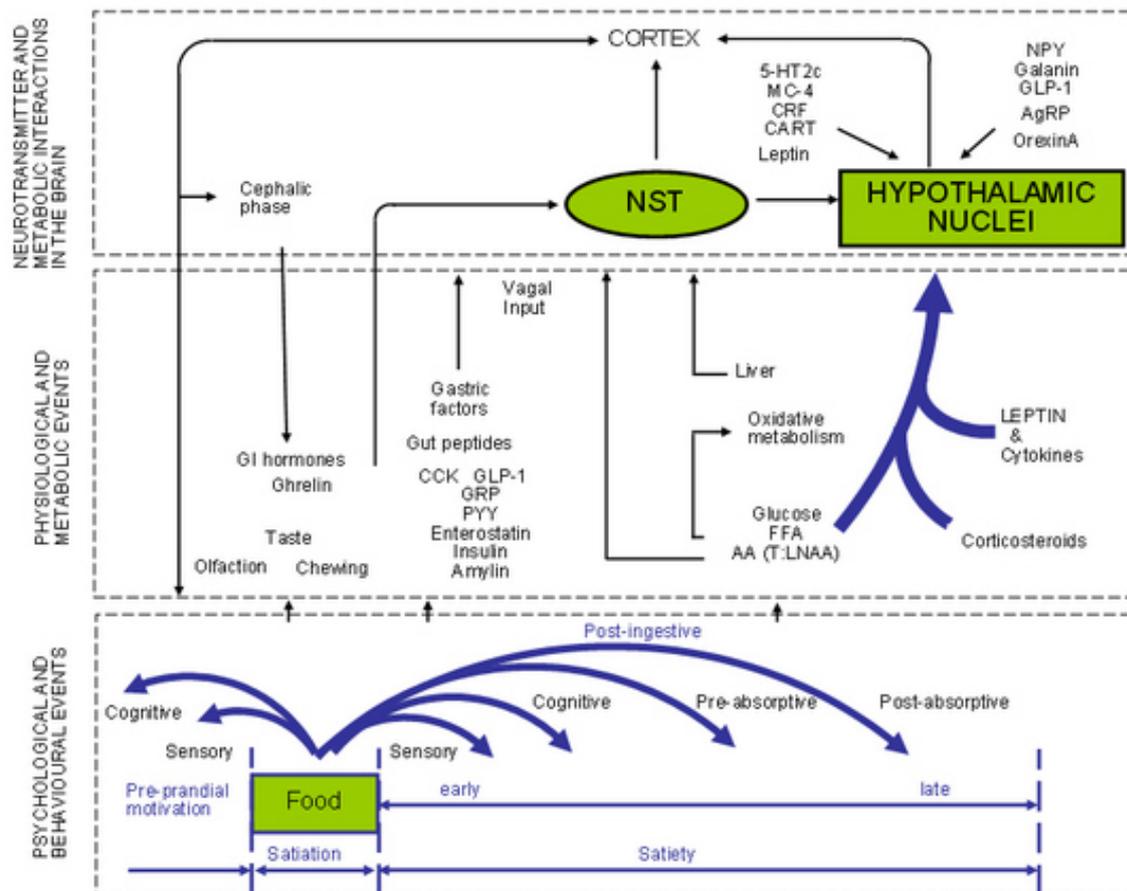


Figure 1.3. Expression of appetite from the 3-stage Psychobiological System.

Abbreviations: PVN, paraventricular nucleus; NST, nucleus of the tractus solitarius; CCK, cholecystokinin; FFA, free fatty acids; T: LNAA, tryptophan: large neutral amino acids. Source Hopkins et al (17).

Of importance, the visual and olfactory food cues induce a physiological response in the gastrointestinal tract to anticipate the ingestion of food even before it is put in the mouth. This is the cephalic phase of appetite (17). During and after an eating episode the control over appetite is provided by afferent signals described in the Satiety Cascade by Blundell et al. (22). More precisely, sensory, cognitive, pre- and post-absorptive events are involved in satiation to gradually turn the eating episode to an end (22), and ‘satiety’ to reduce hunger between eating episodes (21,23).

The signals, which control appetite and interact with each other can be distinguished into two categories: the episodic and tonic signals mainly involved in the short-term (meal to meal) and in the long-term (days and weeks) regulation of appetite, respectively (24). Episodic appetite signals are primarily inhibitory and are secreted by the gut mucosa during eating episodes, such as cholecystokinin (CCK), peptide YY (PYY) and glucagon-like peptide-1 (GLP-1). Ghrelin has both episodic and tonic properties as its blood level is increased just

before an eating episode and promotes hunger in case of weight loss (17). Excitatory tonic signals come from fat-free mass (25), while inhibitory tonic signals such as leptin are secreted from fat mass (26).

Gut peptides (e.g., CCK, PYY and GLP-1) simulate vagal afferents, which in turn stimulate neurons of the nucleus tractus solitarius (NTS) in the brainstem (27). The NTS then relays the signals integrated in the hypothalamic region. The hypothalamus is composed of several nuclei, among which, the arcuate nucleus has been shown to have an important role in the integration of appetite signals, in particular leptin (28,29).

Interestingly, the meal composition (caloric and macronutrient contents) influences the fluctuation of CCK, PYY and GLP-1 (30). Moreover, the appearance, the palatability and the meal size influence satiation, satiety and eating behavior (31).

Obesity alterations of the Psychobiological system

There is evidence of alterations in the regulation of appetite at different levels of the Psychobiological system in relation to obesity. Concerning the first level of the system, cravings for high caloric high palatable foods are more frequent among individuals with overweight compared to individuals with a normal weight (32). In addition to a greater energy and macronutrient intake seen in obesity compared to normal weight, other behavioral operations, including eating patterns, are also altered. For instance, the Seasonal Variation of Blood Cholesterol Study (33) using the data from 499 participants showed that the risk of developing obesity was inversely associated with the number of eating episodes. More precisely, those who reported four or more eating episodes per day had a higher risk of obesity (OR = 45; 95% CI = 0.33-0.91), compared to those with three or less eating episodes (34). Furthermore, the timing of energy intake also appeared to be related to weight status. Individuals eating $\geq 33\%$ of their daily energy intake in the evening were at higher risk to develop obesity (OR = 2; 95% CI = 1.03-3.89) (35).

Appetite signaling also showed evidence for modification in obesity. For instance, patients with obesity had lower postprandial decrease in ghrelin (36). Furthermore, ghrelin-reactive IgG immunoglobulin with an increased affinity for ghrelin are specifically present in the blood of patients with obesity (37). These immunoglobulins bind to ghrelin and inhibit its degradation in the plasma, which could contribute to a longer effect of ghrelin on increasing

appetite and overeating (37). Furthermore, individuals with obesity have a postprandial increase in CKK which persists over time, whereas it is fast decreasing in lean individuals. This might induce a later onset of satiety in obesity (38). Also, high levels of adiposity can weaken tonic inhibitory signals and induce leptin resistance (23,39), which could lead to overconsumption and additional weight gain (23).

Brain integration of appetite signals might also be modified in relation to obesity. Especially, several reviews support the idea of an alteration of the hypothalamic function in obesity (40,41), in which high fat feeding might have a predominant role (40).

Key message

Appetite is partly controlled by synchronous homeostatic processes of a complex psychobiological system, involving i) psychological events and behavioral operations, ii) peripheral physiologic and metabolic events, and iii) neurotransmitter and metabolic interactions in the brain, which are altered in obesity.

1.2.2. Obesity and the hedonic model of appetite regulation

In the event of food abundance, the hedonic processes could override the homeostatic processes to increase consumption of highly palatable foods (19). The definition and nature of palatability has been widely discussed without consensus (42), as it sometimes refers i) to a property of a food (i.e., a food is palatable because it is more stimulating than others), ii) to a property of the organism eating the food (i.e., human have innate response to certain tastes and find it pleasant), or iii) to both (i.e., a food is palatable to someone because it induces an acceptable sensory response to this specific person) (43). For the purpose of this doctoral work, palatability is defined as the hedonic reward or pleasure provided by foods, which are pleasant to the palate or taste (44). Although foods high in fat and / or sweet and / or salt are usually considered palatable, it should be noted that what makes food palatable is not clearly defined and still debated (42). Importantly, Yeomans and colleagues reviewed whether palatability is sensitive to the homeostatic state of individuals and concluded that it rather reflected a hedonic stimulation of appetite (42). Concordantly, highly palatable foods are suggested to be the driver for the “hedonic hunger”, which refers to the desire to consume foods in absence of physical hunger (i.e., without caloric need) (45,46).

Key message

Food palatability is a driver for hedonic appetite. The attribution of a hedonic value to foods determines food preferences and involves two major domains: the sensory domain and the reward domain.

Sensory domain

The sensory experience has a major role in the attribution of a hedonic value to foods, in guiding food choices and ultimately energy intake (47). Taste, odor, texture, temperature, trigeminal sensitivity, but also visual and sound aspects play a role in palatability (48). In this doctoral work, we focus on the gustatory and the olfactory function, as the sensory responses to tastes and smells have a major role in hedonic eating (49–51).

Taste has three functional domains (52). One of these domains is purely sensorial and aims to detect and discriminate tastes. Another domain is related to the physiological role of taste, in order to prepare meal digestion. Finally, taste has an affective or hedonic domain, which plays a role in promoting or discouraging the ingestion of foods in relation to the taste input. This domain can be further divided in appetitive and consummatory behavior, which corresponds to a phase of seeking contact with the stimulus (53) and to a phase of realization and termination of the behavioral pattern. It is well known that humans have an innate taste preference for sweet, fat and / or salty foods, while they tend to dislike sour and bitter foods. Among the underlying mechanisms of taste preference, we can cite molecular and hormonal processes. For instance, the lingual proteins CD36 and GPR120 present in the taste buds (54) were shown to induce a spontaneous fat preference (55). Another example is related to sweet taste. Disse et al. demonstrated in a mice study that the preference for sweet foods was enhanced by peripheral ghrelin, and was mediated through a ghrelin receptor pathway (56). Of importance, learning mechanisms are involved in conditioned taste aversion or preferences when the consequences of ingestion are negative (e.g., nausea) or positive (e.g., nutrition), respectively (57). These processes have to be distinguished to conditioned taste avoidance, which refers to the adverse post-ingestive events that occur when too much food is eaten (58).

Olfaction has two main domains, the first being related to sensory aspects with the main objective of warning against toxic substances. Secondly, olfaction also plays a role in food pleasure, which is the subject of controversy between two points of view as explained by

Joussain and colleagues (59), who suggested that the hedonic valence of an odor is influenced by experience and learning on one hand, and by the physiochemical properties of odorant molecules on the other hand. This double contribution seems relevant to the current work as it has been shown that the response to olfactory stimuli is influenced by various factors, in particular early exposure to the odorant (60) and the verbal context (61). It has also been shown that the complexity of odorants plays a role in pleasantness. More precisely, odorants with low-complexity were rated as more aversive than the odorants with high complexity (62).

Sensory responses are usually recorded with hedonic or intensity scales, or with psychophysical testing, including threshold, discrimination and identification tasks (63). The link between the sensitivity to taste (i.e., detection threshold and suprathreshold sensitivity) and taste preference was recently explored by Chamoun et al. in young adults. They found that higher sensitivities were associated with lower taste preferences for sweet, salt and umami tastes only (64).

Reward domain

The neural basis of palatability was primarily explored by Berridge in 1996 (65). Since then, research on food reward has aroused much controversy concerning its components and whether it is possible to measure and / or to disentangle them as it has been explained elsewhere (17). Given the relevance of food reward in the context of overconsumption and obesity (17), this doctoral work uses the view of Finlayson and colleagues (46,54), who assert that liking and wanting are the two main separate constructs of food reward. Liking is related to the affect (underlying experience of feeling/emotion), while wanting is related to the motivation in relation to a food stimulus. Liking and wanting can be reported subjectively by individuals as the hedonic feeling related to the ingestion of a specific food (i.e., explicit liking) and as the desire to eat a specific food (i.e., explicit wanting). Explicit liking and wanting are usually assessed with visual analog scales (66). Additionally, liking and wanting would partly reflect unconscious processes, and would also have implicit components (46,54), which are usually inferred through the reaction time of responses to a food stimulus (66). The neural pathways of food reward have been recently extensively reviewed by Morales and Berridge (67). Liking for palatable foods is enhanced by hedonic “hotspots”, which are a distributed network located in the nucleus accumbens medial shell, ventral pallidum, orbitofrontal cortex (which is also important for the integration of sensory signals (68)), insula cortex, and brainstem. These

hedonic hotspots are included in the mesocorticolimbic circuitry, which generates wanting independently of liking, although both circuits are interconnected. Liking is mostly mediated by opioids and endocannabinoids, while wanting is mostly mediated by dopamine (65).

Importantly, the hedonic pathways are interacting with the homeostatic pathways. Figure 1.4 shows how highly palatable foods could trigger food consumption, through sensory and reward domains, while low palatable foods could trigger satiation and satiety (69).

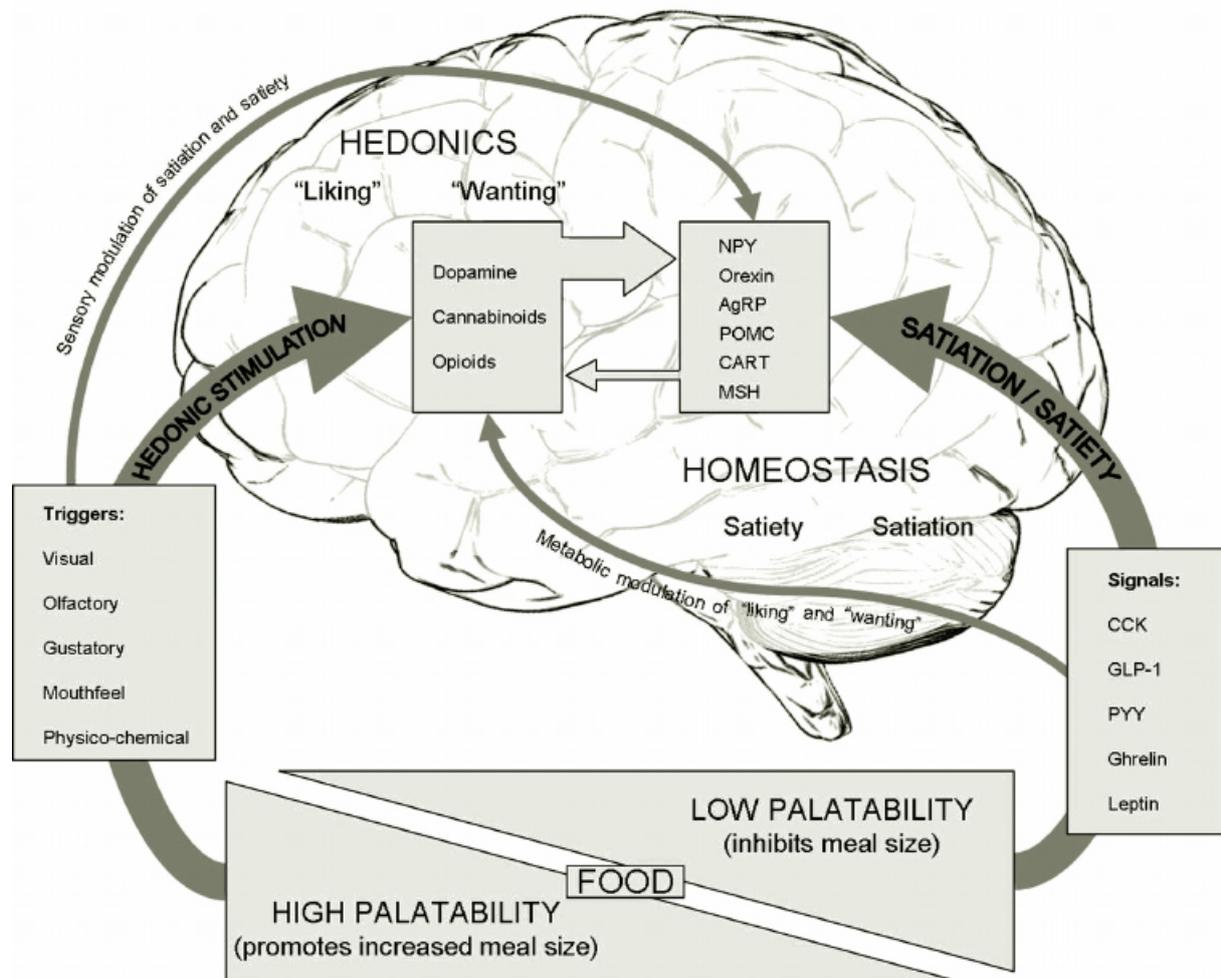


Figure 1.4. Interactions between hedonic and homeostatic system in the brain depend on the palatability of the food.

Source: Gibbons and Blundell, 2015 (69).

Alteration of the hedonic regulation of appetite in the case of obesity

Considering the sensory domain, both gustation and olfaction have shown to be altered in obesity (70,71). More specifically, a decrease in sensory perceptions related to excess weight has been suggested. For example, children and adolescents with obesity had lower taste

sensitivity and perceived intensity compared to those of normal weight (71). Moreover, olfactory function was negatively correlated with body weight (72).

The reward domain is also impaired in obesity. Already in 1971, Schachter proposed the external theory of obesity, which conceptualizes individuals with obesity as more sensitive to external food cues (e.g., smells) and less sensitive to internal homeostatic signals (e.g., hunger, satiety), compared to individuals with a normal weight (73). The link between obesity and reward has been well explored by Kenny (74) and Beaulieu et al. (23) and highlights the differential role of liking and wanting in overconsumption. First, some individuals with obesity would experience a greater reward to food cues, in particular highly palatable ones, which could predispose them to overconsumption and further weight gain (75). This is supported by several studies, which showed an increased activation of the brain reward areas in response to palatable foods among individuals with obesity compared to their normal-weight counterparts (76–78). Furthermore, studies found a correlation between high level of trait reward and body weight (79,80). The role of liking is particularly singled out in promoting overconsumption among individuals susceptible to weight gain through an enhanced hedonic response to palatable foods (81,82). Another avenue of understanding overconsumption is that some individuals might experience deficits in reward that may increase their consumption of palatable foods to satisfy their hedonic needs (83). Along these lines, the incentive-sensitization, which could arise in drug addiction has been proposed to also apply in higher weight gain and / or eating disorder. More precisely, it refers to a process by which the exposure to palatable food may decrease liking (84), while the reinforcing value of food (i.e., wanting) has been shown to sensitize or increase (85).

Obesity and food preferences

The hedonic appetite encompasses the liking and wanting for foods, and involves thoughts about foods and sensory appreciations of certain food attributes that determine food preferences and choices (23,86). Consistently, food preferences can be defined as the *'degree of like or dislike for a food'* (87) or by the *'evaluative attitudes that people express toward foods'* (88) and can thus be evaluated with hedonic scales (88). Food consumption is influenced by food preferences (89), which can also be viewed as a relative choice of one food over the other. Along these lines, food preference can be measured with; i) a forced choice paradigm, ii)

an estimation of relative food or macronutrient intakes using food frequency questionnaire, food recall or food record, or iii) with the help of an ad libitum buffet meal.

The relation between food preference and obesity has been explored through the relative macronutrient consumption in a study using 3-day dietary records (90). It showed that the percentage of energy from fat was higher among individuals with obesity compared to normal weight (90). Additionally, genetic studies showed that the single nucleotide polymorphism (SNP) rs17782313 near the MC4R gene was associated with obesity and with a higher intake of fat (91,92). Other SNPs near the loci SH2B1 and KCTD15, have also been associated with increased fat and carbohydrate intake, respectively (91).

Key message

The hedonic appetite involves sensory signals and reward processes that determine food preferences and choices. Sensory signals are modulated by homeostatic signals, which are integrated into the brain. These homeostatic signals contribute to assign a hedonic value to foods, which is reflected in the construct of palatability. Food reward is the neural basis of palatability, with liking and wanting being the main components related to the pleasure and the drive to eat, respectively. Homeostatic and hedonic processes interplay notably through sensory input and hormonal signals. Individuals with obesity display altered sensory and reward response to palatable foods and altered patterns of food preferences.

1.3 Bariatric surgery as a treatment for obesity

1.3.1. *Bariatric surgery: insight on its effectiveness and associated challenges*

Given the etiological complexity, pathophysiology and the existence of various phenotypes of obesity, its management involve various strategies, from an individual approach to policy programs (93,94). Although a healthy lifestyle, including a balanced diet and a regular physical activity is crucial for preventing obesity, it has been shown that lifestyle modifications and medical treatments have relatively little long-term benefit in patients with obesity (95,96).

Bariatric surgery can be proposed to patients with a moderate complicated or severe obesity (97,98), when the weight loss needed for improving health and quality of life cannot be obtained only through lifestyle modification or medical therapy (98). It is considered a safe and effective treatment for achieving a sustainable weight loss and reducing obesity-related comorbidities (99–102). More precisely, results from the Swedish Obese Subjects (SOS) study (103), which involved 1879 patients with bariatric surgery versus paired controls, indicated a 15 to 25%-weight loss within a 20-year follow-up, a significant reduction of cardiovascular events (adjusted HR (95%CI)=0.47 (0.29-0.76), p=0.002) and of total mortality (adjusted HR (95% CI)=0.71 (0.54-0.92), P=0.01) (100). Various outcomes are used to report weight loss after bariatric surgery, including Total Weight Loss (TWL), percent total weight loss (%TWL), change in BMI, and percent Excess Weight Loss (%EWL) (104). Percent EWL is calculated using the formula: $\%EWL = [(Initial\ Weight) - (Postop\ Weight)] / [(Initial\ Weight) - (Normal\ Weight)] \times 100$. Normal weight is calculated using a BMI of 25 kg.m⁻² (25). Weight loss following bariatric surgery is usually defined as successful when a %EWL > 50% is achieved (105). A recent review highlighted that many factors might contribute to the success of bariatric surgery, such as age, baseline BMI, preoperative comorbidities and the type of surgery (106). Interestingly, findings from the SOS study indicated that the preference towards foods characterized distinctly by their macronutrient content could play a role in successful weight loss. Indeed, individuals who favored protein and carbohydrates over fat had a greater weight loss (107).

These impressive weight loss results have led to a dramatic increase in bariatric surgeries over the past decade (doubled between 2008 and 2018 (108) (see Figure 1.5)). According to the latest available annual survey conducted by the International Federation for

the Surgery of Obesity and Metabolic Disorders (IFSO, 102), nearly 700,000 bariatric surgeries were performed worldwide in 2018. In France the number of bariatric surgeries increased from 12,800 in 2005 to 31,000 in 2011 (109) and is stabilized to more than 45,000 since 2014 (47,084 in 2014 (110) 46,654 in 2018 (108)). France is ranked the 1st country in Europe and 3rd in the world in terms of number of bariatric procedures behind the United States and Brazil (108).

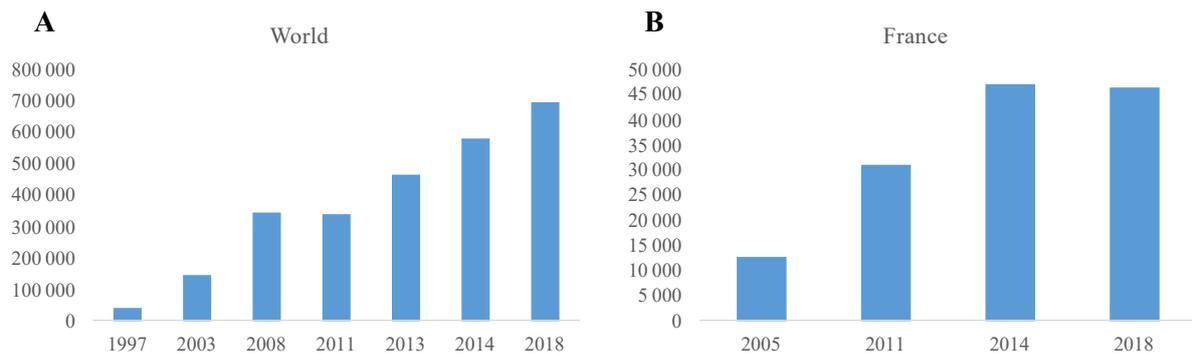


Figure 1.5. Number of bariatric surgeries performed in one year worldwide (panel A) and in France (panel B).

Sources for panel A: Scopinaro (111); Buschwald et al. (112); Buschwald and Oien (113); Buschwald and Oien (114); Angrisani et al. (115); and Angrisani et al. (108). Sources for panel B: Lazzati et al. (109); Debs et al. (110); and Angrisani et al. (108).

Worldwide, the two most commonly performed bariatric surgical techniques, are the Roux-en-Y gastric bypass (RYGB) and the sleeve gastrectomy (SG) (108). Figure 1.6 represents the normal anatomy and the modification induced by RYGB and SG. The RYGB has been first described by Mason in 1967 (116,117). It involves the resection of the stomach to create a small upper gastric pouch with a volume of 15 to 30 ml. A 20-50 cm segment of the distal jejunum inferior to the ligament of Treitz is inserted into this small gastric pouch, while the proximal jejunum is anastomosed below the gastro-jejunostomy, allowing the biliopancreatic juices to drain the alimentary limb (118). Marceau et al. described for the first time in 1993 the sleeve gastrectomy (119), which involves the resection of 70 to 80% of the stomach along the greater curvature, to create a gastric tube with a volume of approximately 100 ml (120).

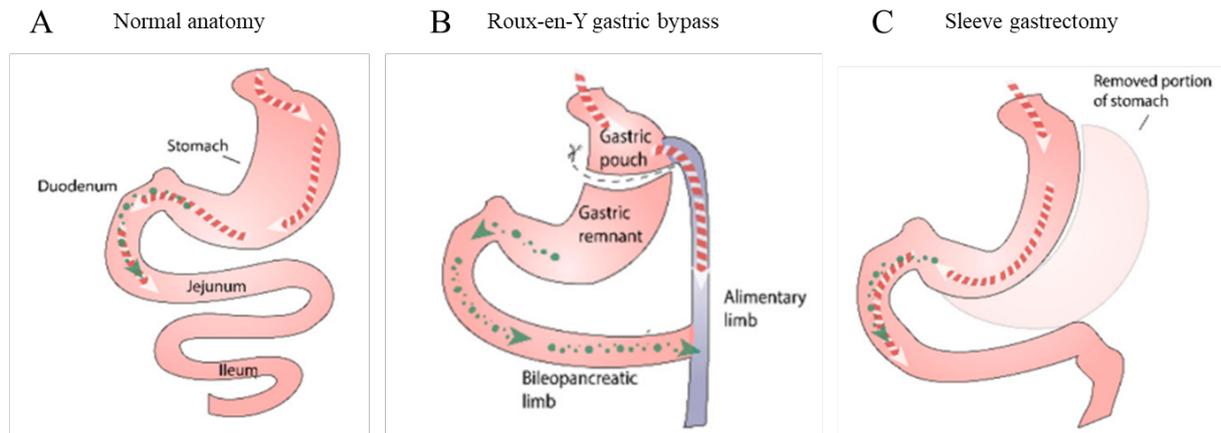


Figure 1.6. Bariatric surgery procedures.

Panel A represent the normal anatomy of the gastrointestinal tract. The two most commonly performed bariatric surgeries are the sleeve gastrectomy (panel B) and the Roux-en-Y gastric bypass (panel C). The discontinued red lines represent the trajectory of the food bowl. The green dots represent the trajectory of the digestive juices. Source: Vujasinovic et al. (121).

Bariatric surgery induces nutritional side effects due to its restrictive and malabsorptive effect. Especially, a deficit in vitamins and minerals can occur after both SG and RYGB, despite a multivitamin supplementation, with the most frequent deficiency being in 25-hydroxyvitamin D (122). Intake of calcium, magnesium, phosphorus and iron is also lower than the recommendations (122). Hair loss is among the most frequent symptoms encounter by the patients (123). Finally, because of the risk of developing protein-energy malnutrition (124), patients are recommended to eat 60 g to 80 g of proteins or 1.1 to 1.5 g per kilogram of ideal body weight (i.e., weight calculated with a BMI of 25 kg.m⁻²) postoperatively (98,125–130). However, most of them fail to eat the minimum intake of 60 g of proteins per day (131).

Despite the overall effectiveness of bariatric surgeries, patients do not all respond in the same way and may have different weight trajectories (132). Surgical failure (i.e., no or modest weight loss) occurs more in patients with a BMI above 50 kg.m⁻² (133). Moreover, patients might regain weight after reaching their lowest postoperative weight (i.e., nadir). The definition of weight regain is not consensual (134) and can be considered depending on the studies as i) an increase > 10 kg from nadir, ii) an increase > 25% EWL from nadir, iii) an increase in BMI of 5 kg.m⁻² from nadir, iv) a weight gain to a BMI > 35 kg.m⁻² after a successful weight loss, v) any weight regain, or vi) an increase > 15% of total body weight from nadir. In the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) cohort (N=1433) (130), the percentage weight regain (interquartile range) was 24.4% (11.6-38.4) (135), which was coherent with similar large cohort studies (136). The causes for weight regain are also multifactorial (137), related to diet, physical activity and motivational issues (138). Maladaptive eating habits, such as binge eating

disorder or emotional eating have also been related to weight regain (106). Along the same lines, increased food urges, severely decreased postoperative well-being and concerns over alcohol or drug use significantly predicted weight regain beyond one year of follow-up (139). In addition, the postoperative time and working in food service related activities were found to be determinants of weight regain (140). However, it remains to be explored whether food preferences and its sensory and reward domains play a role in postoperative weight regain.

Key message

Bariatric surgery is an effective treatment for patients suffering from complicated moderate or severe obesity, which nevertheless involves several challenges. In the preoperative period, the main challenge for the clinicians is to identify those patients whom the benefit of having a bariatric surgery would overcome any potential risks. In the postoperative period, the challenge is for the patient to optimize the results of bariatric surgery by adopting a balanced diet in the long term.

1.3.2. Bariatric surgery, appetite control and food preferences

The mechanisms underlying the effect of bariatric surgery on weight loss are not yet fully understood. Several reviews (141–146) indicated that bariatric surgery plays a role in gastrointestinal motility, in the modification of the gut-brain axis, in the modulation of the intestinal microbiota and in the inflammatory response. There is also growing evidence suggesting that bariatric surgery could modulate different processes involved in the regulation of food intake and eating behavior (146).

Considering the homeostatic control of appetite, bariatric surgery decreases hunger, increases satiety (147) and reduces food cravings (148), the total volume (149) and intake of food (149,150). These modifications might be mediated by changes in appetite signaling, which occur after bariatric surgery (151). Table 1.1 shows some of the main appetite-related signals and how are modified by the bariatric surgery. Overall, leptin resistance is improved, the levels of ghrelin are decreased while satiety signals such as CCK are increased postoperatively.

Table 1.1. Modifications of the major appetite-related signals after bariatric surgery.

Appetite-related signal	Site of production	Effect on food intake	Modification in case of obesity	Modification after bariatric surgery
PYY	L cells terminal ileum and colon	↓ (152)	↓	↔ or slight ↑ fasting Slight ↑ postprandial
GLP-1	L cells ileum and proximal colon	↓ (153,154)	↔ or ↓	↔ or slight ↑ fasting ↑ postprandial
CCK	I cells of the proximal small intestine (duodenum and jejunum)	↓ (155)	↔ fasting ↔ or ↓ postprandial	↔ fasting ↑ postprandial
Ghrelin	Stomach and small intestine	↑ (156)	↔ or ↓ fasting ↔ or ↓ postprandial	↓ fasting ↓ postprandial
Leptin	Adipose tissue	↓ (157)	↑ (158)	↔ or ↓ fasting (159)

Abbreviations: PYY: peptide YY 3-36, GLP-1: glucagon-like peptide-1, CCK: cholecystokinin. Adapted from Meek et al. (151). Arrows indicate the effect of bariatric surgery upon the appetite-related signals: ↑ increase, ↓ decrease or ↔ no modification.

The effects of bariatric surgery on the hedonic regulation of appetite have also been explored through its sensory and reward domains. The effect of bariatric surgery on gustation and olfaction has been recently systematically reviewed. Overall, the results showed that bariatric surgery modified the gustatory (160) and olfactory (72) function, with a prominent effect of sleeve gastrectomy on olfaction. Decreased appreciation of all basic tastes (sour, bitter, sweet, salty, umami) was also observed in the first postoperative week (161). Interestingly, the threshold for detecting sour taste was found to be increased postoperatively (162). However, there are contradicting results, which indicate no change in sensory perceptions (162).

Regarding the reward domain, the postoperative modifications of food reward has been suggestive to be attributable to the increased levels of satiety hormones (163). Brain imaging studies showed decreased activation of the reward system after bariatric surgery (163–165). In particular, weaker activation of reward system neurons was found in response to high energy dense (166–169) and highly palatable foods (high in fat and / or sweet) (170–172). Moreover, differences in activation of the reward system have been described between individuals with a normal weight and individuals with bariatric surgery (173), yet with contrasting results (174).

Overall, these results highlight postoperative modification in the perceived hedonic value of foods and therefore in food preferences. Figure 1.7 shows the possible underlying mechanisms by which the gastrointestinal tract modification might affect hedonic processes, which regulate appetite and energy intake. There is a growing interest in the effect of bariatric surgeries on human's food preferences in recent years. In 1990 Kenler et al. showed changes in preferences in favor of healthy food choices after RYGB and SG (175). In 1995, Trostler et al. observed a postoperative decreased consumption of animal products and snacks (176). Since then, qualitative modifications of food intake after bariatric surgery have been reported, but with inconsistent results (177,178). Interestingly, a decreased appreciation for fatty and sugary foods has been shown postoperatively (179), which could contribute to the effect of bariatric surgery on weight loss. However, using a buffet type meal in a more realistic context, Nielsen et al. did not find any differences in food preference between pre- and post-operative patients (180). This suggests that the modification of the sensory and reward domains might not be translated into behavioral changes. The link between these two domains of food hedonics and phenotypic food preferences as a behavioral aspect needs to be explored in the context of bariatric surgery. A better understanding of how bariatric surgery could potentially modify the attribution of a hedonic value to foods, is needed in order to propose an adapted nutritional strategy to each patient after bariatric surgery.

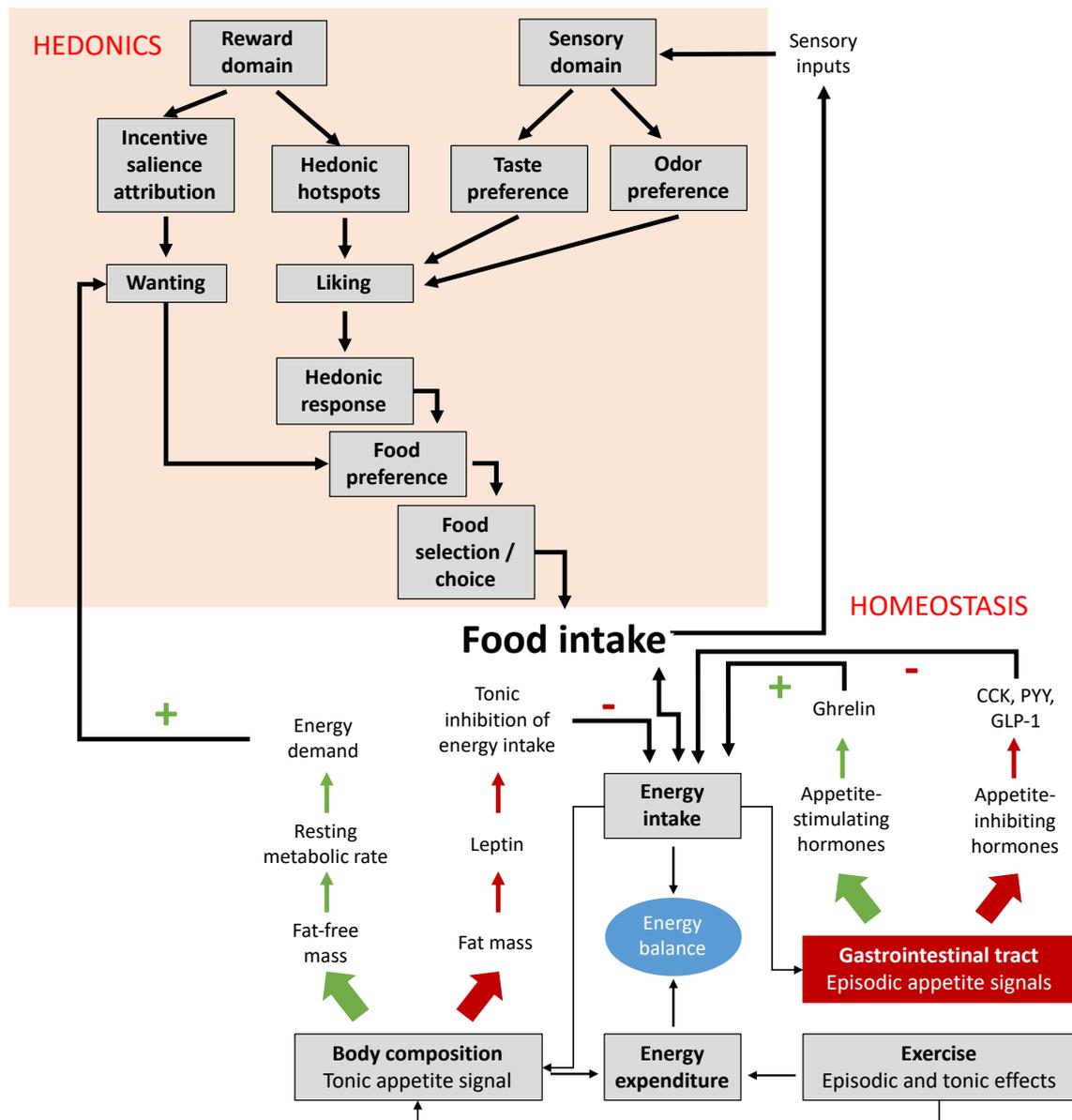


Figure 1.7. By modifying the gastrointestinal tract, bariatric surgery might induce a series of modifications in homeostatic and hedonic processes of appetite regulation.

Adapted from Blundell et al. (181), Drewnowski (51), and Finlayson and Dalton (182).

Key message

Bariatric surgery induces modifications in the homeostatic and hedonic processes of appetite control, which have been shown to be impaired in obesity. Of importance, several studies reported qualitative alterations in food intake. Thus, bariatric surgery could modify food preferences and more specifically the attribution of a hedonic value to a food through modifications of the sensory and the reward domain. A better understanding of these modifications is of paramount importance for managing the postoperative weight loss success and nutritional side effects.

1.4 Aim and objective of the thesis

This doctoral work aims to gain insight into the influence of bariatric surgery in the modification of the hedonic regulation of food intake (i.e., phenotypic food preferences), by responding to the following objectives. For each objective, specific hypotheses have been formulated and the method used for testing them is presented.

Objective 1 (*Chapter II*)

To review the evidence on the link between bariatric surgery and changes in food preferences.

Although several studies have examined changes in food preferences after bariatric surgery, their results remain inconsistent, partly explained by the high variation in study design/setting methods to assess food preferences and types of bariatric surgeries. Exploring the question of postoperative modifications of food preferences by considering different subgroups seemed prudent. We hypothesized that food preference changes following bariatric surgery and that the results differ according to assessment method and type of surgery. To test for these hypotheses, we have performed a systematic review of the literature and a meta-analysis.

Objective 2 (*Chapter III*)

To study the links between food preferences, taste, smell and the weight loss success of bariatric surgery.

Recent reviews have demonstrated that modification of olfactory and gustatory function occur after bariatric surgery, yet little is known on the links between food preferences and sensory alterations after bariatric surgery. We hypothesized that food preferences are different between patients reporting or not sensory alterations and between patients in weight loss success or failure of bariatric surgery. We tested these hypotheses in a cohort of French bariatric patients using an online questionnaire, which included sections about the history of bariatric surgery, the food preferences and taste and smell alterations.

Objective 3 (Chapter IV)**To adapt and use a computerized task to compare food reward between patients with and without bariatric surgery.**

Food reward and its components ‘liking’ and ‘wanting’ are key element of the hedonic regulation of appetite. Several fMRI studies have demonstrated that bariatric surgery modifies activation of the reward brain areas. However, it is not known whether these modifications are translated into behavioral modification of food reward, nor if food reward is different according to the type of surgery performed. We hypothesized that food reward is different between patients with and without bariatric surgery and between patients with different types of surgery. To test these hypotheses, we have adapted the Leeds Food Preferences Questionnaire (LFPQ) for French language and eating habits and we have used this tool to compare food reward between patients with unoperated obesity, patients with a sleeve gastrectomy and patients with a Roux-en-Y gastric bypass.

Objective 4 (Chapter VI)**To develop a protocol to study food preferences after bariatric surgery in an ecological setting.**

Most of the studies, which assessed food preferences used self-reported measurements. Although these methods are useful to easily capture dietary intakes, they are prone to reporting bias. To our knowledge, only one study used real food, with a buffet-type meal in a laboratory setting. It is then important to conduct research in controlled but more realistic environment, to improve the ecological validity of the results. We hypothesized that food preferences in a normal eating environment might differ from those reported in questionnaires and computerized tasks by patients with obesity that have benefited or not from bariatric surgery. Furthermore, we think that in a real context of eating, patients who benefit from a bariatric surgery in the past 12 months have different food preferences compared to patients with a severe complicated or a morbid obesity, candidate for bariatric surgery. To test these hypotheses, we designed a study using a buffet meal in an experimental restaurant, which will be used to study differences in terms of diet quality, food intake and microstructure of the meal between patients with and without bariatric surgery.

1.5 References

1. World Health Organization. Obesity and overweight [Internet]. April 2020. [cited 2021 Feb 11]. Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
2. Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, et al. Health effects of overweight and obesity in 195 countries over 25 years. *N Engl J Med*. 2017 Jul 6;377(1):13–27.
3. Avila C, Holloway AC, Hahn MK, Morrison KM, Restivo M, Anglin R, et al. An Overview of Links Between Obesity and Mental Health. Vol. 4, *Current obesity reports*. 2015. p. 303–10.
4. Pi-Sunyer X. The medical risks of obesity. *Postgrad Med*. 2009 Nov;121(6):21–33.
5. Yusefzadeh H, Rashidi A, Rahimi B. Economic burden of obesity: A systematic review. *Soc Heal Behav*. 2019;2(1):7.
6. NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Obesity in Adults (US). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. Vol. 97, *WMJ : official publication of the State Medical Society of Wisconsin*. National Heart, Lung, and Blood Institute; 1998.
7. Ketel IJG, Volman MNM, Seidell JC, Stehouwer CDA, Twisk JW, Lambalk CB. Superiority of skinfold measurements and waist over waist-to-hip ratio for determination of body fat distribution in a population-based cohort of Caucasian Dutch adults. *Eur J Endocrinol*. 2007 Jun 1;156(6):655–61.
8. Chan DC. Waist circumference, waist-to-hip ratio and body mass index as predictors of adipose tissue compartments in men. *QJM*. 2003 Jun 1;96(6):441–7.
9. Kuk JL, Katzmarzyk PT, Nichaman MZ, Church TS, Blair SN, Ross R. Visceral fat is an independent predictor of all-cause mortality in men. *Obesity*. 2006 Feb;14(2):336–41.
10. Jensen MD. Role of body fat distribution and the metabolic complications of obesity. Vol. 93, *Journal of Clinical Endocrinology and Metabolism*. J Clin Endocrinol Metab; 2008.
11. Khaodhiar L, McCowen KC, Blackburn GL. Obesity and its comorbid conditions. *Clin Cornerstone*. 1999;2(3):17–31.
12. Hall KD, Heymsfield SB, Kemnitz JW, Klein S, Schoeller DA, Speakman JR. Energy balance and its components: implications for body weight regulation. *Am J Clin Nutr*. 2012 Apr 1;95(4):989–94.
13. Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, et al. *Foresight. tackling obesities: future choices - project report*. Second edition. 2007.
14. Deitel M. The obesity epidemic. Vol. 16, *Obesity Surgery*. Springer; 2006. p. 377–8.
15. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: The development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med (Baltim)*. 1999 Dec 1;29(6 I):563–70.
16. Belfort-DeAguiar R, Seo D. *Food Cues and Obesity: Overpowering Hormones and*

- Energy Balance Regulation. Vol. 7, Current obesity reports. *Curr Obes Rep*; 2018. p. 122–9.
17. Hopkins M, Blundell J, Halford J, King N, Finlayson G. The Regulation of Food Intake in Humans. *Endotext*. MDText.com, Inc.; 2000.
 18. Blundell JE, Finlayson G. Is susceptibility to weight gain characterized by homeostatic or hedonic risk factors for overconsumption? *Physiol Behav*. 2004;82(1):21–5.
 19. Lutter M, Nestler EJ. Homeostatic and hedonic signals interact in the regulation of food intake. In: *Journal of Nutrition*. *J Nutr*; 2009. p. 629–32.
 20. Al’Absi M, Li B. Appetite and Appetite Regulation. In: Gellman MD, Turner JR, editors. *Encyclopedia of Behavioral Medicine*. New York, NY: Springer New York; 2013. p. 123–4.
 21. Blundell J. Pharmacological approaches to appetite suppression. Vol. 12, *Trends in Pharmacological Sciences*. 1991. p. 147–57.
 22. Blundell J, De Graaf C, Hulshof T, Jebb S, Livingstone B, Luch A, et al. Appetite control: Methodological aspects of the evaluation of foods. Vol. 11, *Obesity Reviews*. *Obes Rev*; 2010. p. 251–70.
 23. Beaulieu K, Blundell J. The Psychobiology of Hunger – A Scientific Perspective. *Topoi*. 2020 Oct 6;1:3.
 24. Halford JCG, Blundell JE. Separate systems for serotonin and leptin in appetite control. Vol. 32, *Annals of Medicine*. Royal Society of Medicine Press Ltd; 2000. p. 222–32.
 25. Blundell JE, Caudwell P, Gibbons C, Hopkins M, Näslund E, King NA, et al. Body composition and appetite: Fat-free mass (but not fat mass or BMI) is positively associated with self-determined meal size and daily energy intake in humans. *Br J Nutr*. 2012 Feb 14;107(3):445–9.
 26. Blundell JE, Gibbons C, Caudwell P, Finlayson G, Hopkins M. Appetite control and energy balance: Impact of exercise. Vol. 16, *Obesity Reviews*. Blackwell Publishing Ltd; 2015. p. 67–76.
 27. Luquet S, Cruciani-Guglielmacci C. Central control of energy balance. *Cah Nutr Diet*. 2009;44(1):17–25.
 28. Myers MG, Olson DP. Central nervous system control of metabolism. Vol. 491, *Nature*. Nature Publishing Group; 2012. p. 357–63.
 29. Coll AP, Farooqi IS, O’Rahilly S. The Hormonal Control of Food Intake. Vol. 129, *Cell*. Cell Press; 2007. p. 251–62.
 30. Brennan IM, Luscombe-Marsh ND, Seimon R V., Otto B, Horowitz M, Wishart JM, et al. Effects of fat, protein, and carbohydrate and protein load on appetite, plasma cholecystokinin, peptide YY, and ghrelin, and energy intake in lean and obese men. *Am J Physiol - Gastrointest Liver Physiol*. 2012;303(1).
 31. Benelam B. Satiety, satiety and their effects on eating behaviour. *Nutr Bull*. 2009 Jun 1;34(2):126–73.
 32. Roefs A, Boh B, Spanakis G, Nederkoorn C, Lemmens LHJM, Jansen A. Food craving in daily life: comparison of overweight and normal-weight participants with ecological momentary assessment. *J Hum Nutr Diet*. 2019 Dec 20;32(6):765–74.
 33. Merriam PA, Ockene IS, Hebert JR, Rosal MC, Matthews CE. Seasonal variation of

- blood cholesterol levels: Study methodology. *J Biol Rhythms*. 1999 Aug 29;14(4):330–9.
34. Ma Y. Association between Eating Patterns and Obesity in a Free-living US Adult Population. *Am J Epidemiol*. 2003 Jul 1;158(1):85–92.
35. Wang JB, Patterson RE, Ang A, Emond JA, Shetty N, Arab L. Timing of energy intake during the day is associated with the risk of obesity in adults. *J Hum Nutr Diet*. 2014 Apr;27(SUPPL2):255–62.
36. Mittelman SD, Klier K, Braun S, Azen C, Geffner ME, Buchanan TA. Obese adolescents show impaired meal responses of the appetite-regulating hormones ghrelin and PYY. *Obesity*. 2010 May;18(5):918–25.
37. Takagi K, Legrand R, Asakawa A, Amitani H, François M, Tonnoune N, et al. Anti-ghrelin immunoglobulins modulate ghrelin stability and its orexigenic effect in obese mice and humans. *Nat Commun*. 2013;4.
38. Zwirska-Korczala K, Konturek SJ, Sodowski M, Wylezol M, Kuka D, Sowa P, et al. Basal and postprandial plasma levels of PYY, ghrelin, cholecystokinin, gastrin and insulin in women with moderate and morbid obesity and metabolic syndrome. *J Physiol Pharmacol an Off J Polish Physiol Soc*. 2007 Mar;58 Suppl 1:13–35.
39. Blundell JE, Gibbons C, Beaulieu K, Casanova N, Duarte C, Finlayson G, et al. The drive to eat in homo sapiens: Energy expenditure drives energy intake. Vol. 219, *Physiology and Behavior*. Elsevier Inc.; 2020. p. 112846.
40. Velloso LA, Schwartz MW. Altered hypothalamic function in diet-induced obesity. Vol. 35, *International Journal of Obesity*. NIH Public Access; 2011. p. 1455–65.
41. Lee EB, Ahima RS. Alteration of hypothalamic cellular dynamics in obesity. Vol. 122, *Journal of Clinical Investigation*. American Society for Clinical Investigation; 2012. p. 22–5.
42. Yeomans MR, Blundell JE, Leshem M. Palatability: response to nutritional need or need-free stimulation of appetite? *Br J Nutr*. 2004 Aug;92(S1):S3–14.
43. Ramirez I. What do we mean when we say “palatable food”? *Appetite*. 1990 Jun 1;14(3):159–61.
44. Friedman MI, Stricker EM. The Physiological Psychology of Hunger: A Physiological Perspective. Vol. 83, *Psychological Review*. 1976.
45. Lowe MR, Butryn ML. Hedonic hunger: A new dimension of appetite? *Physiol Behav*. 2007 Jul 24;91(4):432–9.
46. Forman EM, Hoffman KL, McGrath KB, Herbert JD, Brandsma LL, Lowe MR. A comparison of acceptance- and control-based strategies for coping with food cravings: An analog study. *Behav Res Ther*. 2007 Oct;45(10):2372–86.
47. McCrickerd K, Forde CG. Sensory influences on food intake control: moving beyond palatability. *Obes Rev*. 2016 Jan 1;17(1):18–29.
48. Hyde RJ, Witherly SA. Dynamic contrast: A sensory contribution to palatability. *Appetite*. 1993 Aug 1;21(1):1–16.
49. Rolls ET. Taste, olfactory and food texture reward processing in the brain and obesity. Vol. 35, *International Journal of Obesity*. Nature Publishing Group; 2011. p. 550–61.
50. Rolls ET. Brain mechanisms underlying flavour and appetite. Vol. 361, *Philosophical*

- Transactions of the Royal Society B: Biological Sciences. Royal Society; 2006. p. 1123–36.
51. Drewnowski A. Taste preferences and food intake. Vol. 17, Annual Review of Nutrition. Annu Rev Nutr; 1997. p. 237–53.
 52. Spector AC. Linking gustatory neurobiology to behavior in vertebrates. Vol. 24, Neuroscience and Biobehavioral Reviews. Pergamon; 2000. p. 391–416.
 53. Craig W. Appetites and Aversions as Constituents of Instincts. Proc Natl Acad Sci. 1917 Dec 1;3(12):685–8.
 54. Degrace-Passilly P, Besnard P. CD36 and taste of fat. Vol. 15, Current Opinion in Clinical Nutrition and Metabolic Care. Curr Opin Clin Nutr Metab Care; 2012. p. 107–11.
 55. Martin C, Passilly-Degrace P, Gaillard D, Merlin JF, Chevrot M, Besnard P. The lipid-sensor candidates CD36 and GPR120 are differentially regulated by dietary lipids in mouse taste buds: Impact on spontaneous fat preference. PLoS One. 2011 Aug 25;6(8).
 56. Disse E, Bussier AL, Veyrat-Durebex C, Deblon N, Pfluger PT, Tschöp MH, et al. Peripheral ghrelin enhances sweet taste food consumption and preference, regardless of its caloric content. Physiol Behav. 2010;101(2):277–81.
 57. Scott TR. Learning through the taste system. Front Syst Neurosci. 2011 Nov 23;5:87.
 58. Parker LA. Taste avoidance and taste aversion: Evidence for two different processes. Learn Behav. 2003 May 1;31(2):165–72.
 59. Jossain P, Chakirian A, Kermen F, Rouby C, Bensafi M. Physicochemical influence on odor hedonics: Where does it occur first? Commun Integr Biol. 2011 Sep;4(5):563–5.
 60. Poncelet J, Rinck F, Bourgeat F, Schaal B, Rouby C, Bensafi M, et al. The effect of early experience on odor perception in humans: Psychological and physiological correlates. Behav Brain Res. 2010 Apr 2;208(2):458–65.
 61. Herz RS. The Effect of Verbal Context on Olfactory Perception. J Exp Psychol Gen. 2003 Dec;132(4):595–606.
 62. Kermen F, Chakirian A, Sezille C, Jossain P, Le Goff G, Ziesel A, et al. Molecular complexity determines the number of olfactory notes and the pleasantness of smells. Sci Rep. 2011 Dec 22;1(1):1–6.
 63. Bartoshuk LM. The biological basis of food perception and acceptance. Food Qual Prefer. 1993 Jan 1;4(1–2):21–32.
 64. Chamoun E, Liu AAS, Duizer LM, Darlington G, Duncan AM, Haines J, et al. Taste Sensitivity and Taste Preference Measures Are Correlated in Healthy Young Adults. Chem Senses. 2019 Jan 29;44(2):129–34.
 65. Berridge KC. Food reward: Brain substrates of wanting and liking. Neurosci Biobehav Rev. 1996;20(1):1–25.
 66. Oustric P, Gibbons C, Beaulieu K, Blundell J, Finlayson G. Changes in food reward during weight management interventions – a systematic review. Vol. 19, Obesity Reviews. Blackwell Publishing Ltd; 2018. p. 1642–58.
 67. Morales I, Berridge KC. ‘Liking’ and ‘wanting’ in eating and food reward: Brain mechanisms and clinical implications. Vol. 227, Physiology and Behavior. Elsevier Inc.; 2020. p. 113152.

68. Rolls ET. Convergence of sensory systems in the orbitofrontal cortex in primates and brain design for emotion. In: *Anatomical Record - Part A Discoveries in Molecular, Cellular, and Evolutionary Biology*. *Anat Rec A Discov Mol Cell Evol Biol*; 2004. p. 1212–25.
69. Gibbons C, Blundell J. Appetite regulation and physical activity – an energy balance perspective. *Hamdan Med J*. 2015 May 20;8(1):33.
70. Valladares Vega M, Obregon Rivas AM. Association of olfactory sensitivity with energy intake: role in development of obesity. *Nutr Hosp*. 2015 Dec;32(6):2385–9.
71. Overberg J, Hummel T, Krude H, Wiegand S. Differences in taste sensitivity between obese and non-obese children and adolescents. *Arch Dis Child*. 2012 Dec;97(12):1048–52.
72. Peng M, Coutts D, Wang T, Cakmak YO. Systematic review of olfactory shifts related to obesity. *Obes Rev*. 2019 Feb 1;20(2):325–38.
73. Schachter S. Some extraordinary facts about obese humans and rats. Vol. 26, *The American psychologist*. *Am Psychol*; 1971. p. 129–44.
74. Kenny PJ. Reward Mechanisms in Obesity: New Insights and Future Directions. Vol. 69, *Neuron*. Cell Press; 2011. p. 664–79.
75. Stice E, Yokum S, Blum K, Bohon C. Weight gain is associated with reduced striatal response to palatable food. *J Neurosci*. 2010 Sep 29;30(39):13105–9.
76. Gautier JF, Chen K, Salbe AD, Bandy D, Pratley RE, Heiman M, et al. Differential brain responses to satiation in obese and lean men. *Diabetes*. 2000;49(5):838–46.
77. Karhunen L. Regional cerebral blood flow during food exposure in obese and normal-weight women. *Brain*. 1997 Sep 1;120(9):1675–84.
78. Rothmund Y, Preuschhof C, Bohner G, Bauknecht HC, Klingebiel R, Flor H, et al. Differential activation of the dorsal striatum by high-calorie visual food stimuli in obese individuals. *Neuroimage*. 2007 Aug 15;37(2):410–21.
79. Davis C, Strachan S, Berkson M. Sensitivity to reward: Implications for overeating and overweight. *Appetite*. 2004 Apr;42(2):131–8.
80. Franken IHA, Muris P. Individual differences in reward sensitivity are related to food craving and relative body weight in healthy women. *Appetite*. 2005 Oct;45(2):198–201.
81. Noury J, Lawton C, Blundell J. Food choice and hedonic responses: Difference between overweight and lean high fat phenotypes. *Int J Obes*. 2002 Jan 1;26:S125.
82. Blundell JE, Stubbs RJ, Golding C, Croden F, Alam R, Whybrow S, et al. Resistance and susceptibility to weight gain: Individual variability in response to a high-fat diet. In: *Physiology and Behavior*. Elsevier Inc.; 2005. p. 614–22.
83. Davis C, Fox J. Sensitivity to reward and body mass index (BMI): Evidence for a non-linear relationship. *Appetite*. 2008 Jan;50(1):43–9.
84. Raynor HA, Epstein LH. Dietary variety, energy regulation, and obesity. *Psychol Bull*. 2001;127(3):325–41.
85. Berridge KC, Robinson TE. The Mind of an Addicted Brain: Neural Sensitization of Wanting Versus Liking. *Curr Dir Psychol Sci*. 1995;4(3):71–5.
86. Finlayson G, King N, Blundell JE. Liking vs. wanting food: Importance for human

- appetite control and weight regulation. Vol. 31, *Neuroscience and Biobehavioral Reviews*. *Neurosci Biobehav Rev*; 2007. p. 987–1002.
87. Pilgrim FJ. The components of food acceptance and their measurement. *Am J Clin Nutr*. 1957 Mar 1;5(2):171–5.
 88. Meiselman HL, Bell R. Eating habits. In: *Encyclopedia of Food Sciences and Nutrition*. Elsevier; 2003. p. 1963–8.
 89. Sanjur D, Randall E, Sanjur D. Food preferences—Their conceptualization and relationship to consumption. *Ecol Food Nutr*. 1981 Dec 1;11(3):151–61.
 90. Jeon KJ, Lee O, Kim HK, Han SN. Comparison of the dietary intake and clinical characteristics of obese and normal weight adults. *Nutr Res Pract*. 2011 Aug 31;5(4):329–36.
 91. Bauer F, Elbers CC, Adan RA, Loos RJ, Onland-Moret NC, Grobbee DE, et al. Obesity genes identified in genome-wide association studies are associated with adiposity measures and potentially with nutrient-specific food preference. *Am J Clin Nutr*. 2009 Oct 1;90(4):951–9.
 92. Qi L, Kraft P, Hunter DJ, Hu FB. The common obesity variant near MC4R gene is associated with higher intakes of total energy and dietary fat, weight change and diabetes risk in women. *Hum Mol Genet*. 2008;17(22):3502–8.
 93. Walker S, Carlos Poston I, Foreyt JP. Successful Management of the Obese Patient. *Am Fam Physician*. 2000 Jun 15;61(12):3615–22.
 94. Lagerros YT, Rössner S. Obesity management: What brings success? Vol. 6, *Therapeutic Advances in Gastroenterology*. SAGE Publications; 2013. p. 77–88.
 95. Sjöström L, Peltonen M, Jacobson P, Sjöström CD, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. *JAMA - J Am Med Assoc*. 2012 Jan 4;307(1):56–65.
 96. Peirson L, Douketis J, Ciliska D, Fitzpatrick-Lewis D, Ali MU, Raina P. Treatment for overweight and obesity in adult populations: a systematic review and meta-analysis. *C Open*. 2014 Nov 19;2(4):E306–17.
 97. Statement on Patient Selection for Bariatric Surgery. *Obes Surg* [Internet]. 1997 Feb 1 [cited 2021 Mar 11];7(1):41–41. Available from: <http://link.springer.com/10.1381/096089297765556259>
 98. Mechanick JI, Apovian C, Brethauer S, Garvey WT, Joffe AM, Kim J, et al. Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures – 2019 update: cosponsored by American Association of Clinical Endocrinologists/American College of Endocrinology,. *Surg Obes Relat Dis*. 2020;16(2):175–247.
 99. Sjöström L, Narbro K, Sjöström CD, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med*. 2007 Aug 23;357(8):741–52.
 100. Sjöström L. Review of the key results from the Swedish Obese Subjects (SOS) trial - a prospective controlled intervention study of bariatric surgery. Vol. 273, *Journal of Internal Medicine*. 2013. p. 219–34.
 101. Colquitt JL, Pickett K, Loveman E, Frampton GK. Surgery for weight loss in adults. Vol.

- 2014, Cochrane Database of Systematic Reviews. John Wiley and Sons Ltd; 2014.
102. Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrback K, et al. Bariatric surgery: A systematic review and meta-analysis. Vol. 292, *Journal of the American Medical Association*. JAMA; 2004. p. 1724–37.
 103. Torgerson JS, Sjöström L. The Swedish Obese Subjects (SOS) study—rationale and results. *Int J Obes*. 2001;25(1):S2–4.
 104. Grover BT, Morell MC, Kothari SN, Borgert AJ, Kallies KJ, Baker MT. Defining Weight Loss After Bariatric Surgery: a Call for Standardization. *Obes Surg*. 2019 Nov 1;29(11):3493–9.
 105. Halverson JD, Koehler RE. Gastric bypass: Analysis of weight loss and factors determining success. *Surgery*. 1981 Sep 1;90(3):446–55.
 106. Masnyj S V., Shea BJ, Khaitan L. Predictors of Success in Bariatric Surgery. Vol. 14, *Current Cardiovascular Risk Reports*. Springer; 2020. p. 1–9.
 107. Kanerva N, Larsson I, Peltonen M, Lindroos AK, Carlsson LM. Changes in total energy intake and macronutrient composition after bariatric surgery predict long-term weight outcome: Findings from the Swedish Obese Subjects (SOS) study. *Am J Clin Nutr*. 2017 Jul 1;106(1):136–45.
 108. Angrisani L, Santonicola A, Iovino P, Ramos A, Shikora S, Kow L. Bariatric Surgery Survey 2018: Similarities and Disparities Among the 5 IFSO Chapters. *Obes Surg*. 2021 Jan 12;1–12.
 109. Lazzati A, Guy-Lachuer R, Delaunay V, Szwarcensztein K, Azoulay D. Bariatric surgery trends in France: 2005–2011. *Surg Obes Relat Dis*. 2014 Mar 1;10(2):328–34.
 110. Debs T, Petrucciani N, Kassir R, Iannelli A, Amor I Ben, Gugenheim J. Trends of bariatric surgery in France during the last 10 years: analysis of 267,466 procedures from 2005–2014. *Surg Obes Relat Dis*. 2016 Sep 1;12(8):1602–9.
 111. Scopinaro N. Second Congress of the International Federation for the Surgery of Obesity, Cancun, Mexico, October 2, 1997: Presidential Address: The IFSO and obesity surgery throughout the world. In: *Obesity Surgery*. *Obes Surg*; 1998. p. 3–8.
 112. Buchwald H, Williams SE. Bariatric surgery worldwide 2003. *Obes Surg*. 2004 Oct 1;14(9):1157–64.
 113. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2008. Vol. 19, *Obesity Surgery*. *Obes Surg*; 2009. p. 1605–11.
 114. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. *Obes Surg*. 2013 Apr;23(4):427–36.
 115. Angrisani L, Santonicola A, Iovino P, Formisano G, Buchwald H, Scopinaro N. Bariatric Surgery Worldwide 2013. *Obes Surg*. 2015 Oct 7;25(10):1822–32.
 116. Mason EE, Ito C. Gastric bypass in obesity. *Surg Clin North Am*. 1967;47(6):1345–51.
 117. Buchwald H. The evolution of metabolic/bariatric surgery. Vol. 24, *Obesity Surgery*. Springer New York LLC; 2014. p. 1126–35.
 118. Olbers T, Lönroth H, Fagevik-Olsén M, Lundell L. Laparoscopic gastric bypass: Development of technique, respiratory function, and long-term outcome. *Obes Surg*. 2003 Jun 1;13(3):364–70.

119. Marceau P, Biron S, Bourque R-A, Potvin M, Hould F-S, Simard S. Biliopancreatic Diversion with a New Type of Gastrectomy. *Obes Surg.* 1993 Feb 1;3(1):29–35.
120. Carlin AM, Zeni TM, English WJ, Hawasli AA, Genaw JA, Krause KR, et al. The comparative effectiveness of sleeve gastrectomy, gastric bypass, and adjustable gastric banding procedures for the treatment of morbid obesity. *Ann Surg.* 2013 May;257(5):791–7.
121. Vujasinovic M, Valente R, Thorell A, Rutkowski W, Haas SL, Arnelo U, et al. Pancreatic exocrine insufficiency after bariatric surgery. Vol. 9, *Nutrients*. MDPI AG; 2017.
122. Moizé V, Andreu A, Flores L, Torres F, Ibarzabal A, Delgado S, et al. Long-Term Dietary Intake and Nutritional Deficiencies following Sleeve Gastrectomy or Roux-En-Y Gastric Bypass in a Mediterranean Population. *J Acad Nutr Diet.* 2013 Mar;113(3):400–10.
123. Ledoux S, Flamant M, Calabrese D, Bogard C, Sami O, Coupaye M. What Are the Micronutrient Deficiencies Responsible for the Most Common Nutritional Symptoms After Bariatric Surgery? *Obes Surg.* 2020 May 20;30(5):1891–7.
124. Martins T de CP, Duarte TC, Mosca ERT, Pinheiro C de F, Marçola MA, De-Souza DA. Severe protein malnutrition in a morbidly obese patient after bariatric surgery. *Nutrition.* 2015 Mar 1;31(3):535–8.
125. Stein J, Stier C, Raab H, Weiner R. Review article: The nutritional and pharmacological consequences of obesity surgery. Vol. 40, *Alimentary Pharmacology and Therapeutics*. Blackwell Publishing Ltd; 2014. p. 582–609.
126. Jastrzebska-Mierzynska M, Ostrowska L, Hady HR, Dadan J. Dietary habits of obese patients qualified for bariatric procedures. *Rocz Panstw Zakl Hig.* 2014;65(1):41–7.
127. Handzlik-Orlik G, Holecki M, Orlik B, Wylelol M, Dulawa J. Nutrition management of the post-bariatric surgery patient. Vol. 30, *Nutrition in Clinical Practice*. SAGE Publications Inc.; 2015. p. 383–92.
128. Heber D, Greenway FL, Kaplan LM, Livingston E, Salvador J, Still C. Endocrine and nutritional management of the post-bariatric surgery patient: An endocrine society clinical practice guideline. Vol. 95, *Journal of Clinical Endocrinology and Metabolism*. Endocrine Society; 2010. p. 4823–43.
129. Moizé VL, Pi-Sunyer X, Mochari H, Vidal J. Nutritional pyramid for post-gastric bypass patients. Vol. 20, *Obesity Surgery*. *Obes Surg*; 2010. p. 1133–41.
130. Andreu A, Moizé V, Rodríguez L, Flores L, Vidal J. Protein intake, body composition, and protein status following bariatric surgery. *Obes Surg.* 2010 Nov;20(11):1509–15.
131. Steenackers N, Gesquiere I, Matthys C. The relevance of dietary protein after bariatric surgery: What do we know? Vol. 21, *Current Opinion in Clinical Nutrition and Metabolic Care*. Lippincott Williams and Wilkins; 2018. p. 58–63.
132. Davis JA, Saunders R. Impact of weight trajectory after bariatric surgery on co-morbidity evolution and burden. *BMC Heal Serv Res* 2020 201. 2020 Apr 3;20(1):1–10.
133. Oliveira Magro D, Geloneze B, Delfini R, Contini Pareja B, Callejas F, Carlos Pareja J. Long-term Weight Regain after Gastric Bypass: A 5-year Prospective Study. Springer. 2008 Jun;18(6):648–51.
134. Voorwinde V, Steenhuis IHM, Janssen IMC, Montpellier VM, van Stralen MM.

- Definitions of Long-Term Weight Regain and Their Associations with Clinical Outcomes. *Obes Surg.* 2020 Feb 1;30(2):527–36.
135. Courcoulas AP, King WC, Belle SH, Berk P, Flum DR, Garcia L, et al. Seven-year weight trajectories and health outcomes in the Longitudinal Assessment of Bariatric Surgery (LABS) study. *JAMA Surg.* 2018 May 1;153(5):427–34.
 136. King WC, Hinerman AS, Courcoulas AP. Weight regain after bariatric surgery: a systematic literature review and comparison across studies using a large reference sample. *Surg Obes Relat Dis.* 2020 Aug 1;16(8):1133–44.
 137. Karmali S, Brar B, Shi X, Sharma AM, De Gara C, Birch DW. Weight recidivism post-bariatric surgery: A systematic review. Vol. 23, *Obesity Surgery*. 2013. p. 1922–33.
 138. Thompson CC, Slattery J, Bundga ME, Lautz DB. Peroral endoscopic reduction of dilated gastrojejunal anastomosis after Roux-en-Y gastric bypass: A possible new option for patients with weight regain. *Surg Endosc Other Interv Tech.* 2006 Nov;20(11):1744–8.
 139. Odom J, Zalesin KC, Washington TL, Miller WW, Hakmeh B, Zaremba DL, et al. Behavioral predictors of weight regain after bariatric surgery. *Obes Surg.* 2010 Mar;20(3):349–56.
 140. Bastos ECL, Barbosa EMWG, Soriano GMS, Santos EA dos, Vasconcelos SML. Fatores determinantes do reganho ponderal no pós-operatório de cirurgia bariátrica. *ABCD Arq Bras Cir Dig (São Paulo)*. 2013 Jan 1;26(suppl 1):26–32.
 141. Miras AD, le Roux CW. Mechanisms underlying weight loss after bariatric surgery. *Nat Rev Gastroenterol Hepatol.* 2013 Oct 9;10(10):575–84.
 142. Nannipieri M, Baldi S, Mari A, Colligiani D, Guarino D, Camastra S, et al. Roux-en-Y gastric bypass and sleeve gastrectomy: Mechanisms of diabetes remission and role of gut hormones. *J Clin Endocrinol Metab.* 2013 Nov;98(11):4391–9.
 143. Arble DM, Sandoval DA, Seeley RJ. Mechanisms underlying weight loss and metabolic improvements in rodent models of bariatric surgery. Vol. 58, *Diabetologia*. Springer Verlag; 2015. p. 211–20.
 144. Pucci A, Batterham RL. Mechanisms underlying the weight loss effects of RYGB and SG: similar, yet different. Vol. 42, *Journal of Endocrinological Investigation*. Springer International Publishing; 2019. p. 117–28.
 145. Huang R, Ding X, Fu H, Cai Q. Potential mechanisms of sleeve gastrectomy for reducing weight and improving metabolism in patients with obesity. *Surg Obes Relat Dis.* 2019 Oct;15(10):1861–71.
 146. Al-Najim W, Docherty NG, Le Roux CW. Food intake and eating behavior after bariatric surgery. *Physiol Rev.* 2018 Jul 1;98(3):1113–41.
 147. Thirlby RC, Bahiraei F, Randall J, Drewnoski A. Effect of Roux-en-Y gastric bypass on satiety and food likes: the role of genetics. *J Gastrointest Surg.* 2006 Feb;10(2):270–7.
 148. Leahey TM, Bond DS, Raynor H, Roye D, Vithiananthan S, Ryder BA, et al. Effects of bariatric surgery on food cravings: do food cravings and the consumption of craved foods “normalize” after surgery? *Surg Obes Relat Dis.* 2012 Jan;8(1):84–91.
 149. Coluzzi I, Raparelli L, Guarnacci L, Paone E, Del Genio G, le Roux CW, et al. Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy. *Obes*

- Surg. 2016 Sep 7;26(9):2059–67.
150. Laurenius A, Larsson I, Melanson KJ, Lindroos AK, Lönroth H, Bosaeus I, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. *Eur J Clin Nutr.* 2013 Feb 9;67(2):168–73.
 151. Meek CL, Lewis HB, Reimann F, Gribble FM, Park AJ. The effect of bariatric surgery on gastrointestinal and pancreatic peptide hormones. Vol. 77, *Peptides*. Elsevier Inc.; 2016. p. 28–37.
 152. Batterham RL, Cowley MA, Small CJ, Herzog H, Cohen MA, Dakin CL, et al. Gut hormone PYY3-36 physiologically inhibits food intake. *Nature.* 2002 Aug 8;418(6898):650–4.
 153. Dailey MJ, Moran TH. Glucagon-like peptide 1 and appetite. Vol. 24, *Trends in Endocrinology and Metabolism*. NIH Public Access; 2013. p. 85–91.
 154. Shah M, Vella A. Effects of GLP-1 on appetite and weight. Vol. 15, *Reviews in Endocrine and Metabolic Disorders*. Kluwer Academic Publishers; 2014. p. 181–7.
 155. Crawley JN, Corwin RL. Biological actions of cholecystokinin. Vol. 15, *Peptides*. Elsevier; 1994. p. 731–55.
 156. Wren AM, Seal LJ, Cohen MA, Brynes AE, Frost GS, Murphy KG, et al. Ghrelin Enhances Appetite and Increases Food Intake in Humans. *J Clin Endocrinol Metab.* 2001 Dec 1;86(12):5992–5992.
 157. Kelesidis T, Kelesidis I, Chou S, Mantzoros CS. Narrative review: The role of leptin in human physiology: Emerging clinical applications. Vol. 152, *Annals of Internal Medicine*. American College of Physicians; 2010. p. 93–100.
 158. Izquierdo AG, Crujeiras AB, Casanueva FF, Carreira MC. Leptin, obesity, and leptin resistance: where are we 25 years later? Vol. 11, *Nutrients*. MDPI AG; 2019.
 159. Beckman LM, Beckman TR, Earthman CP. Changes in Gastrointestinal Hormones and Leptin after Roux-en-Y Gastric Bypass Procedure: A Review. *J Am Diet Assoc.* 2010 Apr;110(4):571–84.
 160. Ahmed K, Penney N, Darzi A, Purkayastha S. Taste Changes after Bariatric Surgery: a Systematic Review. *Obes Surg.* 2018 Oct;28(10):3321–32.
 161. Makaronidis JM, Neilson S, Cheung W-H, Tymoszuk U, Pucci A, Finer N, et al. Reported appetite, taste and smell changes following Roux-en-Y gastric bypass and sleeve gastrectomy: Effect of gender, type 2 diabetes and relationship to post-operative weight loss. *Appetite.* 2016 Dec;107:93–105.
 162. El Labban S, Safadi B, Olabi A. Effect of Roux-en-Y gastric bypass and sleeve gastrectomy on taste acuity and sweetness acceptability in postsurgical subjects. *Nutrition.* 2016;32(11):1299–302.
 163. Goldstone AP, Miras AD, Scholtz S, Jackson S, Neff KJ, Pénicaud L, et al. Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *J Clin Endocrinol Metab.* 2016 Feb 1;101(2):599–609.
 164. Faulconbridge LF, Ruparel K, Loughhead J, Allison KC, Hesson LA, Fabricatore AN, et al. Changes in neural responsivity to highly palatable foods following roux-en-Y gastric bypass, sleeve gastrectomy, or weight stability: An fMRI study. *Obesity.* 2016 May;24(5):1054–60.

165. Frank S, Veit R, Sauer H, Enck P, Friederich HC, Unholzer T, et al. Dopamine depletion reduces food-related reward activity independent of BMI. *Neuropsychopharmacology*. 2016 May 1;41(6):1551–9.
166. Zoon HFA, de Bruijn SEM, Jager G, Smeets PAM, de Graaf C, Janssen IMC, et al. Altered neural inhibition responses to food cues after Roux-en-Y Gastric Bypass. *Biol Psychol*. 2018 Sep;137:34–41.
167. Scholtz S, Miras AD, Chhina N, Prechtel CG, Sleeth ML, Daud NM, et al. Obese patients after gastric bypass surgery have lower brain-hedonic responses to food than after gastric banding. *Gut*. 2014 Jun;63(6):891–902.
168. Ochner CN, Kwok Y, Conceicao E, Pantazatos SP, Puma LM, Carnell S, et al. Selective reduction in neural responses to high calorie foods following gastric bypass surgery. *Ann Surg*. 2011 Mar;253(3):502–7.
169. Giel KE, Rieber N, Enck P, Friederich H-C, Meile T, Zipfel S, et al. Effects of laparoscopic sleeve gastrectomy on attentional processing of food-related information: evidence from eye-tracking. *Surg Obes Relat Dis*. 2014;10(2):277–82.
170. Holsen LM, Davidson P, Cerit H, Hye T, Moondra P, Haimovici F, et al. Neural predictors of 12-month weight loss outcomes following bariatric surgery. *Int J Obes (Lond)*. 2018;42(4):785–93.
171. Ochner CN, Laferrère B, Afifi L, Atalayer D, Geliebter A, Teixeira J. Neural responsivity to food cues in fasted and fed states pre and post gastric bypass surgery. *Neurosci Res*. 2012 Oct;74(2):138–43.
172. Miras AD, Jackson RN, Jackson SN, Goldstone AP, Olbers T, Hackenberg T, et al. Gastric bypass surgery for obesity decreases the reward value of a sweet-fat stimulus as assessed in a progressive ratio task. *Am J Clin Nutr*. 2012 Sep 1;96(3):467–73.
173. Olivo G, Zhou W, Sundbom M, Zhukovsky C, Hogenkamp P, Nikontovic L, et al. Resting-state brain connectivity changes in obese women after Roux-en-Y gastric bypass surgery: A longitudinal study. *Sci Rep*. 2017 Dec 26;7(1):6616.
174. Wang J-L, Yang Q, Hajnal A, Rogers AM. A pilot functional MRI study in Roux-en-Y gastric bypass patients to study alteration in taste functions after surgery. *Surg Endosc*. 2016;30(3):892–8.
175. Kenler HA, Brodin RE, Cody RP. Changes in eating behavior after horizontal gastroplasty and Roux-en-Y gastric bypass. *Am J Clin Nutr*. 1990 Jul 1;52(1):87–92.
176. Trostler, Mann, Zilberbush, Avinoach, Charuzi. Weight Loss and Food Intake 18 Months following Vertical Banded Gastroplasty or Gastric Bypass for Severe Obesity. *Obes Surg*. 1995 Feb 1;5(1):39–51.
177. Kittrell H, Graber W, Mariani E, Czaja K, Hajnal A, Di Lorenzo PM. Taste and odor preferences following Roux-en-Y surgery in humans. Covasa M, editor. *PLoS One*. 2018 Jul 5;13(7):e0199508.
178. Burge JC, Schaumburg JZ, Choban PS, DiSilvestro RA, Flancbaum L. Changes in patients' taste acuity after Roux-en-Y gastric bypass for clinically severe obesity. *J Am Diet Assoc*. 1995 Jun;95(6):666–70.
179. Gero D, Dib F, Ribeiro-Parenti L, Arapis K, Chosidow D, Marmuse J-P. Desire for Core Tastes Decreases After Sleeve Gastrectomy: a Single-Center Longitudinal Observational Study with 6-Month Follow-up. *Obes Surg*. 2017 Nov 30;27(11):2919–26.

180. Nielsen MS, Christensen BJ, Ritz C, Rasmussen S, Hansen TT, Bredie WLPP, et al. Roux-En-Y Gastric Bypass and Sleeve Gastrectomy Does Not Affect Food Preferences When Assessed by an Ad libitum Buffet Meal. *Obes Surg.* 2017 Oct 14;27(10):2599–605.
181. Blundell JE, Caudwell P, Gibbons C, Hopkins M, Naslund E, King N, et al. Role of resting metabolic rate and energy expenditure in hunger and appetite control: A new formulation. Vol. 5, DMM Disease Models and Mechanisms. *Dis Model Mech*; 2012. p. 608–13.
182. Finlayson G, Dalton M. Hedonics of Food Consumption: Are Food ‘Liking’ and ‘Wanting’ Viable Targets for Appetite Control in the Obese? *Curr Obes Rep.* 2012 Mar;1(1):42–9.

Chapter II. A systematic review of food preference modifications after bariatric surgery

Guyot E, Dougkas A, Bagot S, Nazare JA, Disse E & Iceta S. (Submitted).

Abstract

Introduction: Several studies that examined changes of food preferences following bariatric surgery reported inconsistent results. Given the plethora of existing methodologies to assess food preferences, the heterogeneity between study populations and the diversity of obesity surgery techniques, we aimed to synthesize evidence of the link between bariatric surgery and changes in food preferences, considering the method of assessment by a systematic and meta-analytical approach.

Materials and methods: For the systematic review, MEDLINE, Cochrane Library, Web of Science, Cinahl, PsychINFO, ProQuest and Open grey were searched incorporating two blocks of terms ('Intervention' and 'Food Preferences') by 2 independent authors using Covidence. Interventional or observational studies involving obese patients ($BMI \geq 35 \text{ kg.m}^{-2}$) with sleeve gastrectomy (SG) or Roux-en-Y Gastric Bypass (RYGB) and a control group (preoperative or a group not receiving bariatric surgery) were included. The main outcomes were the percentages of energy intake from protein, fat, and carbohydrate, the distribution and intakes of foods and the hedonic evaluation of foods. A meta-analysis was performed comparing the standardized daily mean percentage energy from proteins, carbohydrates and lipids between preoperative and postoperative patients at 1, 3, 6, 12 and 24 months. Pooled effects were calculated using random effects models with the Hedges'g estimator. Sub-group analysis was performed by type of surgery and method of assessment.

Results: Fifty-seven studies (46 prospective, 9 cross-sectional and 2 longitudinal retrospective) concerning 2271 patients with RYGB and 903 patients with SG met the inclusion criteria, of which 24 were eligible for meta-analysis. Overall, the studies were performed in 17 countries, the methods used to assess food preference were varied ($N=16$) and the time points for assessment ranged from 6 d to 10 yr. Despite a total reduction in macronutrient intakes, the meta-analysis revealed a postoperative increase in percentage energy from proteins at 12 mo (0.24, 95%CI: 0.03, 0.46, $\{I^2\}=73\%$), offset by a decrease in percentage energy from fat at 1 mo (-0.47, 95%CI: 0.86, 0.09, $\{I^2\}=72\%$), 6 mo (-0.32, 95%CI: -0.55, -0.09, $\{I^2\}=61\%$), 12 mo (-0.20, 95%CI: -0.32, -0.08, $\{I^2\}=18\%$) and 24 mo (-0.20, 95%CI: -0.31, 0.08, $\{I^2\}=0\%$). There was also a postoperative increased proportion of healthy foods in the patients' diets and decreased hedonic ratings for most of the food groups. These changes seem to progressively evolve towards what the patients consumed preoperatively.

Conclusion: This systematic review highlights the diversity of methods and study settings used to measure food preferences and showed that food preferences change following bariatric surgery, in terms of macronutrients, food selection and overall food appreciation up to 5 yr following bariatric surgery. Further long-term studies are needed, since the overall interpretation of the results is limited by the high heterogeneity estimated among the studies.

Keywords: Food preference; Food choices; Hedonic attitudes; Food reward; Bariatric surgery.

3.1 Introduction

Obesity is a major public health burden concerning more than 500 million people worldwide (1). Although lifestyle interventions are essential for preventing obesity, they have demonstrated little long-term benefit in patients with obesity (2). On the other hand, bariatric surgery induces 15 to 25% of total weight loss in a 20-year follow-up (2) and reduces obesity related comorbidities and mortality (2–4). As a result, it is increasingly applied and is now considered the most effective treatment for obesity (5).

The mechanisms by which bariatric surgery induces weight loss are not yet fully understood. However, studies have demonstrated that the volume ingested by the patients is reduced postoperatively (6), as is the total energy intake (6,7). Patients also experience reduced appetite (8). Especially, fasting hunger is reduced and satiety is prolonged (9). In addition, several studies have shown a better quality of postoperative nutritional intake (6,10). Notably, the contribution of fat in the total energy intake is reduced postoperatively and patients eat more low-energy dense foods (6,7,9,11–13).

Food intake is partly under the control of the reward system (tonsil, ventral tegmental area, hypothalamus, limbic system and pre-frontal cortex). This system assigns a hedonic value to food and generates motivation for food intake. Food reward has been shown to have two distinct components (14). The first component is ‘liking’ and is related to the pleasure and the sensory properties of foods. The second component is ‘wanting’, which is related to the motivation and is defined as an implicit drive to eat. Brain imaging studies showed decreased activation of the reward system after bariatric surgery (11,15,16). In particular, weaker activation of the brain regions related to the reward system was found in response to foods with high energy density (13,17–19) and to highly palatable foods (high in fat and / or sweet) (20–22). In addition, differences in activation of the reward system were observed between normal-weight subjects and subjects after bariatric surgery (23). The attribution of a hedonic value to food also involves the sensory system and in particular gustation and olfaction. Studies have looked at sensory alterations after bariatric surgery and have notably found that taste and odor preferences are altered (8,12) and that the threshold for detecting sour taste is increased (24). There was also a decrease in the appreciation of all basic tastes (sour, bitter, sweet, salty, umami), as early as 6 days after surgery, especially for fatty and sugary foods (25). Other results are however contradictory in showing no changes in sensory perceptions (24).

The attribution of a hedonic value to foods involves thoughts about foods and sensory appreciations of certain food attributes that determine food preferences and choices (26,27). Consistently, food preferences can be defined as the “degree of like or dislike for a food” (28) or by the “evaluative attitudes that people express toward foods” (29) and can thus be evaluated with hedonic scales (29). Food consumption is influenced by food preferences (30), which can also be viewed as a relative choice of one food over others. Along these lines, food preference can be measured with a forced choice paradigm, an estimation of the relative intakes using food frequency questionnaires, food recalls or food records, or directly with the help of an *ad libitum* buffet meal.

Several reviews dealt with changes in food preferences after bariatric surgery (31–36), from different perspectives and with rather consensual results. However, none have looked exhaustively at the literature, by exploring the results according to the types of outcomes (i.e., food preferences as relative intakes or hedonic measures) and considering other types of foods than highly palatable ones, which are usually those high in fat, sweet and / or salt. In addition, no meta-analysis was performed to pool the results.

This systematic review and meta-analysis aimed to synthesize the evidence for the link between bariatric surgery ((Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (SG)), and changes in food preferences. We tackled the subject using two different perspectives. Firstly, from a nutritional point of view, by considering food preferences as a relative choice between foods and secondly from a sensory and bio-psychological point of view by considering food preferences as choices related to the hedonics (i.e., including the evaluative attitudes that people express toward foods (29) and the measures of food reward components ‘liking’ and ‘wanting’ (37)).

3.2 Methods and procedures

2.2.1. Protocol and registration

This review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines (38) and has been registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD42020165801).

2.2.2. Literature search strategy

An electronic search was conducted using the following seven databases: MEDLINE, Cochrane Library, Web of Science, Cinahl, PsycINFO, ProQuest and Open Grey. Search included two themes using the Boolean operator 'AND', and was adapted for each aforementioned database. The first theme was 'bariatric surgery'. The second theme was 'food preference' with a focus on the following main conditions: quantitative measurement of consumption, frequency of consumption, hedonic evaluation, wanting or desire to eat measurement, evaluation of food choices or food preferences. The following is an example of the search syntax used for searching MEDLINE: (((("Bariatric surger*" or "Weight loss surger*" or "Obesity surger*" or "Metabolic surger*" or "Bariatric surgical procedure*" or "Bariatric procedure*" or "Bariatric operation*" or "Gastric bypass" or "Stomach bypass" or RYGB or RYGBP or "Sleeve gastrectomy" or "Gastric sleeve" or LSG) .ab,hw,kf,ti.) OR ("Bariatric Surgery"/ or "Gastric Bypass"/ or Gastrectomy/)) AND (((("Food preferenc*" or "Food choic*" or "Food reward" or "Reward system" or Liking or Wanting or "Food intake" or "Diet* record*" or "Diet* assessment*" or "Diet* survey*" or "Nutrition* record*" or "Nutrition* assessment*" or "Nutrition* survey*").ab,hw,kf,ti.) OR (Food preferences/)). The detailed search strategy is available as Appendix 2.A. Limits were set to include articles published in English after 1960, which corresponds to the decade when bariatric surgery was developed as a treatment for patients with severe obesity. The final search was performed on 1st June 2020.

2.2.3. Inclusion and exclusion criteria

All observational and interventional studies were considered if they involved adult patients with severe obesity (BMI \geq 35 kg.m⁻²) undergoing RYGB or SG. Studies had to compare pre- and post-operative measures of food preferences or to involve a control group of non-operated patients. Studies were excluded if they involved animals, children or adolescents. Results related to other types of surgeries (gastric band, omega-loop gastric bypass, biliopancreatic diversion with duodenal switch, etc.) were excluded.

2.2.4. Study selection and data extraction

All materials were retrieved and exported in Covidence systematic review software, (Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Duplicates were removed. Title and abstracts were screened independently by two reviewers

(E.G., and S.B.). Any disagreement between them was resolved by a third reviewer (S.I.). The full text of retained studies was accessed and further screened according to the eligibility criteria by the two reviewers. Any disagreement was resolved through discussion between the two reviewers. For each study, the following data were extracted: name of the first author, year of publication, country where the study took place, study design, number of participants, age, preoperative Body Mass Index (BMI) and BMI at the end of the follow-up or if not available any weight loss related outcome, method of assessment, and measurement times. In this review, food preference measures (i.e., method of assessment) were considered as a relative choice a) between different macronutrients (e.g., the percentage energy intake from macronutrients and the frequency of foods consumption); b) between different foods, or food groups; and c) as measures related to food reward (e.g., liking, wanting or desire to eat). A narrative synthesis of the findings from the including studies were performed.

2.2.5. *Quality assessment*

The quality of the included studies was assessed independently by two reviewers (E.G., and S.B.) using the ‘Quality assessment tool for quantitative studies’ developed by the Effective Public Health Practice Project (EPHPP) (39,40). This tool is recommended for quality assessment in systematic reviews, which include uncontrolled studies (41). For each study, selection bias, study design, confounders, blinding, data collection method and withdrawals-dropouts were rated as strong, moderate or weak. The overall methodological quality was then rated as strong if there were no weak rating sub-domains, moderate if there was one weak rating and weak if there were two or more weak ratings. Any inconsistencies were resolved by communication between the two authors. We presented the results using a summary bar plot weighted by the study size (42). Such bar plot represents the proportion of information with a given level of bias for each sub-domain of the quality assessment scale. We also used a traffic light plot to represent the risk of bias for each sub-domain of the scale for each study. Quality data processing was done using the software Excel (Microsoft Corporation, 2018. Microsoft Excel, Available at: <https://office.microsoft.com/excel>).

2.2.6. *Statistical analysis*

We performed meta-analyses comparing the daily mean percentage energy from proteins, carbohydrates and lipids between preoperative and postoperative time points. If the percentage energy from the macronutrients was not available, it was calculated based on the

quantity of macronutrients consumed and the total energy intake (4kcal/g for proteins, 4kcal/g for carbohydrates and 9kcal/g for lipids). When data were presented in graphs, we contacted the corresponding author to obtain the numerical data. When no response was received, we estimated the results using WebPlotDigitalizer (43). When the standard deviation (SD) was not available for either the amount consumed or the percentage of energy from the different macronutrients, it was calculated from the standard error of the mean (SEM) or the 95% confidence intervals (CI) (44). When results were available only for subgroups of patients (e.g., for women and men separately, or based on the type or the type of surgery), we combined the subgroups into a single group (44). Because our data were continuous, we used standardized mean differences (SMD) (45). As recommended for studies in the field of health sciences (46), we performed a random-effects-model to pool the effect size. Due to an important number of small size studies, we used the Hedges' *g* estimator (47,48). Hedges' *g* estimator can be interpreted similarly to Cohen's *d*: an effect size of 0.2 is considered as small, 0.5 is considered as medium, and 0.8 is considered as large (49). Data has been encoded on a positive effect size indicating that the proportion of the corresponding macronutrient was greater after bariatric surgery (or among postoperative participants than control) and a negative effect size indicating the opposite. A subgroup analysis was performed according to the type of surgery and the type of assessment method, if there were at least 3 studies per subgroup. We presented the results of the meta-analyses using forest plots. Heterogeneity was assessed using the I^2 statistics. I^2 statistic describes the percentage of variation across studies that is due to heterogeneity rather than chance. A percentage between 0%–40% represents a low heterogeneity; between 30%–60% a moderate heterogeneity; between 50%–90% a substantial heterogeneity and between 75%–100% a considerable heterogeneity (50,51). In case of high heterogeneity, we ran the meta-analyses excluding outliers (i.e., studies for which the confidence interval overlap with the confidence interval of the pooled effect) and we performed influence analyses with the Leave-One-Out method (52) looking at the impact of each study on the results. Publication bias was studied by visual inspection of the funnel plot and with Egger's tests of the intercept (53) to test for funnel plot asymmetry. In case of asymmetry, we performed Duval & Tweedie's trim-and-fill procedure (54), which imputes the missing studies (e.g., small studies with low effect sizes), to correct the funnel plot for asymmetry and to pool the effect size with the imputed studies. All the statistics were performed using the software R (R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical

Computing, Vienna, Austria. URL <https://www.R-project.org/>) and the R package ‘dmetar’ (55).

3.3 Results

2.3.1. Study selection

The numbers of studies assessed at the different stages of the study selection are presented in Figure 2.1. Overall, 57 studies were included in the systematic literature review. The reasons for exclusion are presented in Figure 2.1.

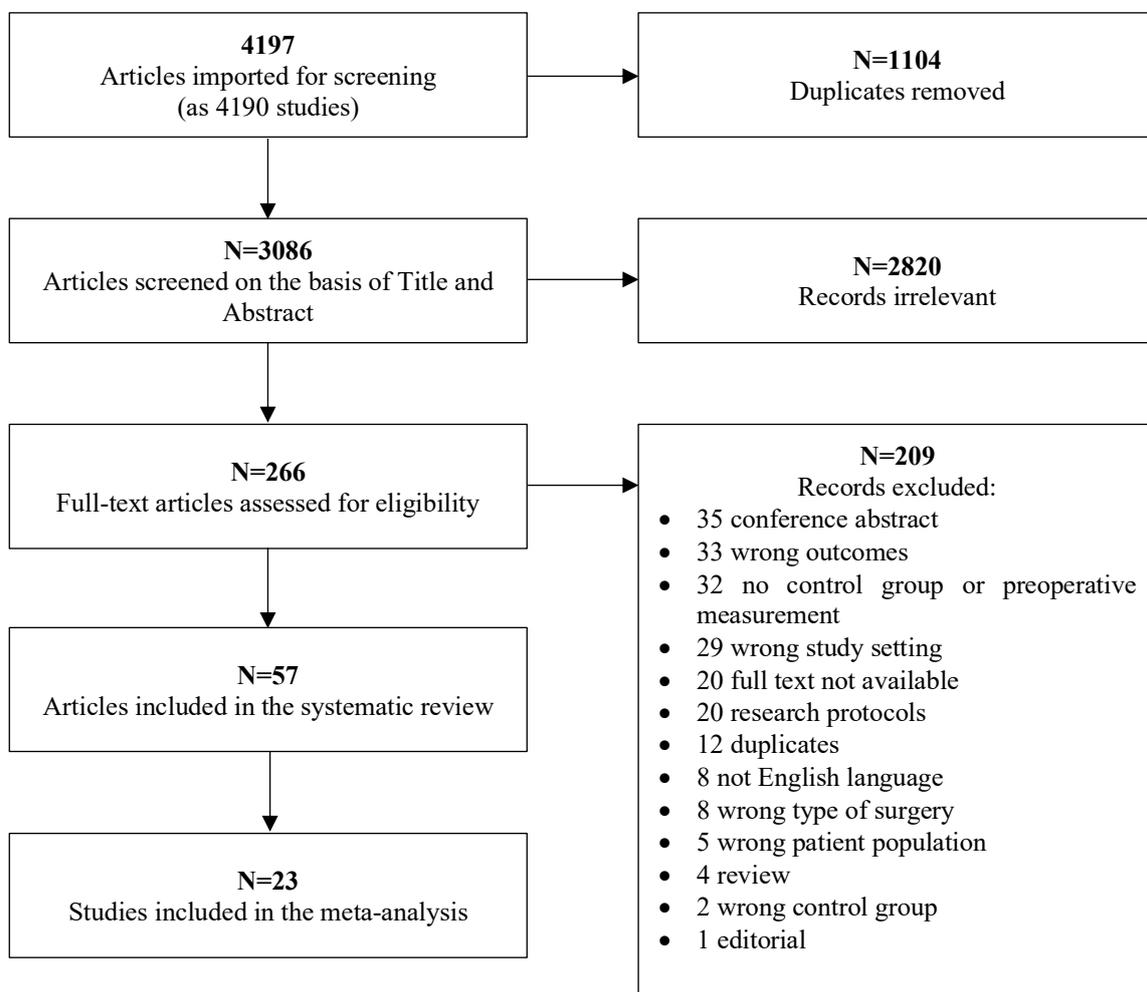


Figure 2.1. Study selection flow diagram.

Among the 36 studies, which assessed macronutrients intake, 13 studies were not included in the meta-analysis because i) the measurement times were not corresponding to our time points of interest (N=4); ii) the means and SDs were not available (N=5); iii) the preoperative measure of intake was under a very low calorie diet (N=2); iv) the result was based on one meal only, not on a daily intake (N=1); and v) the measure was the percentage of preoperative energy from macronutrients at the time of assessment (i.e., before the surgery) (N=1).

2.3.2. Studies and patients' characteristics

The details of the included studies are presented in Table 2.1. Forty-seven studies were prospective, 8 were cross-sectional and 2 were longitudinal retrospective. Fifty-one studies out of 57 were published since 2010, which corresponds to the increasing use of bariatric surgery as a treatment for obesity. The studies were carried out in 16 countries, of which the first 3 were the USA (N=13), Brazil (N=13), and France (N=5). This echoes with the world ranking of countries performing the most bariatric surgeries. The pooled population included in this systematic review was 2271 patients with a RYGB and 903 patients with a SG. Food preferences were assessed by 16 different methods, with the majority being based on food records (N=24), Food Frequency Questionnaires (FFQ) (N=12), and food recalls (N=11). The time points of assessment ranged from 6 days (d) to 10 years (yr), with the majority of measures being performed preoperatively (N=47), and at 1 (N=10), 3 (N=16), 6 (N=20), 12 (N=25) and 24 (N=8) months (mo) postoperatively.

Table 2.1. Characteristics of the studies included by study design.

Reference	Country	Study design	Number of participants	Overall age (yr)	Preoperative / Postoperative BMI (kg/m ²) or other weight loss outcomes	Method of assessment (unit)	Time points
Al Assal, 2020 (56)	Brazil	Prospective	RYGB: 25	45.80 ± 7.95	46.40 ± 5.48 / 32.70 ± 3.54	Food record - 7 d (daily intake)	Preop, 3 mo, 12 mo
Ammon, 2015 (57)	USA	Prospective	SG: 15	45 ± 10	44.85 ± 10.37 / EWL: 22.14 ± 10.33%	Food Preference Questionnaire with hedonic (liking) ratings - 72 items (9-points Likert scale)	Preop, 6 wk
Aron-Wisniewsky, 2016 (58)	France	Prospective	N total: 22 - RYGB: 14 AGB: 8	RYGB: 40.5 [31.0-45.0] ^s AGB: 40.5 [32.0-43.5]	RYGB: 46.3 [42.3-49.3] / 38.2 [35.2-40.4] AGB: 42.8 [42.4-43.8] / 39.1 [37.4-40.3]	Food record - 24 h (serving / d)	Preop, 1 mo, 3 mo
Bavaresco, 2010 (59)	Brazil	Prospective	RYGB: 48	41.9 ± 8.8	51.9 ± 7.8 / 33.6 ± 5.9	Food recall - 24 h (daily intake)	Preop, 1 mo, 3 mo, 6 mo, 8 mo, 12 mo
Brolin, 1994 (60)	USA	Prospective	N total: 138 - RYGB: 108 VBG: 30	RYGB: 38 ± 10 VBG: 39 ± 9	RYGB: 43 ± 4 / EWL: 72% VBG: 42 ± 4 / EWL: 53%	Food recall - 24 h (percentage of daily energy intake)	Preop, 6 mo, 12 mo, 18 mo, 24 mo, 36 mo
Bužga, 2014 (61)	Czech Republic	Prospective	SG: 37	43.5 ± 10.2	43.0 ± 4.9 / 31.9 ± 5.0	Food record - 3 d, FFQ	Preop, 6 mo
Carrasco, 2007 (62)	Chile	Prospective	RYGB: 38	36.3 ± 10.5	44.0 ± 4.5 / 31.6 ± 4.1	Food record - 3 d (daily intake)	Preop, 6 mo, 12 mo
Carrasco, 2012 (63)	Chile	Prospective	N total: 50 - R-RYGB: 26 NR-RYGB: 24	37.6 ± 10.2	43.8 ± 4.8 / EWL: 68.9 ± 12.8% R-RYGB: 42.3 ± 3.6 / EWL: 72.8 ± 12.0% NR-RYGB: 45.5 ± 5.4 / 64.6 ± 12.5%	FFQ - 24 items (frequency of consumption)	Preop, 6 mo, 12 mo
Casagrande, 2012 (64)	Brazil	Prospective	RYGB: 33	37.2 ± 9.6	44.4 ± 5.0 / 27.5 ± 4.5	Food record - 3 d FFQ (daily intake)	Preop, 12 mo

A systematic review of food preference modifications after bariatric surgery

Coluzzi, 2016 (6)	Italy	Prospective	SG: 30	35 (25-66)	43.9 (39.5-57.3) / 28.1 (22.2-41.2)	Food recall - 24 h (daily percentage of energy intakes and intakes)	Preop, 1 mo, 3 mo, 6 mo, 12 mo, 24 mo
Coupaye, 2020 (65)	France	Prospective	N total: 147 - NMV-SG: 108 MV-SG: 39	43.5 ± 10.4	44.5 ± 7.3 / TWL: 23.8 ± 10.3% NMV-SG: 44.4 ± 7.5 / TWL: 23 ± 10% MV-SG: 44.8 ± 6.9 / 26 ± 11	Food record - 4 d (daily intake)	Preop, 44 ± 17 mo
Custodio Afonso Rocha, 2012 (66)	Brazil	Prospective	RYGB: 22	37.91 ± 9.13	44.28 ± 5.45 / 38.23 ± 4.78	Food record - 3 d (daily intake)	Preop, 14 d, 28 d, 42 d, 56 d
da Silva, 2014 (67)	Brazil	Prospective	RYGB: 10	46.5 ± 6.6	47.5 ± 4.1 / -	Food recall - 24 h Food record - 7 d (daily intake)	Preop, 3 mo
Davies, 2020 (68)	New Zealand	Prospective	N total: 44 - Banded RYGB: 22 SG: 22	Banded RYGB: 48.5 ± 5.5 SG: 47.7 ± 6.9	Banded RYGB: 38.2 ± 5.7 / 27.5 ± 5.8 SG: 40.0 ± 5.9 / 30.4 ± 3.6	Food record - 5 d (daily intake)	Preop, 12 mo
Delin, 1997 (69)	Australia	Cross-sectional	N total: 81 - RYGB: 34 OB: 17 NW: 30	-	Current weight: RYGB: 71.42 ± 13.87 kg OB: 111.35 ± 15.79 kg NW: 60.04 ± 9.08 kg	FFQ - 37 items (frequency of consumption)	32 ± 11 mo
Ernst, 2009 (70)	Germany	Cross-sectional	N total: 211 - RYGB: 48 AGB: 73 OB: 45 NO: 45	41.9 ± 12.3	RYGB: 46.5 ± 4.8 / 29.4 ± 4.8 AGB: 44.6 ± 4.3 / 34.7 ± 4.3 OB: 45.4 ± 6.7 NO: 22.1 ± 2.0	FFQ - 24 items (frequency of consumption)	> 12 mo
Farias, 2020 (71)	Brazil	Prospective	RYGB: 32	40.06 ± 10.05	43.85 ± 1.12 / 26.45 ± 0.92	FFQ and NOVA classification (percentage of daily energy intake)	Preop, 6 mo, 24 mo
Faulconbridge, 2016 (11)	USA	Prospective	N total: 59 - RYGB: 22 SG: 18 OB: 19	37.9 ± 8.8	RYGB: 44.6 ± 4.3 / WL: 23.6 ± 1.4% SG: 43.9 ± 4.1 / WL: 21.3 ± 1.0% OB: 43.3 ± 4.4	Liking - 10 items (11 points Likert scale)	Preop, 6mo

Chapter II.

Frank, 2016 (72)	Germany	Cross-sectional	N total: 24 - RYGB: 12 OB: 12	50.4 ± 10.1	RYGB: 52.21 ± 1.90 / 35.71 ± 0.84 OB: 37.81 ± 1.38	Liking and wanting - 40 items (5-points Lickert scale) Desire to eat - Power of Food	7.73 ± 2.68 mo
Freeman, 2014 (73)	Australia	Cross-sectional	N total: 130 - RYGB: 41 SG: 62 AGB: 13 OB: 14	51.2 ± 14.8	RYGB: 42.4 ± 6.7 / 29.0 ± 4.7 SG: 43.2 ± 6 / 30.0 ± 6.6 AGB: 45.5 ± 7.7 / 36.4 ± 5.1 OB: 43.2 ± 11.8	Food recall - 24 h Qualitative Dietary Assessment form (serving sizes)	RYGB: 34.0 ± 12 mo SG: 26.5 ± 10 mo
Garla, 2019 (74)	Brazil	Prospective	RYGB: 20	46.9 ± 6.2	46.4 (37.1-57.5) / 32.4 (27.5-40.2)	Food record - 7 d and FFQ (weekly or daily intake)	Preop, 3 mo, 12 mo
Gero, 2017 (25)	France	Prospective	SG: 100	40.8 ± 12	42.46 ± 6.7 / TWL = 24 ± 6.2%	Food preference questionnaire / disgusting, appetizing - 10 items (5-point Likert scale)	Preop, 6 d, 6 mo
Giusti, 2016 (75)	Switzerland	Prospective	RYGB: 16	39.4 ± 2.4	44.1 ± 1.6 / WL: 39.7 ± 1.0 kg	Food records - 4 and 7 d (daily intake)	Preop, 1 mo, 3 mo, 6 mo, 12 mo, 36 mo
Hubert, 2019 (76)	USA	Cross-sectional	N total: 97 - RYGB: 24 SG: 24 OB: 49	47.1 ± 11.2	RYGB and SG: 47.0 ± 11.1 / 33.8 ± 9.7 OB: 45.7 ± 8.4	Liking survey - 100 items and dietary quality index (scale from -100 to 100)	12 mo
Johnson, 2013 (77)	Norway	Prospective	N total: 139 - RYGB: 76 ILI: 63	44.4 ± 11.2	RYGB: 46.2 ± 4.9 / WL: 30% ILI: 42.6 ± 5.0 / WL: 8%	FFQ - 180 items (daily intake)	Preop, 12 mo
Kenler, 1990 (78)	USA	Prospective	N total: 104 - RYGB: 51 HGP: 53	RYGB: 38 ± 9 HGP: 40 ± 11	RYGB: 50.7 ± 7.5 / WL: 43.8% HGP: 50.7 ± 7.5 / WL: 29.9%	Food recall - 24 h (percentage of daily energy intake)	Preop, 6 mo, 12 mo, 18 mo, 24 mo
Kittrell, 2018 (12)	USA	Cross-sectional	N total: 195 - RYGB: 141 OB: 54	47.2 ± 12.0	RYGB: 48.3 ± 10.7 / 35.7 ± 10.7 OB: 47.9 ± 8.1	Questionnaire - 15 food related pictures and 4 odor related pictures (preference rating from 0=high to 9=low) (Self-Assessment Manikin)	35.7 ± 3.1 mo
Kvehaugen, 2018 (79)	Norway	Prospective	N total: 54 -	45.7 ± 7.74	41.6 ± 3.47 / 29.8 ± 3.69	FFQ	Preop, 6 mo

A systematic review of food preference modifications after bariatric surgery

			RYGB: 43 SG: 11			(percentage of daily energy intake or intake)	
Laurenius, 2013 (7)	Sweden	Prospective	RYGB: 43	43 ± 10	44.5 ± 4.9 / WL: 31.8 ± 9.3%	SOS study dietary questionnaire - 51 questions (percentage of daily energy intake)	Preop, 6 wk, 12 mo, 24 mo
Lopes Pinto, 2019 (80)	Brazil	Prospective	RYGB: 58	39.34 ± 9.38	43.0 ± 5.7 / 27.6 ± 5.4	Food record - 3 d and NOVA classification (daily intake)	Preop, 3 mo, 12 mo
Miras, 2012 (22)	United Kingdom	Prospective	N total: 22 - RYGB: 11 NW: 11	41.3 ± 10.1	RYGB: 49.3 ± 5.0 / 39.5 ± 3.9 NW: 22.7 ± 2.7	Food reward - Progressive ratio task	Preop, 8 wk
Moizé, 2013 (81)	Spain	Prospective	N total: 355 - RYGB: 294 SG: 61	45.4 ± 10.8	RYGB: 47.4 ± 6.0 / EWL: 68.8% SG: 51.6 ± 6.7 / EWL: 65.2%	Food record - 3 d and Food recall - 24 h (percentage of daily energy intake)	Preop, 6 mo, 12 mo, 24 mo, 48 mo, 60 mo
Molin Netto, 2017 (10)	Brazil	Prospective	RYGB: 41	39.4 ± 10.9	44.62 ± 6.32 / 31.66 ± 5.66	FFQ (percentage of patients consuming ≥ 4 d/wk)	Preop, 6 mo
Murphy, 2017 (82)	New Zealand	Prospective	N total: 14 - RYGB: 7 SG: 7	48.5 ± 5.9	RYGB: 38.4 ± 5.2 / 28.0 ± 5.2 SG: 36.9 ± 5.1 / 29.3 ± 2.4	Food record - 3 d (daily intake)	Preop, 12 mo
Nielsen, 2017 (83)	Denmark	Prospective	N total: 39 - RYGB: 29 SG: 10	40.3 ± 9.2	45.0 ± 6.8 / BMI loss: 11.7 ± 0.6	Ad libitum buffet meal (percentage of energy intake during the buffet meal)	Preop, 6 mo, 18 mo
Nielsen, 2019 (84)	Denmark	Prospective	N total: 29 - RYGB: 21 SG: 8	39.3 ± 10.3	RYGB: 47.9 ± 6.5 / 29.8 ± 5.7 SG: 43.5 ± 4.6 / 33.6 ± 3.9	Hedonic rating - 4 items (9-point hedonic scale)	-3 mo (before WL), -2 wk (preop), 6 wk, 6 mo, 18 mo
Nonino, 2019 (85)	Brazil	Longitudinal retrospective	RYGB: 72	44.4 ± 10.4	50.5 ± 8.0 / 36.3 ± 17.0	Food recall - 24 h (daily intake)	Preop, 12 mo, 24 mo, 36 mo, 48 mo, 60 mo, 120 mo
Ochner, 2011 (18)	USA	Prospective	RYGB: 10	35 ± 9	45 ± 5	Desire to eat (scale from 0 to 100)	Preop, 1 mo
Ochner, 2012 (86)	USA	Prospective	RYGB: 14	36 ± 10	45.5 ± 4.4 / 39.8 ± 3.7	Liking and desire to eat (scale from 0 to 100)	Preop, 1 mo

Chapter II.

Odstrcil, 2010 (87)	USA	Prospective	RYGB: 9	50.9 ± 8.7	57.4 ± 6.3 / 36.8 ± 5.1	Food record - 7 and 10 d (percentage of daily energy intake and intake)	Preop, 5 mo, 14 mo
Primeaux, 2015 (88)	USA	Prospective	N total: 18 - RYGB: 10 SG: 8	45.1 ± 12.7	RYGB: 51.3 ± 11.1 / 48.1 ± 11.7 SG: 53.0 ± 8.2 / 49.0 ± 7.4	Geiselman Food Preference Questionnaire - 72 items - Dislike / like (9-point Likert scale)	Preop, 49.8 ± 4.6 d (RYGB) or 60.0 ± 6.9 d (SG)
Robinson, 2019 (89)	USA	Prospective	SG Insulin resistant: 26 SG Insulin sensitive: 13	43.8 ± 9.7	46.2 ± 7.2 / EWL: 10.2 ± 5.0%	Food record - 3 d (percentage of daily energy intake)	-2 wk (preop), operative day, 6 wk
Rosa, 2011 (90)	Brazil	Prospective	RYGB: 9	41 ± 12	51 ± 9 / 43 ± 9	Food record - 3 d (percentage of daily energy intake and intake)	Preop, 3 mo
Ruiz-Lozano, 2016 (91)	Spain	Prospective	N total: 270 - RYGB: 203 SG: 67	52 ± 11	46.5 ± 6.0 / -	Food record - 4 d (percentage of daily energy intake and intake)	Preop, 18 to 24 mo, 60 mo
Ruiz-Tovar, 2018 (92)	Spain	Prospective	SG: 93	45.7 ± 10.8	46.4 ± 7.9 / 27.9 ± 5.6	Alimentary Frequency Questionnaire 1991-2002 (frequency of consumption)	Preop, 12 mo
Sanmiguel, 2017 (93)	USA	Prospective	SG: 8	39.5 ± 8.7	43.4 ± 6.0 / 38.8 ± 6.3	Desire to eat (scale from 0 to 100)	Preop, 1 mo
Scholtz, 2014 (17)	United Kingdom	Cross-sectional	N total: 83 - RYGB: 30 AGB: 28 OB: 25	RYGB: 44.5 ± 6.7 AGB: 42.5 [32.5 - 48.0] OB: 41.0 ± 12.6	RYGB: 47.6 ± 8.1 / 34.4 ± 6.1 AGB: 46.0 [42.2-51.5] / 35.6 [32.4-38.2] OB: 39.5 ± 11.0	Food appeal - 6 items (100 mm VAS)	8.1 (2.6-26.2) mo
Schultes, 2010 (94)	Switzerland	Cross-sectional	N total: 369 - RYGB: 136 OB: 123 NO: 110	41.1 ± 11.1	RYGB: 47.0 ± 5.7 / 29.5 ± 4.7 OB: 45.1 ± 6.3 NO: 22.4 ± 2.1	Desire to eat - Power of Food Scale	22.5 ± 17.2 mo

A systematic review of food preference modifications after bariatric surgery

Sherf Dagan, 2017 (95)	Israel	Prospective	SG: 77	43.1 ± 9.3	42.1 ± 4.8 / 29.1 ± 3.4	Food record - 3d (percentage of daily energy intake and intake)	Preop, 3 mo, 6 mo, 12 mo
Søvik, 2013 (96)	Norway	Prospective	N total: 60 - RYGB: 31 DS: 29	35.6 ± 6.2	RYGB: 54.8 ± 3.24 / BMI loss: 18 ± 6.7 DS: 55.2 ± 3.49 / BMI loss: 24.9 ± 5.0	Food record - 4d (daily intake)	Preop, 12 mo, 24 mo
Thirlby, 2006 (9)	USA	Prospective	RYGB: 76 (43 respondents for this outcome)	43 (18-67)*	52 (38-76)* / 36.4 ± 1.0	Liking high-fat vs. low-fat potato chips (9-point Likert scale)	Preop, 32 mo
Trostler, 1995 (97)	Israel	Prospective	N total: 57 - RYGB: 19 VBG: 36	35.9 ± 11.2	RYGB: 43.0 ± 16.4 / 25 ± 5.7 VBG: 42.6 ± 39.3 / 28.8 ± 29.4	Food record - 7d, food recall - 24 h, FFQ	Preop, 1 mo, 2 mo, 3 mo, 4 mo, 5 mo, 6 mo, 9 mo, 12 mo, 15 mo
Ullrich, 2013 (98)	Switzerland	Prospective	RYGB: 44	-	47.3 ± 7.3 / 29.1 ± 4.0	FFQ - 24 items (frequency of consumption)	Preop, 16 mo
Verger, 2016 (99)	France	Prospective	N total: 52 - RYGB: 22 SG: 30	42.1 ± 9.6	RYGB: 45.5 ± 5.6 / 30.6 ± 4.3 SG: 43.2 ± 6.4 / 38.5 ± 8.8	Food record - 3d (serving per day)	Preop, 3 mo, 12 mo
Vieira, 2019 (100)	Brazil	Prospective	N total: 60 - RYGB SW: 20 RYGB WR: 20 OB: 20	39.9 ± 9.3	RYGB SW: 27.1 ± 4.0 RYGB WR: 31.0 ± 4.8 OB: 42.2 ± 3.3	Food recall - 24 h and food record - 2 d (daily intake)	RYGB SW: 52.3 ± 33.0 mo RYGB WR: 81.9 ± 36.6 mo
Vinolas, 2019 (101)	France	Prospective	N total: 57 - RYGB: 28 SG: 29	44.1 ± 10.1	RYGB: 46.8 ± 6.9 / WL: 29.8% SG: 44.1 ± 9.4 / WL: 27.6%	Food record - 7 d (percentage of energy intake)	Preop, 1 mo, 3 mo, 6 mo, 12 mo
Zaparolli, 2018 (102)	Brazil	Longitudinal retrospective	RYGB: 106	48 (20-64)	39.6 (32.8-67.8) / 26.8 (19.0-48.5)	Food recall - 24 h (prevalence of consumption)	Preop, 3 mo, 6 mo, 12 mo

Abbreviations. AGB: adjustable gastric banding. BMI: body mass index. DS: duodenal switch. EWL: excess weight loss. FFQ: Food Frequency Questionnaire. HGP: horizontal gastroplasty. ILI: subjects with obesity with a lifestyle intervention. MV: with multivitamin supplement. NMV: without multivitamin supplement. NO: subjects without obesity. NR-RYGB: RYGB without resected stomach. NW: normal-weight subjects. OB: subjects with obesity. R-RYGB: RYGB with resected stomach. RYGB: Roux-en-Y gastric bypass. SG: sleeve gastrectomy. SW: stable weight. TWL: total weight loss. VBG: vertical banded gastroplasty. WL: weight loss. WR: weight regain.

Data are presented as mean ± SD, *mean (range), \$median (range) and median [interquartile range]. Weight loss outcomes are indicated in kg.m⁻², unless indicated otherwise.

2.3.3. *Relative choice between macronutrients, foods and food groups*

Relative choice between macronutrients

In total, we performed 15 meta-analyses to study the mean percentage of energy from proteins, carbohydrates and lipids between preoperative and postoperative patients at 1, 3, 6, 12 and 24 mo. Figure 2.2 summarizes the pool effect sizes obtained for each meta-analysis. The forest plots representing the pool effect size for each meta-analysis are available in Appendix 2.B.

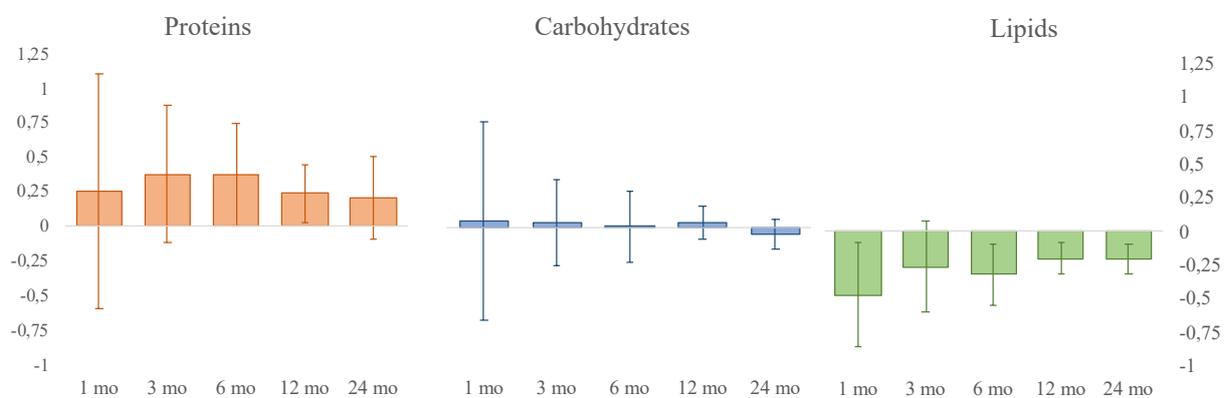


Figure 2.2. Pooled effect sizes for the weighted mean differences, and 95% confidence intervals (CI), in total energy intake from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.

Overall, the meta-analyses revealed a postoperative increase in percentage energy from proteins at 12 mo (0.24, 95%CI: 0.03, 0.46, $\{I^2\}=73\%$), offset by a decrease in percentage energy from fat at 1 mo (-0.47, 95%CI: 0.86, 0.09, $\{I^2\}=72\%$), 6 mo (-0.32, 95%CI: -0.55, -0.09, $\{I^2\}=61\%$), 12 mo (-0.20, 95%CI: -0.32, -0.08, $\{I^2\}=18\%$) and 24 mo (-0.20, 95%CI: -0.31, 0.08, $\{I^2\}=0\%$). There was no postoperative modification of the percentage of energy intake coming from carbohydrates.

Given the substantial heterogeneity found in some effect sizes, we searched for outliers. The exclusion of outliers decreased the heterogeneity, but it did not affect the significance of the effect sizes. Especially, after excluding the study of Bavaresco et al. 2010 (59), the pooled effect size for the weighted mean differences in total energy intake from proteins between preoperative and 12 mo was 0.30, (95%CI: 0.09, 0.50, $\{I^2\}=68\%$). It was -0.17, (95%CI: -0.27, -0.06, $\{I^2\}=0\%$) for the weighted mean differences in energy intake coming from lipids between preoperative and 12 mo after excluding the study of Molin Netto et al. 2017 (10).

Given the small number of studies involving patients undergoing sleeve gastrectomy (N=2 out of 23 studies) and that only one study involved both SG and RYGB patients, a subgroup analysis by type of surgery was not possible. However, we performed a subgroup analysis by method of assessment for the weighted mean differences in total energy intake from proteins and carbohydrates between preoperative and 3 mo. Overall, there was no difference between the food recall (0.63, 95%CI: -0.60, 1.87, $\{I^2\}=96%$, 0.21, 95%CI: -0.54, 0.97, $\{I^2\}=85%$ for proteins and carbohydrates respectively) and food records (0.27, 95%CI: -0.13, 0.67, $\{I^2\}=27%$ and -0.10, 95%CI: -0.37, 0.17, $\{I^2\}=39%$ for proteins and carbohydrates respectively). However, it should be noted that the heterogeneity was lower when food records compared to food recalls were used.

Relative choice between foods or food categories

Table 2.2 summarizes the modifications of the relative choices between foods or food categories after bariatric surgery. A detailed table showing the results for each study is available in Appendix 2.C. There was a postoperative decrease in preference for red meat early after bariatric surgery, which persisted up to 1 yr postoperatively (92,97). It was also the case for other of proteins, such as hot dog, deli meat products, or hamburger (10,92). However, preference for other types of meat did not seem to be impacted by bariatric surgery (70,73,75,98), especially white meat (92) and ham (7,10,98). Two studies even showed an increase in preference for poultry in the longer term after bariatric surgery (70,98). Generally, the results related to fish and eggs were less consistent. For instance, studies showed a decreased preference (58,74), an increased preference (10,61,70,98) or a similar food preference (75,77,92,99) for fish after compared to before bariatric surgery. There was an increased preference for eggs (97) in the first postoperative period, however whether this is maintained up to 6 mo postoperatively remains less consensual (7,70,92,98,99). Concerning dairy products, the results are heterogeneous (58,73,75,77,92,99). However looking at specific types of dairy products, there was a decreased preference for high fat dairy products (e.g., whole milk, sundae, ice cream, cheese, ricotta cheese) (10,60,69,78), while there was an increased preference for the low fat dairy products (e.g., low fat milk, yogurt) in the first postoperative months (10,97). The fruit and vegetable categories are also very broad food categories, which is reflected by conflicting results concerning food preference modifications after bariatric surgery (7,10,58,61,73–75,77,92,97,99). Interestingly, the preference for fresh fruits did not seem to be altered postoperatively, while the preference for fruits with added fat and sugar (i.e., baked and

fried bananas, fruit salad) was decreased (10). Regarding vegetables, there was an increased preference for cooked vegetables (70,98), while the preference for raw vegetables remained stable postoperatively (70,98). One study explored food preference for cooked beans, green peas and lentils and showed a decreased preference 6 mo after bariatric surgery. Most of the studies found a lower postoperative preference for starchy foods (10,58,61,69,70,73,77,92,97–99), yet there were some with no postoperative modification (7,61,70,92,98), especially after 12 mo postoperatively. This trend was also found for drinks, miscellaneous (e.g., mayonnaise, soybean oil, etc.) and sweets.

Overall, when looking at broad food categories, the results are often conflicting between the studies. However, considering specific foods, there were some trends toward a higher preference for healthier food products to the detriment of unhealthy products (i.e., foods high in sugar, fat, salt and energy density (103)) in the first 6 to 12 months after bariatric surgery. The improvement in the quality of the diet towards healthier products has also been explored using the NOVA food classification (104) assigning foods into four categories according to their degree of processing. The higher the food processing, the less healthy it is considered. These studies highlighted a decreased intake per day of all food categories, but a slight increase in the contribution of the unprocessed or minimally processed foods in total energy intake (71,80).

Table 2.2. Relative choices between foods or food categories in comparison with preoperative measures (prospective studies, N=19) or with measures on control groups of patients with obesity (cross-sectional studies, N=3).

Items	Time point				
	1 month (3 studies)	3 months (5 studies)	6 months (10 studies)	12 months (13 studies)	>12 months (11 studies)
Meats	- (58,75)	= (75)	= (75)	= (75)	= (59*,62*,64,87)
Red meat	- (97)	- (97)	- (97)	- (92,97)	- (97)
White meat	N/A	N/A	N/A	= (92)	N/A
Fatty meat	N/A	N/A	- (61)	N/A	N/A
Smoked meat products (high fat contents)	N/A	N/A	- (61)	- (61)	N/A
Chicken or beef fried pastry	N/A	N/A	- (10)	N/A	N/A
Chicken breast (cooked, shredded)	N/A	N/A	- (10)	N/A	N/A
Poultry	N/A	N/A	N/A	N/A	+ (59*,87)
Ham	N/A	N/A	= (10)	= (7)	= (7,98)
Hot dog, frankfurter	N/A	N/A	- (10)	N/A	N/A
Sausage	N/A	N/A	- (10)	N/A	= (59*,87)
Deli meat product	N/A	N/A	N/A	- (92)	N/A
Hamburger	N/A	N/A	- (10)	N/A	N/A
Steak	N/A	N/A	N/A	N/A	- (58*)
Lean beef	N/A	N/A	- (10)	N/A	N/A
Meat Alternatives	N/A	N/A	N/A	N/A	= (62*)
Fish	- (58)= (75)	- (58,74)= (75)	+ (10,61)= (75)	- (74)= (64,66 [§] ,81)	= (75,99) + (59*,87)
Fried fish, shellfish	N/A	N/A	N/A	- (92)	N/A
Eggs	+ (97)	+ (97)	+ (97)	= (7,92)	= (7,99) + (59*,87)
Pizza	N/A	N/A	- (10)	N/A	N/A
Dairy foods	= (58)	- (75)= (58)	- (75)	- (75,92)= (66 [§] ,88)	= (62*,64)
Milk	N/A	N/A	- (67 [#])	- (49,67 [#]) = (7)	- (49,58*,67 [#]) *
Low fat (1-2%) milk	+ (97)	+ (97)	= (10)	N/A	N/A
Whole milk	N/A	N/A	- (10)	N/A	N/A
Soured milk	N/A	N/A	N/A	N/A	= (59*,87)
Yogurt	N/A	N/A	+ (10)	- (66 [§])	= (59*,87)
Ice cream	N/A	N/A	- (10,49,67 [#])	- (50,67 [#])	- (49,58*,67 [#])
Sundae	N/A	N/A	- (10)	N/A	N/A
Cheese	- (75)	- (75)	= (75)	= (7,75)	= (7,75)
Ricotta cheese	N/A	N/A	- (10)	N/A	= (59*)
Curd cheese	N/A	N/A	N/A	N/A	= (59*,87)
Buttermilk	N/A	N/A	N/A	N/A	= (59*,87)
Fruits	- (58)	= (58)	- (10)	= (66 [§] ,81)	= (62*,88) + (7)
Fresh fruits	N/A	N/A	N/A	N/A	= (59*,87)
Bananas (baked, fried)	N/A	N/A	- (10)	N/A	N/A
Fruit salad	N/A	N/A	- (10)	N/A	N/A
Vegetables	- (58,97)	= (58,75)	= (10,61,74)	- (66 [§]) = (61,75) + (92)	= (62*,64,88)
Cooked vegetables	N/A	N/A	N/A	N/A	+ (59*,87)

Chapter II.

Raw vegetables	N/A	N/A	N/A	N/A	= (59*,87)	
Salad	N/A	N/A	N/A	N/A	= (59*,87)	
Beans, green peas, lentils (cooked)	N/A	N/A	- (10)	N/A	N/A	
Cereals	N/A	N/A	N/A	= (7)	- (58*,62*)	= (7,59*,87)
Whole grain	N/A	N/A	N/A	- (66 ^{\$})	N/A	
Breads	N/A	N/A	N/A	= (92)	- (62*)	= (59*,87)
White flour baked goods	N/A	N/A	- (61)	= (61)	N/A	
White bread and toast	N/A	N/A	N/A	N/A	- (59*)	
Whole grain breads	N/A	N/A	N/A	N/A	- (59*)	
Bread dumplings	N/A	N/A	- (61)	N/A	N/A	
Starchy food	- (58,97)	N/A	N/A	- (99)	N/A	
Pastry	N/A	N/A	= (61)	= (61)	N/A	
Cake biscuits, cookies	N/A	N/A	N/A	= (7)	- (98)	= (7)
Potato chips	N/A	N/A	- (10)	N/A	- (58*)	= (59*)
French fried potatoes	N/A	N/A	- (10)	- (92)	N/A	
Finger foods (deep fried pastry)	N/A	N/A	- (10)	N/A	N/A	
Potatoes	N/A	N/A	N/A	N/A	= (59*)	+ (98)
Salted snacks	N/A	N/A	N/A	N/A	= (59*,87)	
Rice	N/A	N/A	= (61)	- (92)	= (61)	= (59*,87)
Pasta	N/A	N/A	N/A	- (92)	= (59*,87)	
Drinks	N/A	N/A	N/A	N/A	N/A	
Water	N/A	N/A	- (79)	N/A	N/A	
High calorie liquids	N/A	N/A	- (67 [#])	- (49,67 [#])	- (49,67 [#])	
Soft beverages	N/A	N/A	- (10,102)	- (7,92,102)	- (98)	= (7,59*)
Fresh juice	N/A	N/A	= (10)	N/A	N/A	
Fruit juice	N/A	N/A	+ (10)	N/A	- (58*,87)	= (59*)
Artificial sugar-sweetened juice	N/A	N/A	= (10)	N/A	N/A	
Soft drinks, soda, fizzy drinks	N/A	N/A	- (10,60)	- (60)	- (49,58*,59*)	= (98)
Diet soft drink	N/A	N/A	N/A	N/A	= (98)	
Alcoholic beverages	N/A	N/A	- (102)	- (102)	= (7)	= (7)
Beer	N/A	N/A	= (61)	- (92)	= (61)	n/a
Wine	N/A	N/A	N/A	= (92)	N/A	
Distillates	N/A	N/A	= (61)	- (61)	N/A	
Miscellaneous	N/A	N/A	N/A	N/A	N/A	
Polyunsaturated fatty acids	N/A	- (74)	N/A	- (74)	N/A	
Mayonnaise	N/A	N/A	- (10)	N/A	N/A	
Margarine	N/A	N/A	= (10)	N/A	N/A	
Soybean oil	N/A	- (74)	N/A	- (74)	*N/A	
Nuts	N/A	N/A	N/A	- (92)	= (66 ^{\$})	= (59*)
Sweets	N/A	N/A	- (49,67 [#]) = (105)	- (49,67 [#] ,81)	- (49,67 [#])	= (59*,87,94)
Sugar	N/A	N/A	- (79) = (10)	N/A	n/a	
Non liquid sweets	N/A	N/A	- (60)	- (49,67 [#])	- (49,67 [#])	
Dessert	N/A	N/A	N/A	= (7)	- (7)	
Chocolate	N/A	N/A	- (10)	- (7)	- (59*,87)	= (7)
Candy	N/A	N/A	= (61)	- (7)	= (61)	= (7,59*)

A systematic review of food preference modifications after bariatric surgery

Guava jam, Dulce de leche	N/A	N/A	- (10)	N/A	N/A
Cooked meals	N/A	N/A	N/A	- (7)	- (7)
Light meals	N/A	N/A	N/A	= (7)	= (7)
Extras	N/A	N/A	N/A	N/A	- (62*)
Processed foods	N/A	- (80)	N/A	- (80,92)	N/A
Unprocessed or minimally processed foods	N/A	- (80)	N/A	- (80)	N/A
Ultra-processed foods	N/A	- (80)	N/A	- (80)	N/A
Processed culinary ingredients	N/A	- (80)	N/A	N/A	N/A
Fibers	N/A	N/A	- (79)	= (71 [#])	N/A
High fat sweet	N/A	N/A	= (105)	N/A	= (83)
High fat savory	N/A	N/A	= (105)	N/A	= (83)
Low fat sweet	N/A	N/A	= (105)	N/A	= (83)
Low fat savory	N/A	N/A	= (105)	N/A	= (83)
Savory	N/A	N/A	= (105)	N/A	= (83)
High fat	N/A	N/A	= (105)	N/A	= (83)
Low fat	N/A	N/A	= (105)	N/A	= (83)
Saturated fat	N/A	N/A	N/A	= (71 [#])	N/A
High energy density	N/A	N/A	N/A	= (7)	= (7)
Low and medium energy density	N/A	N/A	N/A	= (7)	= (7)
Very low energy density	N/A	N/A	N/A	+ (7)	= (7)

The signs – (decrease), + (increase) and = (null) indicate the direction of modification in food preferences reported as frequency of consumption, intake per day, serving per day, serving sizes, percentage of energy intake, or percentage of patients consuming those products (see Table 1 for more information on the assessment method and unit used by the authors). Significance was considered for a p-value < 0.05.

N/A indicates that the results were not assessed by the authors or not reported in the papers.

* Cross-sectional study (results were compared to a control group of patients with obesity).

[§] The control group was patients with obesity with an intensive lifestyle intervention.

[#] Preoperative measures were under very low-calorie diet.

2.3.4. Choices related to hedonics

Table 2.3 shows the results of the changes in the hedonics of foods after bariatric surgery. A detailed table of the results for each study is provided in Appendix 2.C. Overall, studies examined some food categories with certain nutritional (e.g., high in protein, high in fat, etc.) or sensory (e.g., sweet, salty, etc.) properties. They used food preference questionnaires, hedonic scales, the Power of Food Scale and progressive ratio task.

Considering food preferences in the early first months after bariatric surgery, we found inconsistencies between the studies of Ammon et al. (57) and Primeaux et al (88). These studies showed respectively no alteration in food preferences (57) and a postoperative decreased preference for foods high in sugar, high in complex carbohydrate, high in fat, low in fat, high in fat / high in complex carbohydrates and low in fat / high in complex carbohydrates (88).

However, both found that preference for foods high in proteins remain unchanged after bariatric surgery, as well as for foods low in fat / high in sugar. Interestingly, the preference for foods high in fat / high in sugar was diminished in the first postoperative months in both studies. No long term postoperative changes in preference for foods rich in protein was shown in a cross-sectional study by Kittrel et al., who found that preferences for steak and chicken were not significantly different between patients with RYGB and obesity (12).

Several studies explored food preference for specific tastes (i.e., sweet, fatty, salty, sour, bitter and umami). Gero et al. showed that preferences for all tastes were reduced in the immediate postoperative phase (25). Similar results were found when looking at liking for foods. A study found that overall liking was lower among RYGB patients compared to patients with obesity (72) and two studies showed a decreased liking for both high and low calorie foods (11,17). This overall decrease in liking does not seem to last over time as shown by the study of Kittrel et al., who showed no difference in preference for these food related tastes between patients with RYGB and OB after 1 year postoperatively, except for fatty and sweet foods. This low preference for fat in the longer term after bariatric surgery was also found by Nielsen et al. (9).

A decrease in wanting has been demonstrated by Frank et al., who used a wanting scale (72). In addition, a decrease in desire to eat assessed with the Power of Food Scale was found by several studies up to 24 mo postoperatively (72,94,98). Interestingly, a selective decrease in wanting for high calorie foods over low calorie foods was found in the early postoperative period by several studies, which used desire to eat scales (18,86,93). This was also the case in the study of Miras et al., which showed a decrease in food reward in the early stage after bariatric surgery for chocolate and sweets, while this was not the case for vegetables, when using a progressive ratio task (22).

Overall, the results point in the direction of a selective decrease in wanting for highly palatable foods after bariatric surgery, while there is an overall decrease in food preference and liking in the first postoperative months, which seems to be sustained up to 24 mo for highly palatable foods only (high fat and sweet foods).

Table 2.3. Hedonic ratings for foods or food categories in comparison with preoperative measures (prospective studies, N=10) or with measures on control groups of patients with obesity (cross-sectional studies, N=6).

Items	Time points					
	0-2 months (8 studies)	3-6 months (3 studies)	7-9 months (2 studies)	10-12 months (1 study)	13-24 months (4 studies)	>24 months (2 studies)
Liking	N/A	N/A	- (72)	N/A	N/A	N/A
High sugar	- (78 [£]) = (57)	N/A	N/A	N/A	N/A	N/A
High complex carbohydrate	- (77 [§]) = (57)	N/A	N/A	N/A	N/A	N/A
High protein	= (46,77 [§])	N/A		N/A	N/A	N/A
High fat	- (77 [§]) = (57)	N/A	N/A	N/A	N/A	N/A
Low fat	- (78 [£]) = (57)	N/A	N/A	N/A	N/A	N/A
High fat / High sugar	- (47,78 [£])	N/A		N/A	N/A	N/A
High fat / High complex carbohydrate	- (57) = (77 [§])	N/A	N/A	N/A	N/A	N/A
Low fat / High protein	- (78 [£])	N/A	N/A	N/A	N/A	N/A
Low fat / High sugar	= (47,78)	N/A	N/A	N/A	N/A	N/A
Low fat / High complex carbohydrate	- (77 [§]) = (57)	N/A	N/A	N/A	N/A	N/A
Hi fat / Low complex carbohydrate / High protein	= (57)	N/A	N/A	N/A	N/A	N/A
Low fat / Low complex carbohydrate / High protein	= (57)	N/A	N/A	N/A	N/A	N/A
Steak	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Chicken	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Sauerkraut	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Strawberries	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Water	= (25)	= (25)	N/A	N/A	N/A	N/A
Red wine	- (25)	N/A	N/A	N/A	N/A	N/A
Guinness	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Coffee	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Cigarette	- (25)	N/A	N/A	N/A	N/A	N/A
Bitter (grapefruit)	- (25)	- (25)	N/A	N/A	N/A	N/A
Umami	- (25)	- (25)	N/A	N/A	N/A	N/A
Cheese	- (25)	- (25)	N/A	N/A	= (12 [*])	= (12 [*])
Fatty	- (25)	- (25)	N/A	N/A	N/A	N/A
Hamburger	- (25)	- (25)	N/A	N/A	N/A	N/A
French Fries	- (25)	- (25)	N/A	N/A	- (12 [*])	N/A
Sour	- (25)	- (25)	N/A	N/A	N/A	N/A
Pickled cucumber	- (25)	- (25)	N/A	N/A	N/A	N/A
Lemon	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Vinegar	N/A	N/A	N/A	N/A	= (12 [*])	= (12 [*])
Spicy (curry dish)	- (25)	- (25)	N/A	N/A	N/A	N/A
Salty	- (25)	- (25)	N/A	N/A	N/A	N/A
Potatoe chips	- (25)	- (25)	N/A	N/A	= (12 [*])	= (12 [*])

Chapter II.

Pretzels	- (25)	- (25)	N/A	N/A	= (12 [*])	= (12 [*])
Sweet	- (25)	- (25)	N/A	- (65 [*])	N/A	N/A
Chocolate, dark chocolate	- (25)	- (25)	N/A	N/A	= (12 [*])	= (12 [*])
Cake, cookies	- (25)	- (25)	N/A	N/A	- (12 [*])	- (12 [*])
Ice cream	- (25)	- (25)	N/A	N/A	- (12 [*])	- (12 [*])
Refined carbohydrates	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Fat	N/A	N/A	N/A	= (65 [*])	N/A	N/A
High fat proteins	N/A	N/A	N/A	- (65 [*])	N/A	N/A
Low fat proteins	N/A	N/A	N/A	= (65 [*])	N/A	N/A
High fat potatoe chips	N/A	N/A	N/A	N/A	N/A	- (9)
Salty	N/A	N/A	N/A	- (65 [*])	N/A	N/A
Fiber	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Vegetables	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Fruit	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Sour	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Bitter	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Spicy	N/A	N/A	N/A	= (65 [*])	N/A	N/A
Sweet drinks	N/A	N/A	N/A	- (65 [*])	N/A	N/A
Alcohol	N/A	N/A	N/A	- (65 [*])	N/A	N/A
High calorie food	= (86)	- (11)	- (16 [*])	N/A	N/A	N/A
Low calorie food	= (86)	- (11)	- (16 [*])	N/A	N/A	N/A
Wanting	N/A	N/A	- (72)	N/A	N/A	N/A
Desire to eat	N/A	N/A	N/A	N/A	N/A	N/A
Aggregated Power of Food Scale score	N/A	N/A	- (72)	N/A	- (83 [*] ,87)	N/A
Food available	N/A	N/A	N/A	N/A	- (83 [*] ,87)	N/A
Food present	N/A	N/A	N/A	N/A	- (83 [*] ,87)	N/A
Food tasted	N/A	N/A	- (72)	N/A	- (83 [*] ,87)	N/A
High calorie food	- (18,86,93)	N/A	N/A	N/A	N/A	N/A
Low calorie food	= (18,93)	N/A	N/A	N/A	N/A	N/A
Reward	N/A	N/A	N/A	N/A	N/A	N/A
Chocolate, sweets	- (22)	N/A	N/A	N/A	N/A	N/A
Vegetables	= (22)	N/A	N/A	N/A	N/A	N/A

The signs -, + and = indicates the direction of modification in food preferences reported as food preference, hedonic rating, food reward, or desire to eat (see Table 1 for more information on the assessment method and unit used by the authors). Significance was considered for a p-value < 0.05.

N/A indicates that the results were not assessed by the authors or not reported in the papers.

* Cross-sectional study (results were compared to a control group of patients with obesity).

§ The study involved patients with RYGB and patients with SG.

‡ The results were significant for SG patients only.

2.3.5. Quality of the total body of evidence

Quality

Figure 2.3 summarizes the quality of the body of evidence according to the six dimensions of the ‘Quality assessment tool for quantitative studies’. Most of the studies (N=37) had a strong quality, corresponding to 47.5% of the gathered information, when weighted by the number of participants of each study. Seventeen studies had a moderate quality (43.7% of the information) and 3 studies had a weak quality (8.8% of the information). The criteria corresponding to the selection bias were mostly judged to be moderate, because few authors reported the number of participants who agreed to participate in the study out of the total number of eligible participants. The study designs were mostly rated as moderate due to the prospective nature of the cohort studies. The criteria related to the confounding factors were generally rated as strong, since the participants were their own controls in most studies. Blinding was commonly not reported by the authors, which explains the high number of moderate ratings. In most cases, the studies used relevant and validated measurement methods for food preferences and were rated as strong for this criterion. Finally, there were relatively few withdrawals and dropouts (or it was not reported) as only 9 studies were rated as weak for this criterion. The detailed rating for each study is summarized in a traffic light plot representing the risk of bias in each domain of the ‘Quality assessment tool for quantitative studies’ available in Appendix 2.E. No study was excluded from the analyses based on quality assessment.



Figure 2.3. Weighted summary bar-plot representing the proportion of information with a given level of bias for each sub-domain of the ‘Quality assessment tool for quantitative studies’.

Publication bias

Funnel plots for weighted mean differences in total energy intake from proteins, carbohydrates and lipids between preoperative and postoperative measures (1, 3, 6, 12, and 24 mo) using random effect models are available in Appendix 2.F. Egger's regression test suggested no significant bias (all $p > 0.05$), however there was a lack of power ($N < 10$ studies) for meta-analyses performed at 1, 3 and 24 mo.

3.4 Discussion

2.4.1. Main findings

To our knowledge, this is the first systematic review and meta-analyses to investigate the relationship between bariatric surgery and changes in food preferences. With an original approach considering various methods to assess food preferences the present systemic analysis of the evidence showed a change in food preferences in patients with obesity who undergo bariatric surgery at specific times during their weight loss trajectory. Most important, the meta-analysis revealed a post-operative increase in percentage energy from proteins at 12 mo offset by a decrease in percentage energy from fat at 1, 6, 12 and 24 mo after bariatric surgery. There was also a postoperative increased proportion of healthy foods in the patients' diet to the detriment of foods high in sugar, fat, salt and energy density. Moreover, there were decreased hedonic ratings for most of the food groups early after bariatric surgery, which persisted in the longer term for high fat and high sweet foods. Overall, the postoperative food preferences seem to progressively evolve towards what the patients consumed preoperatively.

2.4.2. Comparison with other studies

Clinical studies and reviews

This review showed that postoperative changes in food preferences exist, and they appear to be related to altered sensory abilities observed in post-surgical patients. Indeed, preferences for odors associated with fatty and sweet products (e.g., cakes, fries, ice cream) were lower among people who have been bypassed compared to people with obesity (12). Our findings are consistent with a narrative review by Primeaux et al., which highlighted the decreased preference toward energy dense and highly palatable foods after bariatric surgery and showed that bariatric surgery increases sweet and fat taste perception (31). Other reviews also

found that bariatric surgery leads to alteration of taste perception (32,33), and it should be noted that one found a lower hedonic response to sweet and fatty stimuli after bariatric surgery (33). Interestingly, a high sensitivity to sweet taste was associated with a lower preference rating for sweet taste in healthy adults (106). Thus, we can speculate that this increased taste sensitivity observed after bariatric surgery could negatively influence food preferences. In addition, olfaction may also be involved in postoperative alterations of food preferences, as a review demonstrated that bariatric surgery could improve olfactory abilities, which are deficient in the case of obesity (107). Interestingly, the results related to food reward showed a decrease in motivation to food consumption and a reduction in pleasure correlated with the sensory properties of food (72,86). Our review suggests that both liking and wanting decrease postoperatively, which is in accordance with a recent systematic review by Oustric et al., which found a decreased food reward after weight loss interventions (108).

Pre-clinical animal studies

Our results are in agreement with the main findings of preclinical animal studies regarding changes in food preferences after bariatric surgery (Appendix 2.G), which could elucidate the underlying mechanistic pathways. Concerning the improvement of the postoperative diet quality, the pre-clinical studies displayed similar results to ours, including an increased preference for a vegetable liquid over a low sugar and a low fat liquid (109), a shifted preference towards lower energy-dense foods (110), and a lower preference for high fat over low fat meal/bolus (111–113). Consistent with our findings, several animal studies found that the preference for fat is decreased after bariatric surgery (109,114–117). The low preference towards fats seem to develop progressively after bariatric surgery (112,117). This led Al-Najim et al. to hypothesize that this low preference towards fatty foods results from a conditioned taste avoidance (i.e., associative learning ingesting too much fat may cause postprandial discomfort) rather than a decreased hedonic value of food (118). Similar to our findings, the decreased preference for sweet was highlighted by several studies (119–121). Especially, there was a lower preference for sucrose at the highest concentrations (120,121), suggesting a postoperative improvement in taste sensitivity. Similarly, there was a lower preference for high fat - high sugar diet in rats that had a diversion from the bile duct to the mid-ileum (similar deviation to what is performed in RYGB) compared to controls (122). However, while the meta-analysis showed a lower contribution of lipids in energy intake in favor of protein, one study showed a shift away from fat towards carbohydrate when using a

macronutrient selection paradigm (123). On the other hand, one study found a decreased preference for high sugar after high fat gavage (112). Interestingly, comparing SG and RYGB rats, one study found a decreased preference for high fat food among RYGB rats only (124), while another found an aversion for high fat food among SG rats only (110). Regarding postoperative alterations of food reward, our results are consistent with several pre-clinical studies. Notably, Mathes et al. found that rats had an increased appetitive behavior and an increased reward after RYGB (125). Another study showed a decreased liking for high fat and high sugar (126). However, while we found an overall decreased wanting postoperatively, one study found that wanting, which was initially low preoperatively, was increased at the same level as lean controls after RYGB (126). Finally, another study found no change in food reward for fat or sweet, when using a progressive ratio lever-pressing paradigm. In this task, rats had to make an increasing number of lever press to obtain a reward (sucrose or peanut oil) (110).

2.4.3. Strengths and limitations

Among the strengths of this review include the application of a systemic analysis of the evidence (44), the large number of studies included (N=57) and the performance of meta-analyses (N=23) in a large population of 2271 patients with RYGB and 903 patients with SG. Of importance, given the overall decrease in the ingested volume (6) and energy intake (6,7) after bariatric surgery, the meta-analyses were performed on the contribution of macronutrients to total energy intake, rather than on the actual macronutrient intakes of the patients. Another strength is the high quality of the body of evidence, based on the ratings of the articles using the ‘Quality assessment tool for quantitative studies’ and by the absence of publication bias. However, it should be noted that there was a lack of power when performing the Egger’s tests in some cases, and those results should be interpreted with caution. Importantly, there was a high heterogeneity between the studies included in the meta-analyses. We explored this heterogeneity by removing outliers and conducting sub-group analysis. The removal of outliers did not change the results initially obtained. However, an important source of heterogeneity might be related to the food preference assessment tool used. We found that the heterogeneity was higher when food intake or preferences were assessed using food recall compared to food record, which is in agreement with the study of da Silva et al. showing that 24-hour food recall was less sensitive to postoperative changes in specific macro and micronutrients (67) compared to 7-day food records. It should also be noted that results related to food preferences as relative choices of foods or food groups should be interpreted with caution due to the variation in the

reporting outcomes (e.g., intake per day, proportion of the total energy intake, portion per day, etc.). Finally, the studies included in this review took place in different countries, of which Brazil, USA and to some extent the European countries. This could be another source of heterogeneity given that the socio-cultural background influences food choices (127,128).

2.4.4. *Implications of findings and future research*

This review highlighted the increased contribution of proteins in the postoperative diet. However, Moize et al. found that the protein intake is about 0.5 g/kg/day in the first postoperative year, which is well below the recommended 1.5 g/kg/day (129). Together, these findings suggest that despite the higher contribution of proteins in the total energy intake, the amount remains insufficient to meet postoperative protein requirements. The protein leverage hypothesis (130,131) was primarily developed to explain overeating in the context of obesity and suggests that protein intake is prioritized over carbohydrate and fat intake. In other words, according to this theory, humans eat until their protein needs are met, regardless of the energy content of the foods. Whether the protein leverage hypothesis is applied in bariatric surgery needs further research. This review showed a lower preference towards meat after bariatric surgery. However, studies exploring food preferences for other sources of proteins (e.g., fish, eggs, etc.) gave contrasting results. Also, there were limited data from pre-clinical studies that explored preference towards proteins, except those studies using a macronutrient selection paradigm (114,123). It is worth exploring further the postoperative preference towards non-meat products and possibly to find protein rich foods, which are better accepted than meat in order to reach the patients' protein needs.

Food preferences in relation to hedonic and sensory perception were examined only through certain foods or food categories. These categories were focused on nutritional (e.g., rich in protein, rich in fat, etc.) or sensory (e.g., sweet, salty, etc.) properties of the foods. However, it has been shown that other parameters, for example the texture of the foods and its appearance influence food preferences in the general population (30) and in patients with bariatric surgery (132). Thus, exploring how the hedonic value of food varying in texture, or appearance is impacted by bariatric surgery seems prudent. Among the possible mechanisms related to food hedonics, postoperative alteration of food reward processing has been widely explored by MRI scanning (15–18,86). In this review we found that several studies also studied food reward (9,11,17,18,22,72,76,86,93,94,98). However, few studies explored simultaneously

different components of food reward (i.e., liking and wanting) and how they evolve in relation to each other (72,86). The Leeds Food Preference Questionnaire (LFPQ) (133), could be of help to explore liking and wanting within a single task in the context of bariatric surgery. We also used relative intakes as a measure of food preferences. It is important to note that food intake were mainly explored through self-reported measures, which are prone to desirability bias (134–136) with only the study by Nielsen et al. (105) using an objective measure of assessment via a buffet meal in a laboratory setting. Several studies have shown that patients with obesity are prone to underreport their self-reported intakes (137–140). Taken together and as it has been highlighted in several narrative reviews on food preferences following bariatric surgery (36,141,142), a more realistic environment is recommended in future studies to improve ecological reliability of the findings (143).

Finally, our results indicated that changes in food preferences should be viewed as an evolutionary process that might change over the follow-up period. Thus, it is worth exploring further the food preferences in relation to the weight loss trajectory of the patients and postoperative alteration of food preferences in relation to the weight loss success or failure of the bariatric surgery. We can hypothesize that changes in food preferences by replacing high fat, high sweet and energy dense foods towards healthier food options could contribute to the long-term surgical success.

3.5 Conclusion

Considering various methods to assess food preferences, the present systematic review and meta-analysis showed that food preferences in terms of macronutrient, food selection and overall food appreciation change following bariatric surgery and changes can be observed up to 5 years postoperatively. Especially, there was i) a higher preference for proteins offsets by a lower preference for fats; ii) a postoperative increased preference for healthy foods to the detriment of foods high in sugar, fat, salt and energy density; and iii) overall decreased hedonic ratings, which in the longer term is seen for high fat and high sweet foods. Further studies using real foods in more realistic conditions are needed to improve ecological validity and reliability of these findings. In addition, the link between these changes and the weight loss success or failure of the surgery remains to be explored.

3.6 References

1. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014;384(9945):766–81.
2. Sjöström L, Peltonen M, Jacobson P, Sjöström CD, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. *JAMA - J Am Med Assoc*. 2012 Jan 4;307(1):56–65.
3. Sjöström L. Review of the key results from the Swedish Obese Subjects (SOS) trial - a prospective controlled intervention study of bariatric surgery. Vol. 273, *Journal of Internal Medicine*. 2013. p. 219–34.
4. Sjöström L, Narbro K, Sjöström CD, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med*. 2007 Aug 23;357(8):741–52.
5. Angrisani L, Santonicola A, Iovino P, Ramos A, Shikora S, Kow L. Bariatric Surgery Survey 2018: Similarities and Disparities Among the 5 IFSO Chapters. *Obes Surg*. 2021 Jan 12;1–12.
6. Coluzzi I, Raparelli L, Guarnacci L, Paone E, Del Genio G, le Roux CW, et al. Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy. *Obes Surg*. 2016 Sep 7;26(9):2059–67.
7. Laurenus A, Larsson I, Melanson KJ, Lindroos AK, Lönroth H, Bosaeus I, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. *Eur J Clin Nutr*. 2013 Feb 9;67(2):168–73.
8. Makaronidis JM, Neilson S, Cheung W-H, Tymoszuk U, Pucci A, Finer N, et al. Reported appetite, taste and smell changes following Roux-en-Y gastric bypass and sleeve gastrectomy: Effect of gender, type 2 diabetes and relationship to post-operative weight loss. *Appetite*. 2016 Dec;107:93–105.
9. Thirlby RC, Bahiraei F, Randall J, Drewnoski A. Effect of Roux-en-Y gastric bypass on satiety and food likes: the role of genetics. *J Gastrointest Surg*. 2006 Feb;10(2):270–7.
10. Molin Netto BDBD, Earthman CP, Farias G, Landi Masquio DC, Grotti Clemente AP, Peixoto P, et al. Eating patterns and food choice as determinant of weight loss and improvement of metabolic profile after RYGB. *Nutrition*. 2017 Jan;33:125–31.
11. Faulconbridge LF, Ruparel K, Loughhead J, Allison KC, Hesson LA, Fabricatore AN, et al. Changes in neural responsivity to highly palatable foods following roux-en-Y gastric bypass, sleeve gastrectomy, or weight stability: An fMRI study. *Obesity*. 2016 May;24(5):1054–60.
12. Kittrell H, Graber W, Mariani E, Czaja K, Hajnal A, Di Lorenzo PM. Taste and odor preferences following Roux-en-Y surgery in humans. Covasa M, editor. *PLoS One*. 2018 Jul 5;13(7):e0199508.
13. Zoon HFA, de Bruijn SEM, Jager G, Smeets PAM, de Graaf C, Janssen IMC, et al. Altered neural inhibition responses to food cues after Roux-en-Y Gastric Bypass. *Biol Psychol*. 2018 Sep;137:34–41.
14. Berridge KC. Food reward: Brain substrates of wanting and liking. *Neurosci Biobehav*

- Rev. 1996;20(1):1–25.
15. Frank S, Veit R, Sauer H, Enck P, Friederich HC, Unholzer T, et al. Dopamine depletion reduces food-related reward activity independent of BMI. *Neuropsychopharmacology*. 2016 May 1;41(6):1551–9.
 16. Goldstone AP, Miras AD, Scholtz S, Jackson S, Neff KJ, Pénicaud L, et al. Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *J Clin Endocrinol Metab*. 2016 Feb 1;101(2):599–609.
 17. Scholtz S, Miras AD, Chhina N, Prechtel CG, Sleeth ML, Daud NM, et al. Obese patients after gastric bypass surgery have lower brain-hedonic responses to food than after gastric banding. *Gut*. 2014 Jun;63(6):891–902.
 18. Ochner CN, Kwok Y, Conceicao E, Pantazatos SP, Puma LM, Carnell S, et al. Selective reduction in neural responses to high calorie foods following gastric bypass surgery. *Ann Surg*. 2011 Mar;253(3):502–7.
 19. Giel KE, Rieber N, Enck P, Friederich H-C, Meile T, Zipfel S, et al. Effects of laparoscopic sleeve gastrectomy on attentional processing of food-related information: evidence from eye-tracking. *Surg Obes Relat Dis*. 2014;10(2):277–82.
 20. Holsen LM, Davidson P, Cerit H, Hye T, Moondra P, Haimovici F, et al. Neural predictors of 12-month weight loss outcomes following bariatric surgery. *Int J Obes (Lond)*. 2018;42(4):785–93.
 21. Ochner CN, Laferrère B, Afifi L, Atalayer D, Geliebter A, Teixeira J. Neural responsivity to food cues in fasted and fed states pre and post gastric bypass surgery. *Neurosci Res*. 2012 Oct;74(2):138–43.
 22. Miras AD, Jackson RN, Jackson SN, Goldstone AP, Olbers T, Hackenberg T, et al. Gastric bypass surgery for obesity decreases the reward value of a sweet-fat stimulus as assessed in a progressive ratio task. *Am J Clin Nutr*. 2012 Sep 1;96(3):467–73.
 23. Olivo G, Zhou W, Sundbom M, Zhukovsky C, Hogenkamp P, Nikontovic L, et al. Resting-state brain connectivity changes in obese women after Roux-en-Y gastric bypass surgery: A longitudinal study. *Sci Rep*. 2017 Dec 26;7(1):6616.
 24. El Labban S, Safadi B, Olabi A. Effect of Roux-en-Y gastric bypass and sleeve gastrectomy on taste acuity and sweetness acceptability in postsurgical subjects. *Nutrition*. 2016;32(11):1299–302.
 25. Gero D, Dib F, Ribeiro-Parenti L, Arapis K, Chosidow D, Marmuse J-P. Desire for Core Tastes Decreases After Sleeve Gastrectomy: a Single-Center Longitudinal Observational Study with 6-Month Follow-up. *Obes Surg*. 2017 Nov 30;27(11):2919–26.
 26. Beaulieu K, Blundell J. The Psychobiology of Hunger – A Scientific Perspective. *Topoi*. 2020 Oct 6;1:3.
 27. Finlayson G, King N, Blundell JE. Liking vs. wanting food: Importance for human appetite control and weight regulation. Vol. 31, *Neuroscience and Biobehavioral Reviews*. *Neurosci Biobehav Rev*; 2007. p. 987–1002.
 28. Pilgrim FJ. The components of food acceptance and their measurement. *Am J Clin Nutr*. 1957 Mar 1;5(2):171–5.
 29. Meiselman HL, Bell R. Eating habits. In: *Encyclopedia of Food Sciences and Nutrition*. Elsevier; 2003. p. 1963–8.

30. Sanjur D, Randall E, Sanjur D. Food preferences—Their conceptualization and relationship to consumption. *Ecol Food Nutr.* 1981 Dec 1;11(3):151–61.
31. Primeaux SD, de Silva T, Tzeng TH, Chiang MC, Hsia DS. Recent advances in the modification of taste and food preferences following bariatric surgery. *Rev Endocr Metab Disord.* 2016 Jun 1;17(2):195–207.
32. Shoar S, Naderan M, Shoar N, Modukuru VR, Mahmoodzadeh H. Alteration Pattern of Taste Perception After Bariatric Surgery: a Systematic Review of Four Taste Domains. *Obes Surg.* 2019 May;29(5):1542–50.
33. Ahmed K, Penney N, Darzi A, Purkayastha S. Taste Changes after Bariatric Surgery: a Systematic Review. *Obes Surg.* 2018 Oct;28(10):3321–32.
34. Nielsen MS, Schmidt JB, le Roux CW, Sjodin A, Sjödin A, Sjodin A. Effects of Roux-en-Y Gastric Bypass and Sleeve Gastrectomy on Food Preferences and Potential Mechanisms Involved. *Curr Obes Rep.* 2019 Sep;8(3):292–300.
35. Behary P, Miras AD. Food preferences and underlying mechanisms after bariatric surgery. *Proc Nutr Soc.* 2015 Nov;74(4):419–25.
36. Gero D, Steinert RE, le Roux CW, Bueter M. Do Food Preferences Change After Bariatric Surgery? *Curr Atheroscler Rep.* 2017 Sep;19(9):38.
37. Berridge KC, Robinson TE, Aldridge JW. Dissecting components of reward: “liking”, “wanting”, and learning. Vol. 9, *Current Opinion in Pharmacology.* 2009. p. 65–73.
38. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* 2009 Jul 21;6(7):e1000097.
39. Armijo-Olivo S, Stiles C, Hagen N, Biondo P, Cummings G. Assessment of study quality for systematic reviews: a comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. *J Eval Clin Pract.* 2012;18(1).
40. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: Providing the research evidence for public health nursing interventions. *Worldviews Evidence-Based Nurs.* 2004 Sep;1(3):176–84.
41. Jackson N, Waters E. Criteria for the systematic review of health promotion and public health interventions. Vol. 20, *Health Promotion International.* Oxford Academic; 2005. p. 367–74.
42. Higgins JP, Sterne JA, Savovic J, Page MJ, Hróbjartsson A, Boutron I, et al. A revised tool for assessing risk of bias in randomized trials. *Cochrane Database Syst Rev.* 2016;10(Suppl 1):29–31.
43. Rohatgi A. Webplotdigitizer: Version 4.4 [Internet]. 2020. Available from: <https://automeris.io/WebPlotDigitizer>
44. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ WV (editors), editor. *Cochrane Handbook for Systematic Reviews of Interventions* version 6.1 (updated September 2020). *Cochrane Handbook for Systematic Reviews of Interventions.* Cochrane 2020; 2020.
45. Michael Borenstein, Larry V. Hedges, Julian P. T. Higgins HRR. *Introduction to Meta-Analysis* [Internet]. John Wiley. 2011 [cited 2020 Nov 30]. Available from:

- https://books.google.fr/books/about/Introduction_to_Meta_Analysis.html?id=JQg9jdrq26wC&redir_esc=y
46. Cuijpers P. *Meta-Analyses in Mental Health Research. A Practical Guide*. Amsterdam, 2016.
 47. Hedges L V. Distribution Theory for Glass's Estimator of Effect size and Related Estimators. *J Educ Stat*. 1981 Jun;6(2):107–28.
 48. Hedges L, Olkin I. *Statistical Models for Meta-Analysis*. New York: 1985.
 49. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, 1988.
 50. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *Vol. 327, British Medical Journal*. BMJ Publishing Group; 2003. p. 557–60.
 51. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002 Jun 15;21(11):1539–58.
 52. Viechtbauer W, Cheung MW-L. Outlier and influence diagnostics for meta-analysis. *Res Synth Methods*. 2010 Apr;1(2):112–25.
 53. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *Br Med J*. 1997;315(7109):629–34.
 54. Duval S, Tweedie R. Trim and Fill: A Simple Funnel-Plot–Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. In: *Library WO*, editor. *Biometrics* 56 (2). 2000. p. 455–63.
 55. Harrer M, Cuijpers P, Furukawa T, Ebert DD. dmetar: Companion R Package For The Guide “Doing Meta-Analysis in R” [Internet]. 2019. Available from: <http://dmetar.protectlab.org/>
 56. Al Assal K, Prifti E, Belda E, Sala P, Clément K, Dao M-C, et al. Gut Microbiota Profile of Obese Diabetic Women Submitted to Roux-en-Y Gastric Bypass and Its Association with Food Intake and Postoperative Diabetes Remission. *Nutrients*. 2020 Jan 21;12(2):278.
 57. Ammon BS, Bellanger DE, Geiselman PJ, Primeaux SD, Yu Y, Greenway FL. Short-Term Pilot Study of the Effect of Sleeve Gastrectomy on Food Preference. *Obes Surg*. 2015 Jun 26;25(6):1094–7.
 58. Aron-Wisnewsky J, Verger EO, Bounaix C, Dao MC, Oppert J-M, Bouillot J-L, et al. Nutritional and Protein Deficiencies in the Short Term following Both Gastric Bypass and Gastric Banding. *Covasa M*, editor. *PLoS One*. 2016;11(2):e0149588.
 59. Bavaresco M, Paganini S, Lima TP, Salgado W, Ceneviva R, Dos Santos JE, et al. Nutritional Course of Patients Submitted to Bariatric Surgery. *Obes Surg*. 2010;20(6):716–21.
 60. Brolin RE, Robertson LB, Kenler HA, Cody RP. Weight Loss and Dietary Intake After Vertical Banded Gastroplasty and Roux-en-Y Gastric Bypass. *Ann Surg*. 1994;220(6):782–90.
 61. Bužga M, Zavadilová V, Holéczy P, Švagera Z, Švorc P, Foltys A, et al. Dietary intake and ghrelin and leptin changes after sleeve gastrectomy. *Videosurgery Other Miniinvasive Tech*. 2014;9(4):554–61.
 62. Carrasco F, Papapietro K, Csendes A, Salazar G, Echenique C, Lisboa C, et al. Changes in Resting Energy Expenditure and Body Composition after Weight Loss following

- Roux-en-Y Gastric Bypass. *Obes Surg.* 2007 May 10;17(5):608–16.
63. Carrasco F, Rojas P, Csendes A, Codoceo J, Inostroza J, Basfi-fer K, et al. Changes in ghrelin concentrations one year after resective and non-resective gastric bypass: Associations with weight loss and energy and macronutrient intakes. *Nutrition.* 2012 Jul;28(7–8):757–61.
 64. Casagrande DS, Repetto G, Mottin CC, Shah J, Pietrobon R, Worni M, et al. Changes in Bone Mineral Density in Women Following 1-Year Gastric Bypass Surgery. *Obes Surg.* 2012 Aug 13;22(8):1287–92.
 65. Coupaye M, Sami O, Calabrese D, Flamant M, Ledoux S. Prevalence and Determinants of Nutritional Deficiencies at Mid-Term After Sleeve Gastrectomy. *Obes Surg.* 2020 Jun 3;30(6):2165–72.
 66. Custódio Afonso Rocha V, Ramos de Arvelos L, Pereira Felix G, Nogueira Prado de Souza D, Bernardino Neto M, Santos Resende E, et al. Evolution of nutritional, hematologic and biochemical changes in obese women during 8 weeks after Roux-en-Y gastric bypass. *Nutr Hosp.* 2012;27(4):1134–40.
 67. da Silva MM, Sala PC, Torrinhas RSM de M, Waitzberg DL. Efficiency of the 24-hour food recall instrument for assessing nutrient intake before and after Roux-en-Y gastric bypass. *Nutr Hosp.* 2014 Aug 1;30(6):1240–7.
 68. Davies N, O’Sullivan JM, Plank LD, Murphy R. Gut Microbial Predictors of Type 2 Diabetes Remission Following Bariatric Surgery. *Obes Surg.* 2020 Sep 23;30(9):3536–48.
 69. Delin CR, Watts JM, Saebel JL, Anderson PG. Eating behavior and the experience of hunger following gastric bypass surgery for morbid obesity. *Obes Surg.* 1997 Oct 1;7(5):405–13.
 70. Ernst B, Thurnheer M, Wilms B, Schultes B. Differential Changes in Dietary Habits after Gastric Bypass Versus Gastric Banding Operations. *Obes Surg.* 2009 Mar 26;19(3):274–80.
 71. Farias G, Silva RMO, da Silva PPP, Vilela RM, Bettini SC, Dâmaso AR, et al. Impact of dietary patterns according to NOVA food groups: 2 y after Roux-en-Y gastric bypass surgery. *Nutrition.* 2020 Jun;74:110746.
 72. Frank S, Heinze JM, Fritsche A, Linder K, von Feilitzsch M, Königsrainer A, et al. Neuronal Food Reward Activity in Patients With Type 2 Diabetes With Improved Glycemic Control After Bariatric Surgery. *Diabetes Care.* 2016 Aug;39(8):1311–7.
 73. Freeman RA, Overs SE, Zarshenas N, Walton KL, Jorgensen JO. Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass. *Obes Res Clin Pract.* 2014;8(2):e115-200.
 74. Garla P, Sala P, Torrinhas RSM, Machado NM, Fonseca DC, da Silva MM, et al. Reduced intestinal FADS1 gene expression and plasma omega-3 fatty acids following Roux-en-Y gastric bypass. *Clin Nutr.* 2019 Jun;38(3):1280–8.
 75. Giusti V, Theytaz F, Di Vetta V, Clarisse M, Suter M, Tappy L. Energy and macronutrient intake after gastric bypass for morbid obesity: a 3-y observational study focused on protein consumption. *Am J Clin Nutr.* 2016 Jan 1;103(1):18–24.
 76. Hubert, Papasavas P, Stone, Swede, Huedo-Medina, Tishler, et al. Associations between Weight Loss, Food Likes, Dietary Behaviors, and Chemosensory Function in Bariatric

- Surgery: A Case-Control Analysis in Women. *Nutrients*. 2019 Apr 9;11(4):804.
77. Johnson LK, Andersen LF, Hofsvø D, Aasheim ET, Holven KB, Sandbu R, et al. Dietary changes in obese patients undergoing gastric bypass or lifestyle intervention: a clinical trial. *Br J Nutr*. 2013 Jul 14;110(1):127–34.
 78. Kenler HA, Brodin RE, Cody RP. Changes in eating behavior after horizontal gastropasty and Roux-en-Y gastric bypass. *Am J Clin Nutr*. 1990 Jul 1;52(1):87–92.
 79. Kvehaugen AS, Farup PG. Changes in gastrointestinal symptoms and food tolerance 6 months following weight loss surgery: associations with dietary changes, weight loss and the surgical procedure. *BMC Obes*. 2018 Dec 3;5:29.
 80. Lopes Pinto S, da Silva DCG, Bressan J. Absolute and Relative Changes in Ultra-processed Food Consumption and Dietary Antioxidants in Severely Obese Adults 3 Months After Roux-en-Y Gastric Bypass. *Obes Surg*. 2019 Jun 5;29(6):1810–5.
 81. Moizé V, Andreu A, Rodríguez L, Flores L, Ibarzabal A, Lacy A, et al. Protein intake and lean tissue mass retention following bariatric surgery. *Clin Nutr*. 2013 Aug;32(4):550–5.
 82. Murphy R, Tsai P, Jüllig M, Liu A, Plank L, Booth M. Differential Changes in Gut Microbiota After Gastric Bypass and Sleeve Gastrectomy Bariatric Surgery Vary According to Diabetes Remission. *Obes Surg*. 2017 Apr 13;27(4):917–25.
 83. Søndergaard Nielsen M, Rasmussen S, Just Christensen B, Ritz C, le Roux CW, Berg Schmidt J, et al. Bariatric Surgery Does Not Affect Food Preferences, but Individual Changes in Food Preferences May Predict Weight Loss. *Obesity*. 2018 Dec;26(12):1879–87.
 84. Nielsen MS, Andersen INSKK, Lange B, Ritz C, le Roux CW, Schmidt JB, et al. Bariatric Surgery Leads to Short-Term Effects on Sweet Taste Sensitivity and Hedonic Evaluation of Fatty Food Stimuli. *Obesity*. 2019 Sep;
 85. Nonino CB, Oliveira BAP de, Chaves RCP, Silva LTPE, Pinhel MA de S, Ferreira F de C, et al. Is there any change in phenotypic characteristics comparing 5 to 10 years of follow-up in obese patients undergoing Roux-en-Y gastric bypass? *Arq Bras Cir Dig*. 2019 Oct;32(3):e1453.
 86. Ochner CN, Stice E, Hutchins E, Afifi L, Geliebter A, Hirsch J, et al. Relation between changes in neural responsivity and reductions in desire to eat high-calorie foods following gastric bypass surgery. *Neuroscience*. 2012 May;209:128–35.
 87. Odstrcil EA, Martinez JG, Santa Ana CA, Xue B, Schneider RE, Steffer KJ, et al. The contribution of malabsorption to the reduction in net energy absorption after long-limb Roux-en-Y gastric bypass. *Am J Clin Nutr*. 2010 Oct 1;92(4):704–13.
 88. Primeaux SD, Tzeng TH, Allerton TD, Chiang MC, Cosentino G, Dubin RL, et al. Differences in short-term food preferences following vertical sleeve gastrectomy and Roux-en-Y gastric bypass surgery. *Obes Res Clin Pract*. 2015 Nov 2;9(6):628–32.
 89. Robinson KN, Rowitz B, Oliphant UJ, Donovan SM, Teran-Garcia M. Larger omental adipocytes correlate with greater Fetuin-A reduction following sleeve gastrectomy. *BMC Obes*. 2019 Dec 6;6:15.
 90. Rosa FT, de Oliveira-Penaforte FR, de Arruda Leme I, Padovan GJ, Ceneviva R, Marchini JS. Altered plasma response to zinc and iron tolerance test after Roux-en-Y gastric bypass. *Surg Obes Relat Dis*. 2011 May;7(3):309–14.

91. Ruiz-Lozano T, Vidal J, de Hollanda A, Scheer FAJL, Garaulet M, Izquierdo-Pulido M. Timing of food intake is associated with weight loss evolution in severe obese patients after bariatric surgery. *Clin Nutr.* 2016 Dec;35(6):1308–14.
92. Ruiz-Tovar J, Bozhychko M, Del-Campo JM, Boix E, Zubiaga L, Muñoz JL, et al. Changes in Frequency Intake of Foods in Patients Undergoing Sleeve Gastrectomy and Following a Strict Dietary Control. *Obes Surg.* 2018 Jun 17;28(6):1659–64.
93. Sanmiguel CP, Jacobs J, Gupta A, Ju T, Stains J, Coveleskie K, et al. Surgically Induced Changes in Gut Microbiome and Hedonic Eating as Related to Weight Loss. *Psychosom Med.* 2017 Oct;79(8):880–7.
94. Schultes B, Ernst B, Wilms B, Thurnheer M, Hallschmid M. Hedonic hunger is increased in severely obese patients and is reduced after gastric bypass surgery. *Am J Clin Nutr.* 2010 Aug 1;92(2):277–83.
95. Sherf Dagan S, Tovim T Ben, Keidar A, Raziell A, Shibolet O, Zelber-Sagi S. Inadequate protein intake after laparoscopic sleeve gastrectomy surgery is associated with a greater fat free mass loss. *Surg Obes Relat Dis.* 2017 Jan 1;13(1):101–9.
96. Søvik TT, Karlsson J, Aasheim ET, Fagerland MW, Björkman S, Engström M, et al. Gastrointestinal function and eating behavior after gastric bypass and duodenal switch. *Surg Obes Relat Dis.* 2013 Sep;9(5):641–7.
97. Trostler, Mann, Zilberbush, Avinoach, Charuzi. Weight Loss and Food Intake 18 Months following Vertical Banded Gastroplasty or Gastric Bypass for Severe Obesity. *Obes Surg.* 1995 Feb 1;5(1):39–51.
98. 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 Jan 1;23(1):50–5.
99. Verger EO, Aron-Wisnewsky J, Dao MC, Kayser BD, Oppert J-M, Bouillot J-L, et al. Micronutrient and Protein Deficiencies After Gastric Bypass and Sleeve Gastrectomy: a 1-year Follow-up. *Obes Surg.* 2016 Apr 24;26(4):785–96.
100. Vieira FT, Faria SLCM, Dutra ES, Ito MK, Reis CEG, da Costa THM, et al. Perception of Hunger/Satiety and Nutrient Intake in Women Who Regain Weight in the Postoperative Period After Bariatric Surgery. *Obes Surg.* 2019 Mar 18;29(3):958–63.
101. Vinolas H, Barnette T, Ferrandi G, Monsaingeon-Henry M, Pupier E, Collet D, et al. Oral Hydration, Food Intake, and Nutritional Status Before and After Bariatric Surgery. *Obes Surg.* 2019 Sep 17;29(9):2896–903.
102. Zaparolli MR, DA-Cruz MRR, Frehner C, Branco-Filho AJ, Schieferdecker MEM, Campos ACL, et al. Food intake evaluation during the first year of postoperative of patients with type 2 diabetes mellitus or glycemic alteration submitted to Roux-en-Y gastric bypass. *Arq Bras Cir Dig.* 2018 Jul 2;31(2):e1367.
103. Lobstein T, Davies S. Defining and labelling “healthy” and “unhealthy” food. Vol. 12, *Public Health Nutrition.* Cambridge University Press; 2009. p. 331–40.
104. Augusto Monteiro C, Cannon G, Moubarac J-C, Bertazzi Levy R, Laura Louzada MC, Constante Jaime P. Commentary The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. 2017;
105. Nielsen MS, Christensen BJ, Ritz C, Rasmussen S, Hansen TT, Bredie WLPP, et al. Roux-En-Y Gastric Bypass and Sleeve Gastrectomy Does Not Affect Food Preferences

- When Assessed by an Ad libitum Buffet Meal. *Obes Surg.* 2017 Oct 14;27(10):2599–605.
106. Chamoun E, Liu AAS, Duizer LM, Darlington G, Duncan AM, Haines J, et al. Taste Sensitivity and Taste Preference Measures Are Correlated in Healthy Young Adults. *Chem Senses.* 2019 Jan 29;44(2):129–34.
 107. Peng M, Coutts D, Wang T, Cakmak YO. Systematic review of olfactory shifts related to obesity. *Obes Rev.* 2019 Feb 1;20(2):325–38.
 108. Oustric P, Gibbons C, Beaulieu K, Blundell J, Finlayson G. Changes in food reward during weight management interventions – a systematic review. Vol. 19, *Obesity Reviews.* Blackwell Publishing Ltd; 2018. p. 1642–58.
 109. Seyfried F, Miras AD, Bueter M, Prechtl CG, Spector AC, le Roux CW. Effects of preoperative exposure to a high-fat versus a low-fat diet on ingestive behavior after gastric bypass surgery in rats. *Surg Endosc.* 2013 Nov;27(11):4192–201.
 110. Wilson-Perez HE, Chambers AP, Sandoval DA, Stefater MA, Woods SC, Benoit SC, et al. The effect of vertical sleeve gastrectomy on food choice in rats. *Int J Obes (Lond).* 2013 Feb;37(2):288–95.
 111. Zheng H, Shin AC, Lenard NR, Townsend RL, Patterson LM, Sigalet DL, et al. Meal patterns, satiety, and food choice in a rat model of Roux-en-Y gastric bypass surgery. *Am J Physiol Regul Integr Comp Physiol.* 2009 Nov;297(5):R1273-82.
 112. le Roux CW, Bueter M, Theis N, Werling M, Ashrafian H, Lowenstein C, et al. Gastric bypass reduces fat intake and preference. *Am J Physiol Regul Integr Comp Physiol.* 2011 Oct;301(4):R1057-66.
 113. Hao Z, Townsend RL, Mumphrey MB, Patterson LM, Ye J, Berthoud HR. Vagal Innervation of Intestine Contributes to Weight Loss After Roux-en-Y Gastric Bypass Surgery in Rats. *Obes Surg.* 2014 Dec 1;24(12):2145–51.
 114. Arble DM, Pressler JW, Sorrell J, Wevrick R, Sandoval DA. Sleeve gastrectomy leads to weight loss in the Magel2 knockout mouse. *Surg Obes Relat Dis.* 2016 Dec 1;12(10):1795–802.
 115. Hankir MK, Seyfried F, Hintschich CA, Diep T-A, Kleberg K, Kranz M, et al. Gastric Bypass Surgery Recruits a Gut PPAR-alpha-Striatal D1R Pathway to Reduce Fat Appetite in Obese Rats. *Cell Metab.* 2017 Feb;25(2):335–44.
 116. Mathes CM, Bohnenkamp RA, le Roux CW, Spector AC. Reduced sweet and fatty fluid intake after Roux-en-Y gastric bypass in rats is dependent on experience without change in stimulus motivational potency. *Am J Physiol Regul Integr Comp Physiol.* 2015 Oct;309(8):R864-74.
 117. Mathes CM, Letourneau C, Blonde GD, Roux CWL, Spector AC. Roux-en-y gastric bypass in rats progressively decreases the proportion of fat calories selected from a palatable cafeteria diet. *Am J Physiol - Regul Integr Comp Physiol.* 2016 May 1;310(10):R952–9.
 118. Al-Najim W, Docherty NG, Le Roux CW. Food intake and eating behavior after bariatric surgery. *Physiol Rev.* 2018 Jul 1;98(3):1113–41.
 119. Hajnal A, Kovacs P, Ahmed T, Meirelles K, Lynch CJ, Cooney RN. Gastric bypass surgery alters behavioral and neural taste functions for sweet taste in obese rats. *Am J Physiol Gastrointest Liver Physiol.* 2010 Oct;299(4):G967-79.

120. Bueter M, Miras AD, Chichger H, Fenske W, Ghati MA, Bloom SR, et al. Alterations of sucrose preference after Roux-en-Y gastric bypass. *Physiol Behav.* 2011 Oct;104(5):709–21.
121. Tichansky DS, Glatt AR, Madan AK, Harper J, Tokita K, Boughter JD. Decrease in sweet taste in rats after gastric bypass surgery. *Surg Endosc.* 2011 Apr;25(4):1176–81.
122. Goncalves D, Barataud A, De Vadder F, Vinera J, Zitoun C, Duchampt A, et al. Bile Routing Modification Reproduces Key Features of Gastric Bypass in Rat. *Ann Surg.* 2015 Dec;262(6):1006–15.
123. Mul JD, Begg DP, Alsters SIM, van Haaften G, Duran KJ, D'Alessio DA, et al. Effect of vertical sleeve gastrectomy in melanocortin receptor 4-deficient rats. *Am J Physiol Endocrinol Metab.* 2012 Jul;303(1):E103-10.
124. Saeidi N, Nestoridi E, Kucharczyk J, Uygun MK, Yarmush ML, Stylopoulos N. Sleeve gastrectomy and Roux-en-Y gastric bypass exhibit differential effects on food preferences, nutrient absorption and energy expenditure in obese rats. *Int J Obes (Lond).* 2012 Nov;36(11):1396–402.
125. Mathes CM, Bueter M, Smith KR, Lutz TA, le Roux CW, Spector AC. Roux-en-Y gastric bypass in rats increases sucrose taste-related motivated behavior independent of pharmacological GLP-1-receptor modulation. *Am J Physiol - Regul Integr Comp Physiol.* 2012 Mar;302(6):751–67.
126. Shin AC, Zheng H, Townsend RL, Patterson LM, Holmes GM, Berthoud H-R. Longitudinal assessment of food intake, fecal energy loss, and energy expenditure after Roux-en-Y gastric bypass surgery in high-fat-fed obese rats. *Obes Surg.* 2013 Apr;23(4):531–40.
127. Rozin P. The socio-cultural context of eating and food choice. In: *Food Choice, Acceptance and Consumption* [Internet]. Springer US; 1996 [cited 2021 Feb 25]. p. 83–104. Available from: https://link.springer.com/chapter/10.1007/978-1-4613-1221-5_2
128. Enriquez JP, Archila-Godinez JC. Social and cultural influences on food choices: A review [Internet]. *Critical Reviews in Food Science and Nutrition*. Bellwether Publishing, Ltd.; 2021 [cited 2021 Feb 25]. Available from: <https://www.tandfonline.com/doi/abs/10.1080/10408398.2020.1870434>
129. Moize V, Geliebter A, Gluck ME, Yahav E, Lorence M, Colarusso T, et al. Obese patients have inadequate protein intake related to protein intolerance up to 1 year following Roux-en-Y gastric bypass. *Obes Surg.* 2003 Feb 1;13(1):23–8.
130. Simpson SJ, Raubenheimer D. Obesity: The protein leverage hypothesis. Vol. 6, *Obesity Reviews*. *Obes Rev*; 2005. p. 133–42.
131. Raubenheimer D, Simpson SJ. Protein Leverage: Theoretical Foundations and Ten Points of Clarification [Internet]. Vol. 27, *Obesity*. Blackwell Publishing Inc.; 2019 [cited 2021 Feb 28]. p. 1225–38. Available from: <https://pubmed.ncbi.nlm.nih.gov/31339001/>
132. Stano S, Alam F, Wu L, Dutia R, Ng SN, Sala M, et al. Effect of meal size and texture on gastric pouch emptying and glucagon-like peptide 1 after gastric bypass surgery. *Surg Obes Relat Dis.* 2017 Dec 1;13(12):1975–83.
133. Finlayson G, King N, Blundell JE. Is it possible to dissociate “liking” and “wanting” for foods in humans? A novel experimental procedure. *Physiol Behav.* 2007 Jan

- 30;90(1):36–42.
134. Klesges LM, Baranowski T, Beech B, Cullen K, Murray DM, Rochon J, et al. Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8- to 10-year-old African-American girls: Results from the Girls health Enrichment Multisite Studies (GEMS). *Prev Med (Baltim)*. 2004;38(SUPPL.):78–87.
 135. Herbert JR, Clemow L, Pbert L, Ockene IS, Ockene JK. Social Desirability Bias in Dietary Self-Report May Compromise the Validity of Dietary Intake Measures. *Int J Epidemiol*. 1995 Apr 1;24(2):389–98.
 136. Kristal AR, Andrilla CHA, Koepsell TD, Diehr PH, Cheadle A. Dietary assessment instruments are susceptible to intervention- associated response set bias. *J Am Diet Assoc*. 1998 Jan 1;98(1):40–3.
 137. Wehling H, Lusher J. People with a body mass index ≥ 30 under-report their dietary intake: A systematic review. Vol. 24, *Journal of Health Psychology*. SAGE Publications Ltd; 2019. p. 2042–59.
 138. Lissner L. Measuring food intake in studies of obesity. *Public Health Nutr*. 2002 Dec;5(6a):889–92.
 139. Heitmann BL, Lissner L. Dietary underreporting by obese individuals—is it specific or non-specific? *BMJ*. 1995 Oct 14;311(7011):986.
 140. Goris AH, Westerterp-Plantenga MS, Westerterp KR. Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. *Am J Clin Nutr*. 2000 Jan 1;71(1):130–4.
 141. Kapoor N, Al-Najim W, le Roux CW, Docherty NG. Shifts in Food Preferences After Bariatric Surgery: Observational Reports and Proposed Mechanisms. *Curr Obes Rep*. 2017 Sep;6(3):246–52.
 142. Mathes CM, Spector AC. Food selection and taste changes in humans after Roux-en-Y gastric bypass surgery: a direct-measures approach. *Physiol Behav*. 2012 Nov;107(4):476–83.
 143. Meiselman HL. Methodology and theory in human eating research. *Appetite*. 1992 Aug 1;19(1):49–55.

Chapter III. Food preferences and their perceived modifications before and after bariatric surgery: a cross sectional study

Guyot E, Dougkas A, Robert M, Nazare JA, Iceta S & Disse E. (Published paper DOI: 10.1007/s11695-021-05342-9).

Abstract

Introduction: Changes in food preferences, taste, and smell following bariatric surgery have been previously described but with inconsistent results. We aimed to describe current food preferences and their perceived changes before and after the surgery. We further compared food preferences based on the presence or absence of taste and smell alterations, to the duration of the follow-up (< 2 or ≥ 2 y) and to the success or failure of the procedure.

Materials and methods: This cross-sectional study was conducted with a self-administered online questionnaire. Two years was the cut-off between short and long-term follow-up. Success was defined as an Excess Weight Loss (EWL) greater or equal to 50%.

Results: In total 220 post-operative patients answered the questionnaire. Patients with taste alterations (64%) had significantly lower preferences for red meat, milk, cheese, desserts, fried foods and water (all $p < 0.05$) relative to the non-taste alteration group, while those with smell alterations (38%) had significantly lower preference for cheese only ($p < 0.05$) relative to the non-smell alteration group. Patients with a ≥ 2 y follow-up had a higher liking for desserts, fried foods, fat, bread, hot drinks and alcohol compared to patients with a < 2 y follow-up (all $p < 0.05$). Patients having success in surgery had higher liking scores for green vegetables and lower liking scores for starchy foods, milk, and sweet dairy products (all $p < 0.05$).

Conclusions: Our study suggests that patients who underwent bariatric surgery have different food preference patterns according to their sensory perceptions, the duration of their follow-up, and the success of bariatric surgery.

Keywords: Food preference; Olfaction; Gustation; Weight loss; Bariatric surgery.

3.1 Introduction

Bariatric surgeries were originally designed to restrict food intake and/or limit the absorption of ingested nutrients and ultimately caloric intake. However, changes in eating behavior, including a decrease in hunger, could be considered as one of the underlying mechanisms (1,2). Modifications in food preferences towards lower energy-dense foods (low fat, low sugar) have been reported following the surgery (3–5). Other food groups have also been affected by these postoperative changes in food preferences and might be involved in the success or the risk of the surgery. For instance, although an adequate protein intake is important to maintain fat-free mass in the first post-operative months (6), less than half of operated patients (7) do reach the minimum recommended daily intake of 60 g of protein (8). This low protein intake could reflect a low preference towards protein-rich foods after surgery, which could pose a post-operative nutritional risk of developing protein-energy malnutrition.

Sensory attributes of foods are known to influence food choices and consequently food preferences in the general population (9–11). Although recent systematic reviews demonstrated that changes in taste perception (12) and olfactory function (13) occur following bariatric surgery, the link between sensory alteration and post-operative food preferences remains poorly explored. Besides, a qualitative study showed that after a certain time following surgery it was more difficult for patients to maintain a healthy diet with some patients returning to their old habits (14), suggesting that food preferences may depend on the postoperative period. Thus, the role of food preferences in relation to weight loss success needs to be investigated.

We hypothesized that sensory alterations and post-operative follow-up duration could have an impact on patients' food preferences. Furthermore, we hypothesized that over a 2-year follow-up, food preferences would be different between patients achieving and those not achieving a successful degree of weight loss after surgery.

Our primary objective was to describe current food preferences and their perceived retrospective changes before and after the surgery among patients who underwent bariatric surgery. As secondary objectives, we compared food preferences between patients with and without taste or smell alterations, between patients with less and greater than 2 years of follow-up, and between patients in success or failure of bariatric surgery.

3.2 Material and methods

3.2.1 Study population

Participants older than 18 years who underwent a bariatric procedure were eligible to participate in this cross-sectional study. The recruitment was held from September to December 2019 using advertisements on social media and health care units, as well as email campaigns and invitations to health care professionals, Specialized Centers for Obesity, and patients' associations. Patients were invited to follow an internet link provided in the advertisement or email to access the information form and complete an anonymous self-report online questionnaire. Only those with fully completed questionnaires were included in the study. The study was approved by the Ethics Committee (2019-A00774-53) and was registered in Clinical Trials.gov (NCT03911115).

3.2.2 Data collection and calculations

An online questionnaire was developed specifically for this study (see Appendices 3.A and 3.B) using food categories typically found in food frequency questionnaires, sensory-related questions by the Taste and Smell Questionnaire (15), and adapting the modalities of the responses based on the paper by Lim (16). The questionnaire included different sections related to 1) bariatric surgery and weight history, 2) food exclusions and food preferences, 3) taste and smell alterations, 4) food rejections and 5) socio-demographic background. The questionnaire was distributed via WEPI 1.0 © Epiconcept 1996-2013 (www.wepi.org) and took about 15 minutes to complete.

We defined 3 modalities for the variable type of surgery: SG, RYGB and other bariatric procedures summarized as one group. The food exclusions for medical reasons, religious or personal beliefs were recorded with an open-ended question. Four-point liking scales ranging from "a lot" to "not at all" were used to assess current food preferences of 24 food items: red meat, white meat, fish, seafood, eggs, delicatessen, green vegetables, colored vegetables, legumes, starchy foods, milk, plain dairy products, sweet dairy products, cheese, fruits, dried fruits, dessert and sweets, fried foods, added fat, bread, still water, hot drinks, sweet drinks, alcohol. A food preference score was calculated based on the four-points liking scales ranging from 0 to 3. Patients when completing the questionnaire indicated the current preferences of the 24 food items but also if they liked those 24 food items similar to, less or more than before the

surgery. The answers were coded as 0, -1, and +1, respectively. Concerning taste and smell alteration, patients had to evaluate whether the tastes/smells of the food/drink changed since their surgery between “strongly agree” to “strongly disagree”. Participants were considered as those with taste/smell alteration if they ‘agree’ or ‘totally agree’ to have taste/smell modifications compared to before the surgery. In addition to these closed questions, patients could freely specify which food or smell was concerned. We defined that 2 years would be the threshold for comparing patients according to their follow-up time. The success of bariatric surgery was calculated for patients with at least 2 y of follow-up as a Percentage Excess Weight Loss (%EWL) $\geq 50\%$. Excess weight loss was calculated using the formula: $\%EWL = [(Initial\ Weight) - (Postop\ Weight)] / [(Initial\ Weight) - (Normal\ Weight)] \times 100$. Normal weight was calculated using a BMI of 25 kg.m⁻² (25). We recorded different types of ‘*food rejections*’ with three open-ended questions. Patients could write in text-words which foods / drinks they found 1) not appetizing (e.g., avoidance due to low palatability of the foods) 2) disgusting (e.g., avoidance due to a strong dislike) 3) unbearable (e.g., avoidance due to a conditioned taste aversion such as pain, nausea or blockage) at the time of completion of the questionnaire.

3.2.3 *Statistical analysis*

Socioeconomic characteristics of the participants and surgery outcomes were compared between patients with RYGB, SG and other types of bariatric surgery. Wilcoxon Rank-Sum tests were performed to compare food preferences between patients with or without self-reported taste / smell alteration, to compare food preferences between patients < 2 y follow-up (short-term follow-up) and patients ≥ 2 y follow-up (long-term follow-up) and to compare food preferences between patients in success or failure of their bariatric surgery. In addition, Pearson’s correlations were performed to further investigate the link between excess weight loss and food preferences.

Open-ended questions were analyzed with distribution frequencies. All statistical analyses performed were two-sided, with a Type I error set at 0.05. Qualitative data were analyzed using the frequency of citation among the responders. There were no missing data on the main outcome (food preferences). The statistical analysis for this paper was generated using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA).

3.3 Results

3.3.1 Sample characteristics and surgery outcomes

Among the 220 participants who answered the online questionnaire, 32% had an RYGB, 56% had an SG and 12% had other procedures (i.e., omega-loop gastric bypass (N=16), gastric band (N=6), fundoplication (N=2), banded gastric bypass (N=1), biliopancreatic derivation with duodenal switch (N=1), single anastomosis duodenum-ileal bypass (N=1)).

Table 3.1 shows the characteristics of the participants according to their bariatric procedure. There was no difference between participants with different bariatric surgery, except for age ($p=0.021$), physical inactivity ($p=0.0063$), and follow-up duration ($p=0.030$).

Table 3.1. Characteristics of the patients.

	All n = 220	RYGB n = 71	SG n = 122	Other procedure n = 27	<i>P</i>
Women (%)	89.6	93.0	88.5	85.2	0.33
Age (y)	41.0 (19.0- 68.0)	44.0 (25.0- 64.0)	39.0 (19.0- 67.0)	46.5 (20.0- 68.0)	0.021
Household (%)					0.27
Alone without a child	13.6	21.1	10.7	7.4	
Alone with child(ren)	5.5	5.6	5.7	3.7	
Living with a partner without a child	26.4	24.0	27.0	29.6	
Living with a partner with child(ren)	49.1	47.9	48.4	55.6	
Other	5.0	1.4	8.2	0.0	
Education level (%)					0.65
Postgraduate	62.7	66.2	61.5	59.3	
Undergraduate	30.0	24.0	32.8	33.3	
Secondary	5.0	7.0	4.1	3.7	
Employment (%)					0.55
Higher intellectual profession, manager, artisan, shopkeeper	19.1	21.1	17.2	22.2	
Employee, worker and intermediate occupation	60.5	57.8	64.7	48.2	
Unemployed, student or retiree	17.7	18.3	15.6	25.9	

Physical activity (%)					0.46
More than 30 min a day	60.9	60.6	59.0	70.4	
Less than 30 min a day	37.3	38.0	39.4	25.9	
Physical inactivity (%)					0.0063
Less than 7 h a day	57.7	47.9	58.2	81.5	
More than 7 h a day	40.9	50.7	41.0	14.8	
Smoking status (%)					0.76
Never smoked	70.5	66.2	71.3	77.8	
Former smoker	12.7	12.7	13.9	7.4	
Smoker	14.5	18.3	13.1	11.1	
Weight before the surgery (kg)	116.0 (77.7-221.0)	118.0 (83.0-199.0)	117.0 (91.0-221.0)	109.0 (77.7-162.0)	0.20
BMI before the surgery	42.3 (30.4-64.6)	43.4 (35.9-58.1)	42.1 (33.6-64.6)	42.6 (30.4-58.1)	0.23
Current body weight (kg)	81.0 (42.0-195.0)	78.0 (42.0-155.0)	82.0 (48.0-195.0)	76.5 (54.0-150.0)	0.27
Current BMI (kg.m ⁻²)	29.3 (17.4-57.0)	28.7 (19.2-46.2)	29.4 (17.4-57.0)	27.2 (22.6-53.8)	0.35
BMI loss (kg.m ⁻²) (mean ± SD)	13.3 ± 5.7	14.6 ± 5.9	12.9 ± 5.5	11.9 ± 5.2	0.055
Percentage Excess Weight Loss (%) (mean ± SD)	75.5 ± 30.6	78.9 ± 31.8	73.2 ± 30.5	77.0 ± 28.2	0.45
Current weight trajectory (%)					0.73
Weight loss	43.6	45.1	45.1	33.3	
Weight stable	44.1	40.8	43.5	55.6	
Weight regain	10.9	12.7	9.8	11.1	
Missing data	1.4	1.4	1.6	0.0	
Time since surgery (mo)	16.2 (0.1-229.1)	16.4 (0.1-212.5)	14.4 (0.3-101.5)	27.4 (3.8-229.1)	0.030

Abbreviations: BMI: Body mass index; SG: sleeve gastrectomy; RYGB: Roux-en-Y gastric bypass. Data are presented as median (range) unless noted otherwise. p values are for the differences between patients with RYGB, SG and other types of bariatric surgery on the basis of Kruskal–Wallis H test, Pearson’s χ^2 test or Fisher’s exact test.

3.3.2 Food preferences following bariatric surgery and perceived post-operative modifications

Figure 3.1 shows the current food preferences of the participants as well as the perceived change in food preferences after the surgery. The five most preferred food items at the time patients completed the questionnaire were green and colored vegetables, cheese, fruits and hot

drinks. The five least current preferred food items were fat, milk, fried foods, sweet drinks and alcohol.

Regarding the perceived modifications of food preferences prior relative to following the surgery, liking for high-fat high-sweet foods (i.e., fried foods, sweet drinks, fat, and desserts) decreased while preferences for healthier food options (i.e., fruits, vegetables, and fish) increased.

Concerning the food exclusions for medical, religious, or personal beliefs, 41 out of 220 patients indicated at least a single food exclusion. In total 64 food items were subject to exclusion. The frequency distribution indicates that the food items varied greatly, and most of the food items were cited only once (N=45). The other food items had respectively 2 (N=14), 3 (N=4) and 4 (N=1) occurrences.

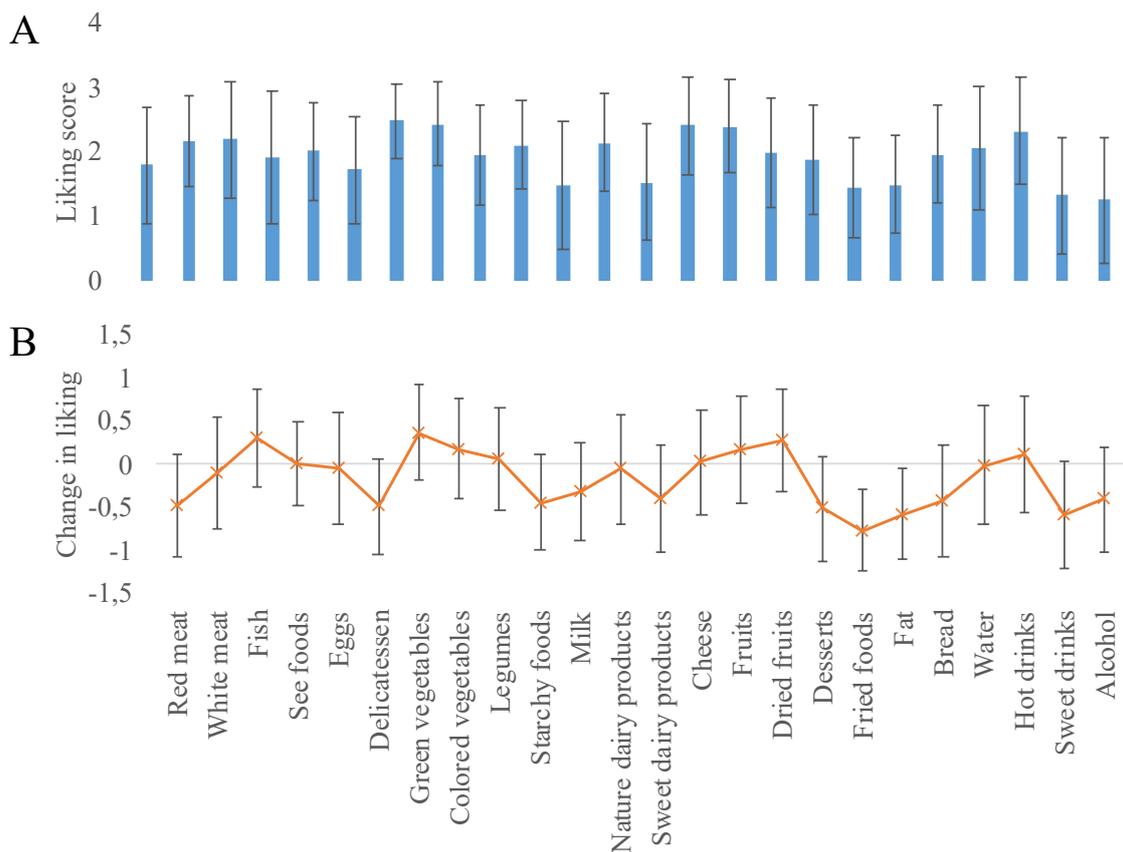


Figure 3.1. Description of food preferences and their postoperative perceived modifications among 220 participants with bariatric surgery.

Panel A. Liking scores for 24 food groups at the time of completion of the questionnaire. Higher score indicates higher liking. Panel B. Perceived modification in liking before and after bariatric surgery assessed at the time of completion of the questionnaire. A positive score indicates post-operative higher liking, a negative score indicates post-operative lower liking. Data are presented as mean (SD).

3.3.3 Food preferences between participants with and without taste or smell alterations

Among the 64% of patients who agreed or totally agreed that they had taste alterations, 53% presented an increase in taste perception. Odor change was reported by 38% of patients, who mainly indicated an increase in smell perception (77%). Only 32% of patients reported having no change in taste or odor (see Appendix 3.C for more details). The most common reported modifications of taste were for vegetables (n=15), fruits and meat (n=14), coffee (n=13), sweet (n=11), red meat and sweet products (n=9), cheese, fat and fruit juice (n=8), all foods and sweet drinks (n=7). The most common smell alterations were reported for fried foods (n=15), fish and meat (n=8), and all the foods (n=7). Changes after the surgery for 35 non-food odors, including bodily odors (n=8), were reported in the free comments.

Figure 3.2 panel A shows the differences in food preferences among patients with and without taste / smell alterations. Of importance, those with taste alterations had significantly lower preferences for red meat, milk, cheese, desserts, fried foods and water (all $p < 0.05$) relative to the non-taste alteration group, while those with smell alterations had a significantly lower preference for cheese only ($p < 0.05$) relative to the non-smell alteration group (Figure 3.2.B).

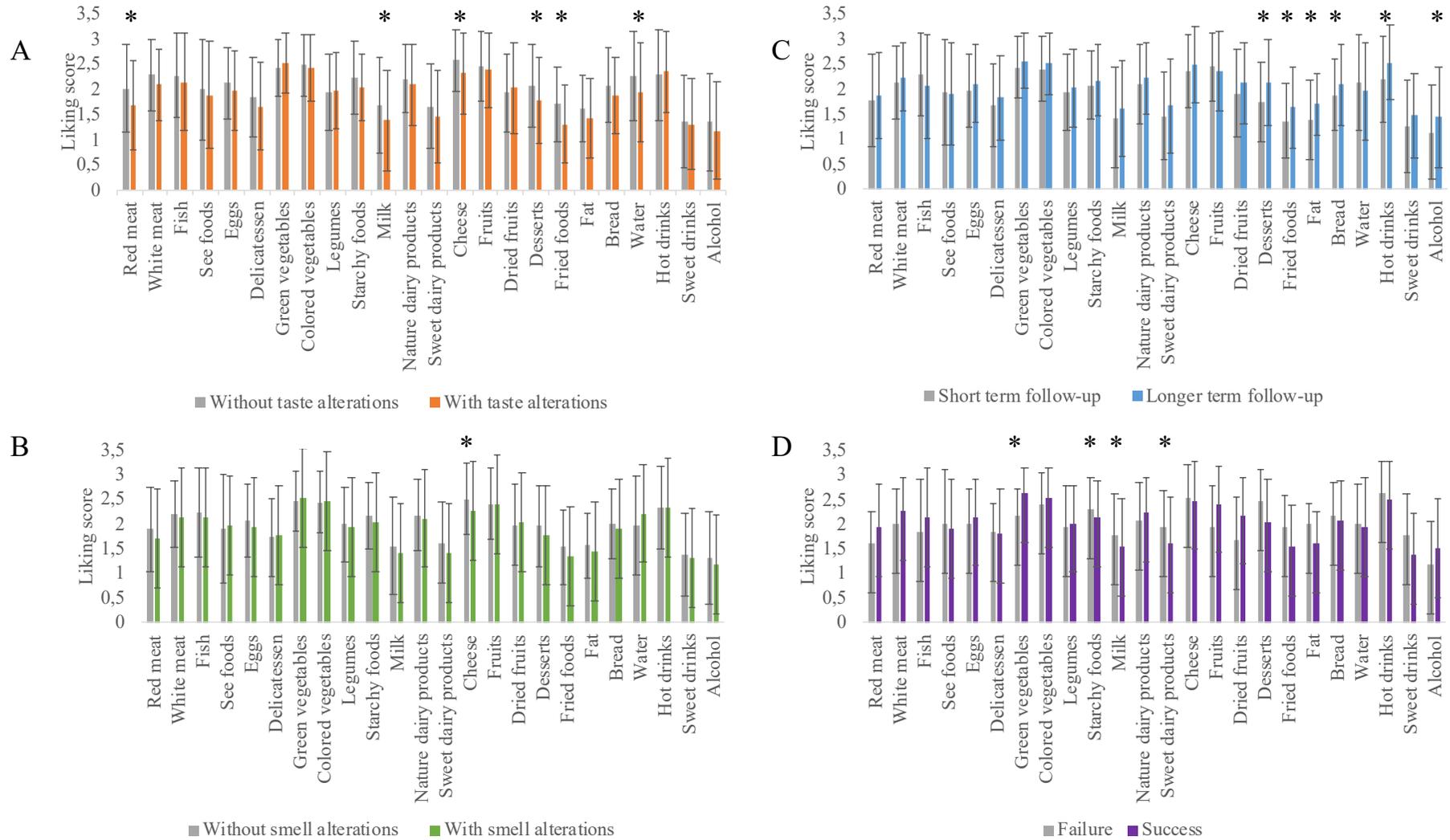


Figure 3.2. Comparison of liking scores between the patients with and without taste alterations (panel A, N=220), with and without smell alterations (panel B, N=220), in a short- and long-term follow-up (panel C, N=220) and in failure or success of bariatric surgery (panel D, N=81). A star indicates a significant difference between the groups ($p < 0.05$) on the basis of Wilcoxon Rank-Sum tests. Data are presented as mean (SD).

3.3.4 Food preferences according to the postoperative follow-up duration

As shown in Figure 3.2.C, participants in the long-term follow-up (≥ 2 y) had a higher liking for desserts, fried foods, fat, bread, hot drinks, and alcohol compared to patients in the short-term follow-up (< 2 y) (all $p < 0.05$).

3.3.5 Food preferences between patients in success and failure of bariatric surgery

Figure 3.2.D shows the food preference scores according to the success or failure of bariatric surgery among a sub-sample of 81 patients, who reached 2 years of follow-up. Patients with surgery success had higher liking scores for green vegetables and lower liking scores for starchy foods, milk, and sweet dairy products (all $p < 0.05$). Excess weight loss was positively correlated with liking for green vegetables ($r=0.17$, $p=0.040$) and alcohol ($r=0.20$, $p=0.013$) while it was negatively correlated with liking for starchy foods ($r=-0.24$, $p=0.0030$), milk ($r=-0.19$, $p=0.021$), sweet dairy products ($r=-0.16$, $p=0.0047$), and sweet drinks ($r=-0.19$, $p=0.017$).

3.3.6 Food rejections

Overall, 128 patients declared at least one food item as not appetizing. The most commonly cited items were fried foods (N=15), red meat (N=14), meat (N=9), bread (N=8), dishes with sauce (N=8), sweet drinks (N=7), alcohol, sparkling drinks, milk and French fries (all cited N=6) and cheese, soda, cake, fat and pastries (all cited N=5). Ninety-five patients found at least one food item as disgusting at the time of completion of the questionnaire. Red meat (N=7) and fried foods (N=6) were those most often reported. Finally, 103 patients reported unbearable foods, including pasta (N = 9), milk (N = 8), rice (N = 7), tomato (N = 6) and red meat (N = 5).

3.4 Discussion

To our knowledge, this is the first study that describes food preferences of patients who underwent bariatric surgery and compares these food preferences according to the presence or absence of taste and smell alterations, to the duration of the follow-up (< 2 or ≥ 2 y) and to the success or failure of the procedure.

Results showed that green and colored vegetables, cheese, fruits, and hot drinks were among the most preferred food items following bariatric surgery, while fat, milk, fried foods, sweet drinks, and alcohol were among the least preferred. Considering the modifications of food preferences, the reported liking for high-fat high-sweet foods (i.e., fried foods, sweet drinks, fat, and desserts) decreased while preferences for healthier food options (i.e., fruits, vegetables, and fish) increased compared to before the surgery. Our results are in line with other studies, which show a decreased preference for high-fat, high-carbohydrate foods and high-fat, high-sugar foods after SG (17) and a reduced interest in sweet and high-fat foods at 6 and 12 months after SG (18). Several studies showed that patients decrease their intake of foods high in fat and sweet after RYGB (19–21), whilst, others showed that there is no decrease in preference for high-fat, high-carbohydrate foods after RYGB (22) even when assessed with an ad-libitum buffet (23). We can speculate that these changes might be due to a conditional response secondary to learning as patients showed an increased awareness of the importance of healthier food choices following bariatric surgery (18).

By using a subjective questionnaire to characterize olfactory and gustatory function, we found that an increased taste and smell perception was reported by most and 38% of the participants, respectively. In addition, we found that patients with and without sensory alterations had different food preferences. Several studies used psychophysical testing to characterize the olfactory and gustatory function following bariatric surgery with inconsistent results. For instance, Hanci et al. showed that the olfactory function (threshold, detection and identification scores) improved over time (preoperative vs. 1, 3, and 6 mo; 1 vs. 3 and 6 mo; and 3 vs. 6 mo) following an SG (24). Holinski et al. found an improvement in both chemosensory functions, which were not significantly different to healthy controls 6 mo after bariatric surgery (25). However, Jurowich et al. showed a significant improvement in olfactory function following SG but not after RYGB (26). This result might be attributed to a lower baseline mean threshold, discrimination and identification score (TDI) among patients with SG (27.1 ± 3.9) comparatively to RYGB patients (32.6 ± 3.6) and controls (32.1 ± 5.3), which increased up to 31.1 ± 3.5 , 6 mo postoperatively (statistically significant change), while 6 mo scores were 34.1 ± 3.6 for RYGB and 30.8 ± 6.1 for controls (statistically non-significant changes). On the other hand, Enck et al. found no difference in olfactory function comparing before and 12 mo after SG (TDI 26.9 ± 6.0 and 27.6 ± 5.3 , respectively). Contrasted results were also found concerning sweet taste. While an increased sweet taste sensitivity has been reported in several studies (4,22,24,25), detection thresholds for sucrose appeared to remain

unchanged (27–29). Interestingly, in the study of Nielsen et al. the detection threshold for sweet taste decreased following both RYGB and diet-induced weight loss (30). Also, a recent meta-analysis showed that olfactory function was negatively correlated with body weight and that bariatric surgery improved olfactory function (13). The mechanisms underlying sensory alterations have not yet been clearly elucidated. One of the most highly cited plausible mechanism involves postoperative endocrine changes. For instance, ghrelin and leptin have shown their role in the modulation of olfaction (31). Another possible mechanism is through the vagus nerve as bariatric surgery implies denervation and remodeling of the vagal afferent synapses and vagal stimulation has been shown to improve olfaction (32).

Time since surgery is an important factor in considering the weight trajectory following bariatric surgery that could be potentially linked with food preferences. Long-term results can be estimated from 2 years of follow-up, thus, participants below and above 2 y of follow-up were compared. There was a higher appreciation of highly palatable foods after 2 years of follow-up. In agreement with our results, one study showed that the percentage of total energy intake from sweets and soda was significantly lower from preoperative intakes up to 2 y following RYGB (33). However, in this study, the consumption of milk and ice cream products remained significantly different compared to baseline up to 3 y.

Considering whether there is any link between food preferences and the success or failure of bariatric surgery, we found that successful bariatric patients had higher liking scores for green vegetables and lower liking scores for starchy foods, milk, and sweet dairy products. Our data support the idea that food preferences might play a role in the success of bariatric surgery and are supported by a recent study by Hubert et al., which showed that after 1 year of follow-up the patterns of liking were associated with healthier food choices (34). These results suggest that personalized long-term nutritional monitoring is necessary for patients.

In this study we measured different types of ‘food rejections’. Although most of the patients declared at least one food rejection, there were relatively few occurrences for each food item. Red meat was among the most rejected food items, which is in line with studies showing a decreased consumption of red meat (35,36). In addition, Trostler et al. found that red meat was avoided by most of the patients due to post-prandial discomfort (37). In our study, avoidance of high fat and high sweet was mostly attributed to low palatability or a strong dislike, while avoidance of pasta and rice was mainly attributed to a conditioned taste aversion. Our results are only partly in line with a recent review (2) which showed that the hypothesis of a

conditioned taste aversion caused by high-fat and high-carbohydrate meals is unlikely, but that patients are likely to have developed a conditioned taste avoidance (e.g., patients find foods high in fat and high in carbohydrates still palatable after bariatric surgery but reduce the ingested quantities). We hypothesize that rice and pasta might cause a conditioned taste aversion by being responsible for a post prandial discomfort or sickness.

This study has some limitations, especially its cross-sectional design, which cannot be used to infer causality concerning the studied parameters. Moreover, the changes in food preferences before and after bariatric surgery were assessed by the patients as they perceived them at the time of completion of the questionnaire. Thus, we cannot exclude possible memory bias given that the completion time was not standardized among our participants and was long for some of them (> 2 years). Finally, to avoid respondent fatigue and comply with sensitive personal data regulation, we chose to limit the number of items and not to assess all the parameters known to play a role in food preferences, including post-operative food intolerances, ethnicity, and complete medical history. However, we directly asked participants whether they excluded foods for medical, religious, or personal reasons. In addition, patients were able to answer 'not applicable' in the section of the questionnaire related to their food preferences. Our descriptive results are unlikely to be impacted by these aspects because frequencies of the distribution indicated that the results varied greatly among the patients and each declared food exclusion had few occurrences. However, future studies aiming at exploring the modifications before and after surgery should consider taking into account more potential confounding factors in their analyses and/or stratify the results based on pre-selected characteristics of the participants.

3.5 Conclusion

Perceived changes in food preference following bariatric surgery highlighted a decrease in liking for high-fat high-sweet foods and an increase in healthier options. Food preferences were different between patients with and without taste and smell alterations, and between patients in a short and long-term follow-up. Furthermore, food preferences differed in patients who achieved a successful weight loss relative to those who did not. Future research should develop an assessment tool for precision medicine in the bariatric field. Notably, the success or failure of bariatric surgery could be potentially predicted by monitoring several factors including frequent assessment of smell/taste alterations and food preferences before and during the follow-up phase, which needs to be confirmed in human intervention studies.

3.6 References

1. Seyfried F, Miras AD, Bueter M, Prechtel CG, Spector AC, le Roux CW. Effects of preoperative exposure to a high-fat versus a low-fat diet on ingestive behavior after gastric bypass surgery in rats. *Surg Endosc.* 2013 Nov;27(11):4192–201.
2. Al-Najim W, Docherty NG, Le Roux CW. Food intake and eating behavior after bariatric surgery. *Physiol Rev.* 2018 Jul 1;98(3):1113–41.
3. Kittrell H, Graber W, Mariani E, Czaja K, Hajnal A, Di Lorenzo PM. Taste and odor preferences following Roux-en-Y surgery in humans. Covasa M, editor. *PLoS One.* 2018 Jul 5;13(7):e0199508.
4. Burge JC, Schaumburg JZ, Choban PS, DiSilvestro RA, Flancbaum L. Changes in patients' taste acuity after Roux-en-Y gastric bypass for clinically severe obesity. *J Am Diet Assoc.* 1995 Jun;95(6):666–70.
5. Miras AD, le Roux CW. Bariatric surgery and taste: novel mechanisms of weight loss. *Curr Opin Gastroenterol.* 2010 Mar;26(2):140–5.
6. Dagan SS, Goldenshluger A, Globus I, Schweiger C, Kessler Y, Sandbank GK, et al. Nutritional Recommendations for Adult Bariatric Surgery Patients: Clinical Practice. *Adv Nutr An Int Rev J.* 2017 Mar 1;8(2):382–94.
7. Steenackers N, Gesquiere I, Matthys C. The relevance of dietary protein after bariatric surgery: What do we know? Vol. 21, *Current Opinion in Clinical Nutrition and Metabolic Care.* Lippincott Williams and Wilkins; 2018. p. 58–63.
8. Sherf Dagan S, Tovim T Ben, Keidar A, Raziel A, Shibolet O, Zelber-Sagi S. Inadequate protein intake after laparoscopic sleeve gastrectomy surgery is associated with a greater fat free mass loss. *Surg Obes Relat Dis.* 2017 Jan 1;13(1):101–9.
9. McCrickerd K, Forde CG. Sensory influences on food intake control: moving beyond palatability. *Obes Rev.* 2016 Jan 1;17(1):18–29.
10. Boesveldt S, Bobowski N, McCrickerd K, Maître I, Sulmont-Rossé C, Forde CG. The changing role of the senses in food choice and food intake across the lifespan. *Food Qual Prefer.* 2018 Sep 1;68:80–9.
11. Cox DN, Melo L, Zabarás D, Delahunty CM. Acceptance of health-promoting Brassica vegetables: The influence of taste perception, information and attitudes. *Public Health Nutr.* 2012 Aug;15(8):1474–82.
12. Ahmed K, Penney N, Darzi A, Purkayastha S. Taste Changes after Bariatric Surgery: a Systematic Review. *Obes Surg.* 2018 Oct;28(10):3321–32.
13. Peng M, Coutts D, Wang T, Cakmak YO. Systematic review of olfactory shifts related to obesity. *Obes Rev.* 2019 Feb 1;20(2):325–38.
14. Lynch A. “When the honeymoon is over, the real work begins.” Gastric bypass patients' weight loss trajectories and dietary change experiences. *Soc Sci Med.* 2016 Feb 1;151:241–9.
15. Rawal S, Hoffman HJ, Honda M, Huedo-Medina TB, Duffy VB. The Taste and Smell Protocol in the 2011–2014 US National Health and Nutrition Examination Survey (NHANES): Test–Retest Reliability and Validity Testing. *Chemosens Percept.* 2015 Sep 3;8(3):138–48.

16. Lim J. Hedonic scaling: A review of methods and theory. Vol. 22, Food Quality and Preference. Elsevier; 2011. p. 733–47.
17. Ammon BS, Bellanger DE, Geiselman PJ, Primeaux SD, Yu Y, Greenway FL. Short-Term Pilot Study of the Effect of Sleeve Gastrectomy on Food Preference. *Obes Surg.* 2015 Jun 26;25(6):1094–7.
18. Coluzzi I, Raparelli L, Guarnacci L, Paone E, Del Genio G, le Roux CW, et al. Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy. *Obes Surg.* 2016 Sep 7;26(9):2059–67.
19. le Roux CW, Bueter M. The physiology of altered eating behaviour after Roux-en-Y gastric bypass. *Exp Physiol.* 2014 Sep 1;99(9):1128–32.
20. Lissner L, Troiano RP, Midthune D, Heitmann BL, Kipnis V, Subar AF, et al. OPEN about obesity: Recovery biomarkers, dietary reporting errors and BMI. *Int J Obes.* 2007 Jun;31(6):956–61.
21. Munzberg H, Laque A, Yu S, Rezai-Zadeh K, Berthoud H-RR, Münzberg H, et al. Appetite and body weight regulation after bariatric surgery. *Obes Rev [Internet].* 2015 Feb 1 [cited 2020 Aug 1];16 Suppl 1(S1):77–90. Available from: <https://pubmed.ncbi.nlm.nih.gov/25614206/>
22. Bueter M, Miras AD, Chichger H, Fenske W, Ghatel MA, Bloom SR, et al. Alterations of sucrose preference after Roux-en-Y gastric bypass. *Physiol Behav.* 2011 Oct;104(5):709–21.
23. Nielsen MS, Christensen BJ, Ritz C, Rasmussen S, Hansen TT, Bredie WLPP, et al. Roux-En-Y Gastric Bypass and Sleeve Gastrectomy Does Not Affect Food Preferences When Assessed by an Ad libitum Buffet Meal. *Obes Surg.* 2017 Oct 14;27(10):2599–605.
24. Hanci D, Altun HH, Altun HH, Batman B, Karip AB, Serin KR, et al. Laparoscopic Sleeve Gastrectomy Improves Olfaction Sensitivity in Morbidly Obese Patients. *Obes Surg.* 2016 Mar 1;26(3):558–62.
25. Holinski F, Menenakos C, Haber G, Olze H, Ordemann J. Olfactory and Gustatory Function After Bariatric Surgery. *Obes Surg.* 2015 Dec;25(12):2314–20.
26. Jurowich CF, Seyfried F, Miras AD, Bueter M, Deckelmann J, Fassnacht M, et al. Does bariatric surgery change olfactory perception? Results of the early postoperative course. *Int J Colorectal Dis.* 2014;29(2):253–60.
27. Nance K, Eagon JC, Klein S, Pepino MY. Effects of Sleeve Gastrectomy vs. Roux-en-Y Gastric Bypass on Eating Behavior and Sweet Taste Perception in Subjects with Obesity. *Nutrients.* 2017 Dec;10(1).
28. Pepino MY, Bradley D, Eagon JC, Sullivan S, Abumrad NA, Klein S. Changes in taste perception and eating behavior after bariatric surgery-induced weight loss in women. *Obesity (Silver Spring).* 2014 May;22(5):E13-20.
29. Scruggs, Buffington, Jr C. Taste Acuity of the Morbidly Obese before and after Gastric Bypass Surgery. *Obes Surg.* 1994 Feb;4(1):24–8.
30. Nielsen MS, Andersen INSKK, Lange B, Ritz C, le Roux CW, Schmidt JB, et al. Bariatric Surgery Leads to Short-Term Effects on Sweet Taste Sensitivity and Hedonic Evaluation of Fatty Food Stimuli. *Obesity.* 2019 Sep;
31. Palouzier-paulignan B, Lacroix MC, Aimé P, Baly C, Caillol M, Congar P, et al.

- Olfaction under metabolic influences. *Chem Senses*. 2012 Nov;37(9):769–97.
32. Maharjan A, Wang E, Peng M, Cakmak YO. Improvement of olfactory function with high frequency non-invasive auricular electrostimulation in healthy humans. *Front Neurosci*. 2018 Apr 24;12(APR).
 33. Brolin RE, Robertson LB, Kenler HA, Cody RP. Weight Loss and Dietary Intake After Vertical Banded Gastroplasty and Roux-en-Y Gastric Bypass. *Ann Surg*. 1994;220(6):782–90.
 34. Hubert, Papasavas P, Stone, Swede, Huedo-Medina, Tishler, et al. Associations between Weight Loss, Food Likes, Dietary Behaviors, and Chemosensory Function in Bariatric Surgery: A Case-Control Analysis in Women. *Nutrients*. 2019 Apr 9;11(4):804.
 35. Ruiz-Tovar J, Bozhychko M, Del-Campo JM, Boix E, Zubiaga L, Muñoz JL, et al. Changes in Frequency Intake of Foods in Patients Undergoing Sleeve Gastrectomy and Following a Strict Dietary Control. *Obes Surg*. 2018 Jun 17;28(6):1659–64.
 36. Johnson LK, Andersen LF, Hofsø D, Aasheim ET, Holven KB, Sandbu R, et al. Dietary changes in obese patients undergoing gastric bypass or lifestyle intervention: a clinical trial. *Br J Nutr*. 2013 Jul 14;110(1):127–34.
 37. Trostler, Mann, Zilberbush, Avinoach, Charuzi. Weight Loss and Food Intake 18 Months following Vertical Banded Gastroplasty or Gastric Bypass for Severe Obesity. *Obes Surg*. 1995 Feb 1;5(1):39–51.

Chapter IV. Alterations in food reward following bariatric surgery

Guyot E, Disse E, Nazare JA, Oustric P, Robert M, Dougkas A & Iceta S. (Submitted).

Abstract

Introduction: The role of food reward (liking and wanting) in preferences of various and diverse food categories in relation to the type of bariatric surgery remains unexplored. In a cross-sectional design, we aimed to use a behavioral computerized task in a clinical setting to compare food reward between patients with a sleeve gastrectomy (SG) or a Roux-en-Y gastric bypass (RYGB) and non-operative patients with obesity (OB).

Materials and methods: We assessed food reward using an extensive and adapted version of the Leeds Food Preference Questionnaire (LFPQ). Binge eating, impulsivity and food addiction were assessed with self-report questionnaires. Statistical analysis of food preferences included ANOVAs.

Results: Eighty-six patients (30 OB, 30 SG and 26 RYGB) were included (women: 69%; age: 41.8 (1.3) y). The body mass index was 41.2 (4.0); 31.5 (3.7) and 31.3 (2.9) kg.m⁻² for patients with OB, SG and RYGB, respectively and the median post-operative follow up was 12 months. Liking score for ‘high fat – sweet foods’ was significantly different between non- and post-operative patients ($p < 0.001$). Overall, liking scores were significantly different between patients with obesity with or without bariatric surgery among all the studied food categories (all $p < 0.05$), except for foods low in fat – savory and foods with fibers – without sauce. The wanting scores were significantly different between groups of patients for ‘foods high in carbohydrates – fluid’, ‘dairy products – without color’ and ‘high fat – sweet foods’ (all $p < 0.05$).

Conclusion: In conclusion, there were no major differences in liking and wanting between SG and RYGB. Overall, the liking for a large range of food categories was lower among post-operative patients compared to non-operative patients with obesity, while wanting was lower among post-operative patients for 3 foods groups only, including palatable foods. The LFPQ could be clinically relevant to identify postoperative alterations in food reward and to guide caregivers to provide personalized advice to patients in the context of precision bariatric medicine.

Keywords: Food reward; Liking; Wanting; Food preferences; Bariatric surgery; Eating behavior.

3.7 Introduction

Bariatric surgery is considered the most effective treatment in case of obesity, to achieve sustained weight loss, reduce comorbidities and mortality (1–3). In France, the most commonly performed surgical techniques are sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) (4). These operations have a direct effect on food intake, including reducing ingested volume (5) and total energy intake (5,6), as well as reducing hunger and extending satiety (7). In addition, changes in food preferences have been reported after bariatric surgery (8–10).

Among the neural processes that are involved in post-operative modifications of food preferences, attention was drawn to the reward system, which is described as dysfunctional in the case of obesity (11,12). Food reward has been shown to have two distinct components (13). The first component is ‘liking’ and is related to the pleasure and the sensory properties of foods. The second component is ‘wanting’, which is related to the motivation and is defined as an implicit drive to eat. Interestingly, a post-operative decrease in neuronal activity in brain areas corresponding to the reward system have been described (14–18). However, there is a crucial need to better understand whether these changes in brain activity are translated into measurable changes in food reward at the individual level.

A study reported decreased hedonic ratings for foods high in fat, in carbohydrates, in sweet, high in fat and sweet, low in fat and high in carbohydrates, and low in fat and high in protein after a SG (19). Another study reported similar results using a food preference questionnaire (20). A study reported that liking and wanting scores based on a 5-point Likert type scale on the questions “How much do you want to eat this food now?” and “How much do you like this food in general?”, were diminished after a RYGB for foods high in fat using food pictures displayed during an fMRI paradigm (21). Interestingly, a decreased hedonic rating was found for foods low in fat – high in proteins after a SG (19), suggesting avoidance of protein-rich foods.

Those studies mainly focused on energy and macronutrient contents of foods (19–21). However, several factors including appearance, texture, taste and the nature of foods could influence food preferences in the general population (22) and in patients with a bariatric surgery (23). In addition, most of the studies so far failed to separate and explore the impact of the type of surgery on food preferences given that the analysis was conducted on only one type of surgery or by combining patients with different types of surgeries. To our knowledge, there is

no study that assessed ‘wanting’ as a component of food reward using a behavioral computerized task to compared patients with unoperated obesity, with SG, and with RYGB. Eventually, the role of the two components of the food reward (liking and wanting) in preferences of various and diverse food categories in relation to the type of bariatric surgery using a behavioral task remains unexplored.

The aim of the present study was to compare food reward for extended various food categories between patients who received different bariatric surgeries (SG and RYGB) and non-operative patients with obesity as controls (OB). To analyze food reward in the 3 groups of patients, the primary endpoint was the liking score for ‘high fat – sweet foods’ using the Leeds Foods Preference Questionnaire (LFPQ) as described below. The secondary endpoints were liking and wanting scores for all the studied food categories using the LFPQ, food choices and fat and sweet appeal bias.

3.8 Material and Methods

3.8.1 Subjects

Patients hospitalized for an obesity multidisciplinary evaluation or a post-bariatric surgery follow-up (6, 12 or 24 months after a SG or a RYGB) were eligible. Inclusion criteria were: age between 18 to 65 years old, BMI between 18.5 and 60 kg.m⁻² with a minimum of 35 kg.m⁻² for the OB group. Patients with psychiatric co-morbidities, under psychotropic treatments or having food evictions, as well as those unable to give their consent and understanding French were excluded. This study was approved by a national ethic Committee (2017-A02953-50, on January 16th, 2018) and was registered in Clinical Trials.gov (NCT03486210).

3.8.2 Data collection and calculations

Food reward

Among the various tools that exist to measure food reward, we have used the LFPQ (24) (Figure 4.1) as it has been widely validated against actual food selection (25–28).

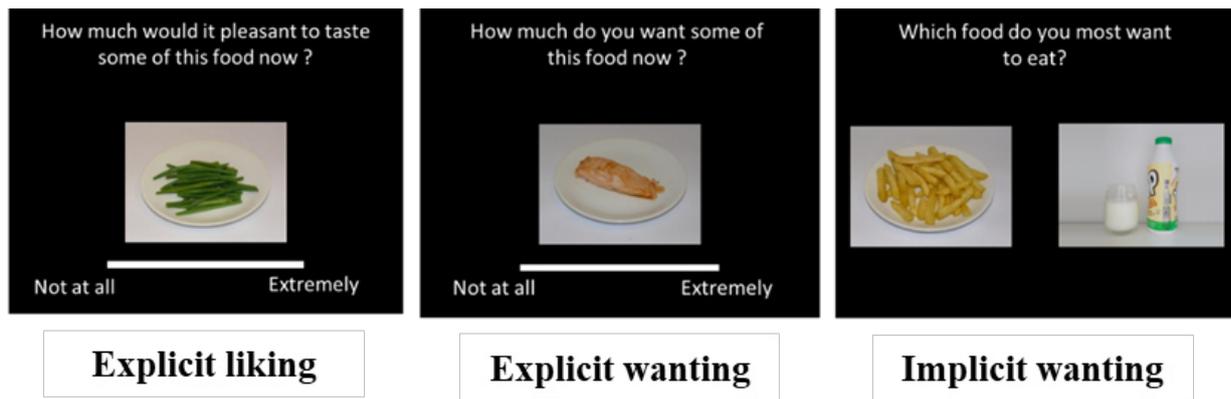


Figure 4.1. Leeds Food Preference Questionnaire.

The LFPQ is practical as it allows to assess explicit liking, explicit and implicit wanting, food choices and taste and sweet appeal bias at the same time. Explicit liking was measured using Visual Analog Scales (VAS) on the question “How pleasant would it be to taste some of this food now?”. Explicit wanting was assessed with the question « How much do you want some of this food now?”. Implicit wanting was computed using a forced choice task during which a spontaneous choice must have been made between all combinations of food items presented consecutively in pairs. A wanting score for a given food category is calculated from the frequency of choice and non-choice of this food category and the reaction time of the participants (29). This score ranges between -100 and 100 and must be interpreted in relation to the scores of the other food categories evaluated in the task. A positive score indicates that the considered food category was chosen more often and faster than the others. A negative score indicates the opposite. Food choices (e.g., relative preferences), correspond to the mean frequency of selection of each food category (29). Finally, the appeal biases allow the effect of fat and sweet to be studied separately. Fat and sweet appeal bias are calculated by subtracting the mean low-fat scores from the mean high-fat scores and the mean savory from the mean sweet scores, respectively (29).

The original LFPQ uses food pictures varying along two dimensions: fat (high and low) and taste (sweet and savory) (29). We have decided to use the version of Van der Meij (30). Although it was initially intended for use among the elderly, this version seemed relevant to explore food preferences among bariatric patients. In particular, it was composed of 6 tasks which allowed us to assess liking and wanting for 11 food categories varying in nutritional composition (high/low in carbohydrates, high/low in fat, high/low in protein, dairy/nondairy, with/without fiber, with/without meat) and/or in taste (savory/sweet), appearance (with/without color, with/without variation, with/without sauce) and texture (solid/fluid) (Table 4.1). These

food categories were combined within a task (i.e., high fat – sweet, high fat – savory, low fat – sweet, low fat – savory).

Table 4.1. Dichotomous food categories tested with the LFPQ.

Task	Studied dimensions	Combined food categories
1	High carbohydrates (HC) / Low carbohydrates (LC) Solid (SO) / Fluid (FL)	HC-SO
		HC-FL
		LC-SO
		LC-FL
2	Dairy (DA) / Nondairy (ND) Color (CO) / No color (NC)	DA-CO
		DA-NC
		ND-CO
		ND-NC
3	High fat (HF) / Low fat (LF) Savory (SA) / Sweet (SW)	HF-SA
		HF-SW
		LF-SA
		LF-SW
4	Fiber (FI) / No fiber (NF) Sauce (SC) / No sauce (NS)	FI-SC
		FI-NS
		NF-SC
		NF-NS
5	Meat (ME) / No meat (NM) High fat (HF) / Low fat (LF)	ME-HF
		ME-LF
		NM-HF
		NM-LF
6	High protein (HP) / Low protein (LP) Variation (VA) / No variation (NV)	HP-VA
		HP-NV
		LP-VA
		LP-NV

The tasks were administered to patients in a random order. Task 3 corresponds to the original LFPQ.

We adapted this version for its use in a French population by translating the instructions from English to French and adapting food items to reflect French eating habits (29). To validate the new set of food pictures, we asked 20 health professionals specialized in nutrition or dietetics and 20 non-specialized counterparts whether the food pictures correspond to what they can eat in France?" using a 9-point Likert-type scale where 1 represented 'Not at all', and 9 'Extremely'. Food items with a score less than or equal to 5 was considered not representative of French eating habits and were replaced again. The list of food items used is available in Appendix 4.A.

Behavioral assessment

Binge eating and its severity was assessed using the French version (31) of the Binge Eating Scale (BES) (32), which has already been used in the context of bariatric surgery (33). This 16-items self-administered scale explores characteristics of behavioral, emotional and cognitive manifestations of binge eating. An individual dimensional score is obtained by summing the score of each items, offering a possible range from 0 to 46 (the higher the score the more severe the binge eating disorder) (32). It is also possible to use a categorical score, where a score greater than or equal to 18 indicates a binge eating disorder (32). In our sample, the BES displayed a good internal consistency with a Cronbach's $\alpha = 0.86$.

Food addiction was detected using the French version (34) of the Yale Food Addiction Scale 2.0 (YFAS) (35). The YFAS has been validated for its use in a bariatric population (36). This 35-items self-administered questionnaire is designed to assess the symptoms and severity of food addiction over the past 12 months. Patients were asked to respond based on what best described their eating habits during this period. Each item is measured with an 8-point Likert-type scale ranging from 0 ("Never") to 7 ("Everyday"). A symptom criterion of food addiction is scored as 1 when 1 item or more under this criterion symptom is scored as 1. Criterion 12, assessing clinical significance, is not included in the count score, offering a possible number of symptoms of food addiction from 0 to 11. Food addiction is diagnosed when the number of food addiction is greater or equal to 2 and when the criterion 12 is scored as 1. Moreover, the severity of food addiction can be defined as followed: 2 to 3 criteria indicate a mild food addiction, 4 to 5 criteria indicate a moderate and 6 or more criteria indicate a severe food addiction. In our sample, internal consistency was good with a Cronbach's $\alpha = 0.86$.

Impulsive behavior was assessed with the short French Impulsive Behavior Scale (UPPS-P) (37). This 20-items self-report scale explores 5 facets of impulsivity: 'positive urgency', 'negative urgency', 'lack of premeditation', 'lack of perseverance' and 'sensations seeking'. Each item is measured in a 4-point Likert-type scale ranging from 1 ("I agree strongly") to 4 ("I disagree strongly"). The score of each facet of impulsive behavior correspond to the sum of individual item score with a possible range from 4 to 16. In our sample, overall Cronbach's $\alpha = 0.83$.

Other covariates

Information on gender, age, preoperative and current body weight and body mass index (BMI) kg.m^{-2} was collected based on the medical record of the patients. Weight loss was calculated as the preoperative body weight minus the current body weight. BMI loss was calculated as the preoperative BMI minus the current BMI. Excess weight loss was calculated using the formula: $\%EWL = [(Initial\ Weight) - (Postop\ Weight)] / [(Initial\ Weight) - (Normal\ Weight)] \times 100$. Normal weight was calculated using a BMI of $25\ \text{kg.m}^{-2}$ (25). Having a budget constraint to purchase foods and smoking status were self-reported by the patients. Ratings of hunger, fullness and desire to eat were assessed immediately prior to processing the LFPQ using visual analog scales (100 mm) from ‘Not at all’ to ‘Extremely’ of the following questions: “How hungry do you feel now?”, “How full do you feel now?” and “How strong is your urge to eat now?”. Time since the last meal was also recorded.

3.8.3 Sample size calculation

The primary endpoint of the study (liking score for ‘high fat – sweet foods’), was compared between the three groups of patients using an ANOVA test. We assumed that the group of patients with OB would have similar values as those typically observed in a hungry condition (29). A sample size of 27 patients per group was calculated as sufficient with a risk alpha set at 5% and a power of 80% to detect a difference of 15 points in 0 to 100 liking scale. We had to recruit up to 30 patients per group ($n = 90$) to compensate for missing data for the main outcome.

3.8.4 Statistical analyses

General characteristics, appetite sensations and time since the last meal of patients with OB, SG and RYGB were compared using ANOVAs, Pearson’s, χ^2 test or Fisher’s exact test as appropriate. Mann-Whitney U test was performed to compare non-normal continuous variable (i.e., time since the surgery) between patients with SG and RYGB.

The primary endpoint (liking for ‘high fat – sweet foods’) and the secondary endpoints (liking and wanting scores for all the studied food categories) were compared between OB, SG and RYGB patients using ANOVAs with further adjustment for hunger, fullness, time since the last meal and the interaction between group of patients and these 3 variables. Food choices and

fat and sweet appeal bias were compared between the 3 groups of patients using ANOVAs. When relevant, Tukey's post-hoc tests were performed to adjust for multiple comparisons.

In the present study, patients having a wanting score < -100 and > 100 were considered as outliers and were excluded from the analyses. Missing data for food preferences and covariates were excluded from the multivariate analyses.

Sensitivity analyses were performed to compare liking for the studied food groups between OB and operated patients (SG and RYGB merged into one group), who had a hunger level greater than 50 out of 100. Moreover, among the operated patients, we compared liking and wanting scores between patients at 6-, 12- and 24-month follow-up.

Pearson's correlations were performed to study the link between food reward for 'high fat – sweet foods' and behavioral traits (binge eating, food addiction and impulsivity).

Data are presented as mean (SEM), least squares mean (SEM) or median (IQR). All the statistical analyses were conducted using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). All tests of significance were two sided and $p < 0.05$ was considered significant.

3.9 Results

3.9.1 Characteristics of the subjects

Eighty-six patients (30 OB, 30 SG and 26 RYGB) out of 90 were included in the study. Table 4.2 shows the characteristics of the patients according to their group.

Table 4.2. Socioeconomic and behavioral characteristics of the 86 included patients according to their operative status.

	All n = 86	OB n = 30	SG n = 30	RYGB n = 26	P
Sociodemographic data					
Women (%)	68.6	56.7	76.7	73.1	0.21
Age (yr)	41.8 (1.3)	37.9 (2.6) ^a	38.3 (1.7) ^a	50.5 (1.8) ^b	<.0001
Smoking status (%)	17.4	13.3	20.0	19.2	0.82
Food budget constraint (%)	12.8	10.0	10.0	19.23	0.56

Reported Anthropometric data					
Preoperative weight (kg)	120.9 (23.4)	119.2 (4.0)	127.3 (5.1)	115.4 (3.3)	0.15
Preoperative BMI (kg.m ⁻²)	42.7 (0.6)	41.2 (1.0) ^a	45.5 (1.1) ^b	41.4 (1.1) ^a	0.0058
Postoperative body weight (kg)	-	-	88.2 (3.7)	87.3 (2.9)	<.0001
Postoperative BMI (kg.m ⁻²)	-	-	31.5 (0.8)	31.3 (0.9)	<.0001
EWL (%)	-	-	70.4 (2.9)	64.7 (4.6)	0.31
Appetite sensations					
Mean hunger (mm)	31.0 (3.3)	52.0 (5.6) ^a	20.8 (5.2) ^b	19.2 (4.2) ^b	<.0001
Mean fullness (mm)	57.8 (3.4)	29.8 (5.3) ^a	69.0 (5.0) ^b	67.8 (5.7) ^b	<.0001
Mean desire to eat (mm)	33.3 (3.3)	29.2 (5.4) ^a	21.6 (5.2) ^b	20.4 (3.9) ^b	<.0001
Time since last meal (min)	321 (41)	676 (66) ^a	154 (43) ^b	109(37) ^b	<.0001
Binge eating					
Binge eating score	8.7 (0.8)	14.2 (1.3) ^a	4.2 (0.8) ^b	7.6 (1.3) ^b	<.0001
No binge-eater (%)	82.6	70.0	96.7	80.8	0.010
Binge-eater (%)	12.8	26.7	0.0	11.5	
Moderate (%)	11.6	23.4	0.0	11.5	
Severe (%)	1.2	3.3	0.0	0.0	
Food addiction					
Nb of symptoms	1.6 (0.2)	1.9 (0.5)	1.0 (0.3)	1.8 (0.3)	0.27
No food addiction (%)	77.9	73.3	76.7	84.6	0.48
Food addiction (%)	15.1	20.0	13.3	11.5	
Light (%)	7.0	3.3	10.0	7.6	
Moderate (%)	3.5	6.7	3.3	0.0	
Severe (%)	4.6	10.0	0.0	3.9	
Impulsivity					
Positive urgency	10.1 (0.3)	10.3 (0.5)	9.6 (0.5)	10.5 (0.5)	0.40
Negative urgency	9.6 (0.3)	9.6 (0.6)	9.1 (0.4)	10.1 (0.5)	0.44
Lack of premeditation	7.2 (0.24)	7.4 (0.5)	7.0 (0.3)	7.0 (0.4)	0.70
Lack of perseverance	6.2 (0.2)	6.3 (0.5)	6.0 (0.3)	6.1 (0.3)	0.88
Sensations seeking	9.3 (0.3)	8.9 (0.6)	9.7 (0.5)	9.4 (0.5)	0.50

Abbreviations: OB: non-operative patients with obesity; SG: group with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass. Data are presented as mean (SEM), or median (interquartile range). p values are for the differences between patients with OB, SG and RYGB on the basis of Student's t-test, ANOVAs, Pearson's χ^2 test, Fisher's exact test or Mann-Whitney U test, as appropriate. a,b mean values within a row with different superscript letters were significantly different (P<0.05) followed by Tukey's post-hoc test. * indicates that for the 20 patients at 6 months of bariatric surgery follow-up, this also reflects 6 months before surgery.

Overall, 69% of the patients were women. Patients with a RYGB were significantly older (50.5 (1.9) y) compared to those with a SG (38.3 (9.6) y) and those with OB (37.9 (14.0) y). Patients with SG had a significant higher preoperative BMI compared to those with OB and RYGB. The follow-up time after bariatric surgery was 12 (6-24) months for both post-operative groups, with 20, 17 and 19 patients at 6, 12, and 24 mo of follow-up respectively.

Patients in the OB group had higher hunger and desire to eat ratings and lower fullness ratings compared to those with bariatric surgery. It should be noted that the time between the last meal and the LFPQ test was significantly longer in the OB patients compared to post-operative patients. In total, 26.7% of patients in the OB group while none of the patients with SG and only 11.5% of patients with RYGB had a binge eating disorder. There was no difference in food addiction or impulsivity scores among the studied groups of patients.

Overall, there was less than 5% missing data for the socioeconomic and behavioral characteristics of the participants, with the exception of food addiction where it was 7.0%.

3.9.2 Relationship between explicit liking for foods and bariatric surgery

Explicit liking scores are presented in Figure 4.2 and Appendix 4.B. Explicit liking scores for ‘high fat – sweet foods’ (OB: 57.1 (4.7); SG: 26.4 (4.7); RYGB: 23.2 (5.0)) were significantly different between the groups of patients ($p < 0.0001$). This difference remained significant after adjusting the model for hunger, fullness, time since the last meal and their interaction with the group of patients ($p < 0.0001$).

Considering all the studied food categories, adjusted explicit liking scores were significantly different between OB, SG and RYGB patients (all $p < 0.05$) except for foods ‘high in carbohydrates – fluid’, ‘low in carbohydrates – fluid’, ‘dairy products – without color’ and ‘foods with fibers – without sauce’.

Detailed results of post-hoc tests are shown in Appendix 4.B. Overall, patients with a bariatric surgery had lower explicit liking scores compared to patients with obesity. However, some differences between the two types of surgeries should be noted. Especially, patients with RYGB had significantly lower explicit liking scores for ‘low fat – sweet foods’, compared to patients with SG ($p < 0.05$).

When conducting sensitivity analysis in the sub-group of patients having a hunger level greater than 50 out of 100 (N=22), we found that explicit liking for 'high fat-sweet foods' ($p=0.028$) and 'foods without meat-high in fat' ($p=0.023$) was significantly higher among OB (N=13) than operated patients (N=9). There was no difference in explicit liking between operated patients at 6, 12 and 24 mo.

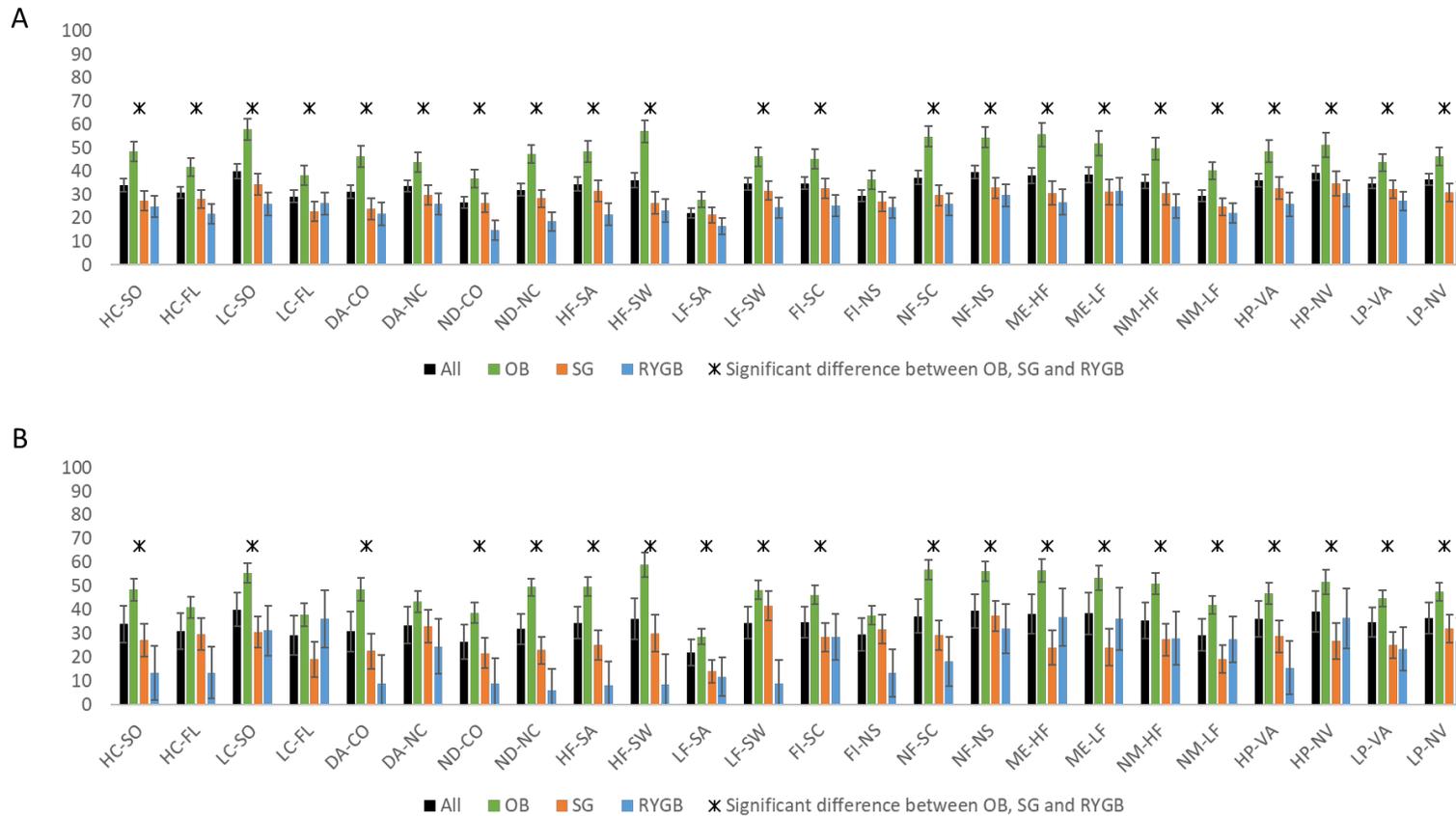


Figure 4.2. Comparison of explicit liking scores between OB, SG and RYGB patients.

Abbreviations: CO, color; DA, dairy; FI, fiber; FL, fluid; HC, high carbohydrate; HF, high fat; HP, high protein; LC, low carbohydrate; LF, low fat; LP, low protein; ME, meat; NC, no color; ND, nondairy; NF, no fiber; NM, no meat; NS, no sauce; NV, no variation; OB: non-operative patients with obesity; SA, savory; SC, sauce; SG: group of patients with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass; SO, solid; SW, sweet; VA, variation. Data are presented as mean (SEM) or least square mean (SEM). p values are for the differences between patients with OB, SG and RYGB on the basis of ANOVAs unadjusted (panel A) or adjusted (panel B) for hunger, fullness, time since the last meal, interaction between group of patients and hunger, interaction between group of patients and fullness, and interaction between group of patients and time since the last meal.

3.9.3 *Relationship between explicit wanting for foods and bariatric surgery*

Analyses of explicit wanting gave similar results to the comparison of explicit liking. There was a significant difference between patients with obesity, SG and RYGB for all the studied food groups, except for '*low fat – savory foods*' (see Appendix 4.B for more details).

3.9.4 *Relationship between implicit wanting for foods and bariatric surgery*

Figure 4.3 and Appendix 4.B shows the implicit wanting scores. Regarding the unadjusted scores, there was a significant difference between OB, SG and RYGB patients for '*foods low in carbohydrates – fluid*', '*dairy products – without color*', and '*foods high in fat – sweet*' (all $p < 0.05$).

Similar results were obtained even after adjustment for hunger, fullness, time since the last meal and the interaction between group of patients and these variables except that the implicit wanting scores for '*foods high in fat – sweet*' between the groups of patients was of borderline significance ($p = 0.052$) and implicit wanting scores for '*foods low in fat – sweet*' was significant ($p = 0.015$).

Post-hoc tests are available in Appendix 4.B and revealed that patients with OB or SG had lower implicit wanting scores for '*foods low in carbohydrates – fluid*' than patients with RYGB ($p = 0.028$); patients with OB had lower implicit wanting scores for '*dairy products – without color*' than patients with SG or RYGB; and that patients with OB or RYGB had lower wanting scores for '*foods low in fat – sweet*' than patients with SG. More precisely, post-operative patients had a positive implicit wanting score for '*dairy products – without color*' and a negative implicit wanting score for '*high fat – sweet foods*' whereas it was the opposite for patients in the OB group. This means that '*high fat – sweet foods*' were more often rejected relatively to the other food categories by post-operative patients, while they were more often chosen relative to the other food categories by non-operative patients with obesity. Interestingly, even if not significant, a different pattern with a negative wanting score for post-operative patients and a positive score among patients with OB was also seen for 5 other food categories, such as '*foods high in carbohydrates – solid*'.

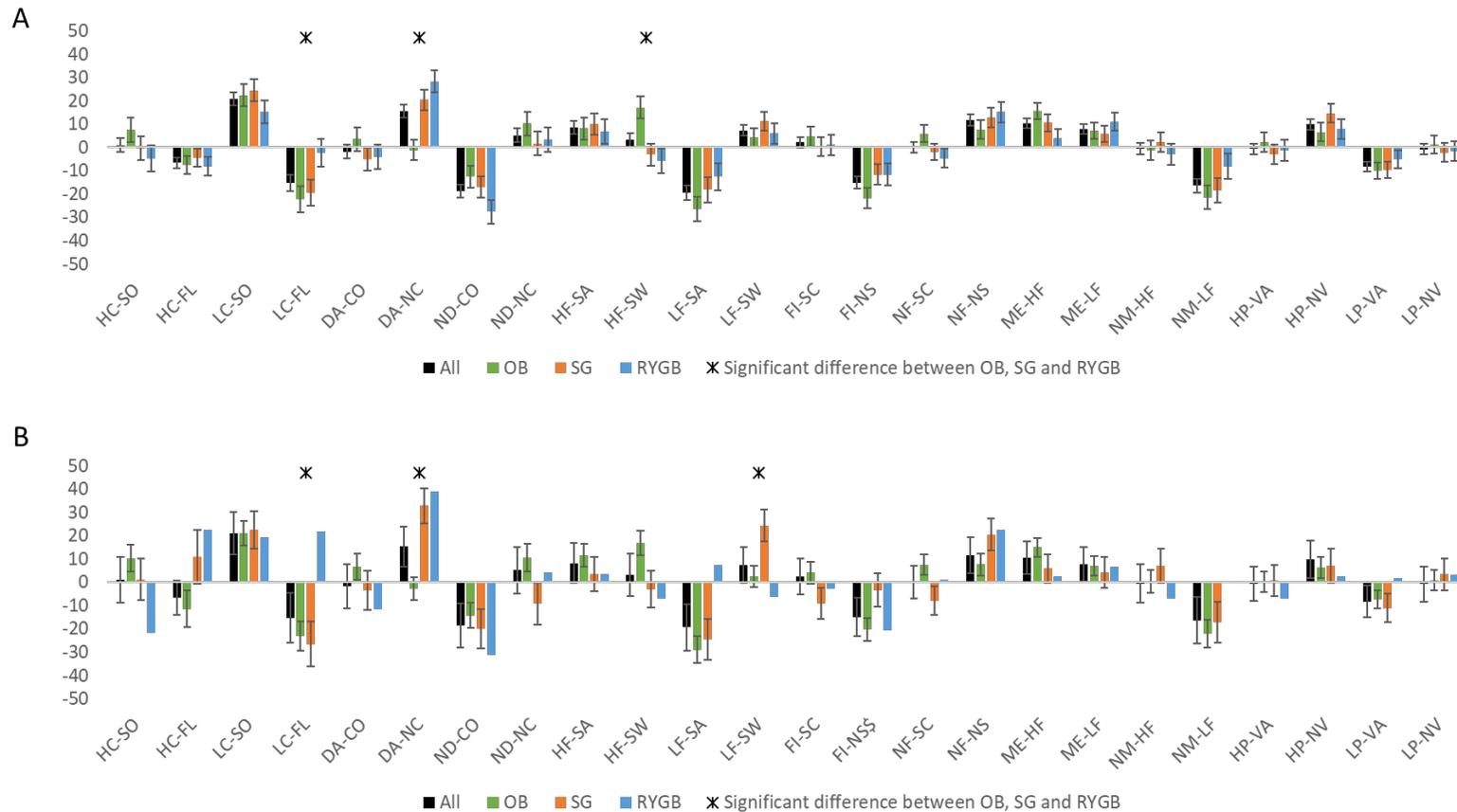


Figure 4.3. Comparison of implicit wanting scores between OB, SG and RYGB patients.

Abbreviations: CO, color; DA, dairy; FI, fiber; FL, fluid; HC, high carbohydrate; HF, high fat; HP, high protein; LC, low carbohydrate; LF, low fat; LP, low protein; ME, meat; NC, no color; ND, nondairy; NF, no fiber; NM, no meat; NS, no sauce; NV, no variation; OB: non-operative patients with obesity; SA, savory; SC, sauce; SG: group of patients with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass; SO, solid; SW, sweet; VA, variation. Data are presented as mean (SEM) or least square mean (SEM). p values are for the differences between patients with OB, SG and RYGB on the basis of ANOVAs unadjusted (panel A) or adjusted (panel B) for hunger, fullness, time since the last meal, interaction between group of patients and hunger, interaction between group of patients and fullness, and interaction between group of patients and time since the last meal.

3.9.5 Relationship between food choices and bariatric surgery

The results are displayed in Table 4.3. There were no significant differences in food choices between OB, SG and RYGB patients, except for '*dairy products – without color*', '*high fat – sweet foods*' and '*low fat – savory foods*'. Post-hoc tests indicated that patients with OB chose less '*dairy products – without color*' compared to operated patients. It was the opposite for '*high fat – sweet foods*'. Finally, patients with RYGB chose more the '*low-fat – savory foods*' compared to Ob and SG patients.

Table 4.3. Comparison of food choices between patients with OB, SG and RYGB.

	All n=86	OB n=30	SG n=30	RYGB n=26	p-value
Food choices					
High carbohydrate – solid	23.9 (1.1)	25.7 (2.0)	23.8 (1.9)	22.0 (1.9)	0.42
High carbohydrate – fluid	21.9 (0.9)	21.8 (1.5)	22.6 (1.3)	21.2 (1.8)	0.81
Low carbohydrate – solid	31.6 (1.0)	32.4 (1.5)	32.7 (1.8)	29.4 (2.0)	0.37
Low carbohydrate – fluid	18.6 (1.3)	16.1 (1.9)	17.0 (2.2)	23.4 (2.4)	0.051
Dairy products – color	23.8 (1.1)	25.9 (1.9)	22.5 (1.7)	22.8 (1.9)	0.34
Dairy products – no color	29.7 (1.1)	23.9 (1.7) ^a	31.4 (1.7) ^b	34.7 (1.6) ^b	<.0001
Nondairy products – color	16.7 (1.1)	19.0 (2.1)	17.5 (1.7)	13.2 (1.6)	0.079
Nondairy products – no color	25.7 (1.1)	27.2 (1.7)	24.6 (1.7)	25.3 (2.2)	0.59
High fat – savory	27.6 (1.0)	27.2 (1.7)	27.9 (1.9)	27.7 (1.7)	0.96
High fat – sweet	25.2 (1.1)	30.1 (1.9) ^a	23.2 (1.7) ^b	21.9 (1.9) ^b	0.0034
Low fat – savory	16.5 (1.0)	13.0 (1.3) ^a	17.4 (1.9) ^{ab}	19.6 (1.6) ^b	0.019
Low fat – sweet	26.7 (0.8)	25.7 (1.5)	27.5 (1.3)	26.9 (1.3)	0.62
Fiber – sauce	25.3 (0.8)	26.0 (1.6)	25.0 (1.3)	24.8 (1.4)	0.82
Fiber – no sauce	18.7 (1.0)	17.0 (1.7)	19.1 (1.7)	20.2 (1.7)	0.42
No fiber – sauce	24.0 (0.8)	26.5 (1.4)	23.1 (1.2)	22.3 (1.7)	0.083
No fiber – no sauce	28.0 (0.8)	26.5 (1.5)	28.8 (1.3)	28.8 (1.3)	0.41
Meat – high fat	27.4 (0.9)	29.8 (1.3)	27.5 (1.3)	24.7 (1.7)	0.053
Meat – low fat	27.3 (0.8)	27.1 (1.3)	26.4 (1.6)	28.5 (1.3)	0.56
No meat – high fat	23.9 (0.9)	23.5 (1.5)	24.9 (1.7)	23.2 (1.5)	0.72
No meat – low fat	17.3 (1.0)	15.5 (1.9)	17.2 (1.7)	19.6 (1.7)	0.29
High protein – variation	24.1 (0.8)	24.7 (1.4)	23.6 (1.5)	24.0 (1.3)	0.84
High protein – no variation	28.0 (0.8)	27.0 (1.5)	29.3 (1.6)	27.7 (1.2)	0.53
Low protein – variation	20.7 (0.8)	19.8 (1.6)	20.9 (1.4)	21.4 (1.0)	0.68
Low protein – no variation	23.2 (0.8)	24.5 (1.5)	22.3 (1.4)	22.9 (1.1)	0.50

Data are presented as mean (SEM). Different superscript letters within a row indicates a significant difference ($p < 0.05$) using Tukey's post-hoc test.

3.9.6 Relationship between fat and sweet appeal bias and behavioral traits

Table 4.4 shows the results related to the fat and sweet appeal bias scores. The fat appeal bias scores were all significantly different between patients with OB, SG and RYGB. Post-hoc tests revealed that the operated patients had lower scores compared to unoperated patients. This means that OB patients had a higher appeal for 'high-fat foods' compared to operated patients. Concerning the sweet appeal bias, the analyses revealed a significant difference between the groups for explicit wanting only.

Table 4.4. Comparison of fat and sweat appeal bias between OB, SG and RYGB patients.

	All n=86	OB n=30	SG n=30	RYGB n=26	p-value
Fat appeal bias					
Explicit liking	7.0 (1.7)	15.8 (3.3) ^a	2.5 (2.2) ^b	1.9 (2.2) ^b	0.0003
Explicit wanting	6.2 (1.7)	16.1 (3.4) ^a	1.7 (2.0) ^b	-0.1 (1.8) ^b	<.0001
Implicit wanting	13.5 (4.7)	29.9 (7.2) ^a	6.9 (5.4) ^{ab}	2.2 (10.8) ^b	0.032
Sweet appeal bias					
Explicit liking	7.1 (2.0)	13.4 (3.5)	2.6 (4.0)	4.9 (2.3)	0.062
Explicit wanting	6.8 (2.0)	13.5 (3.4) ^a	2.4 (4.0) ^b	4.0 (1.7) ^{ab}	0.040
Implicit wanting	0.5 (8.1)	5.3 (16.8)	8.2 (6.9)	-14.0 (17.1)	0.51

Abbreviations: OB: non-operative patients with obesity; SG: group of patients with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass. Data are presented as mean (SEM). p values are for the differences between patients with OB, SG and RYGB on the basis of ANOVAs. Different superscript letters within a row indicates a significant difference ($p < 0.05$) using Tukey's post-hoc test.

3.9.7 Relationship between food preference for 'high-fat – sweet' foods and behavioral traits

The correlations between explicit liking, explicit and implicit wanting for 'high fat – sweet foods' and the studied behavioral traits are displayed in Table 4.5. Considering the overall sample of patients, the binge eating score was positively correlated with preference for 'high fat – sweet foods'. In addition, 'negative and positive urgency' correlated lightly with the implicit wanting for 'high fat – sweet foods'. Overall, food reward for 'high fat – sweet foods' and behavioral traits were not correlated among bariatric surgery patients, except for a positive correlation between implicit wanting for 'high fat – sweet foods' and the binge eating score among SG patients.

Table 4.5. Correlations between food reward and behavioral traits of bariatric surgery patients.

High fat – sweet foods		All n=86			OB n=30			SG n=30			RYGB n=26		
		EL	EW	IW	EL	EW	IW	EL	EW	IW	EL	EW	IW
Binge eating score	r ²	0.48082	0.49274	0.39803	0.31761	0.30935	0.10039	0.26196	0.24926	0.39052	0.1229	0.14602	0.25453
	p-value	<.0001	<.0001	0.0005	0.11	0.12	0.63	0.2	0.22	0.049	0.61	0.54	0.28
Food addiction	r ²	0.13958	0.12946	0.23226	0.22438	0.19744	0.17905	0.13037	0.1206	0.32893	-0.13924	-0.15164	0.12063
	p-value	0.24	0.28	0.05	0.27	0.33	0.38	0.53	0.56	0.1	0.56	0.52	0.61
Nb of symptoms of food-addiction	r ²	0.11132	0.1059	0.06898	0.18361	0.13913	0.079	0.04862	0.04117	0.16667	-0.21406	-0.1841	-0.29992
	p-value	0.35	0.38	0.56	0.37	0.5	0.7	0.81	0.84	0.42	0.36	0.44	0.2
Negative urgency	r ²	0.23097	0.21481	0.24495	0.48611	0.5245	0.31613	0.36322	0.20379	0.35727	-0.07895	-0.04606	0.09933
	p-value	0.051	0.07	0.038	0.012	0.0059	0.12	0.068	0.32	0.073	0.74	0.85	0.68
Positive urgency	r ²	0.16033	0.14054	0.28294	0.18664	0.21507	0.28002	0.25434	0.11158	0.21215	-0.0171	-0.01393	0.36981
	p-value	0.18	0.24	0.016	0.36	0.29	0.17	0.21	0.59	0.3	0.94	0.95	0.11
Lack of premeditation	r ²	0.20427	0.18806	0.13104	0.31055	0.34796	0.19759	0.06361	-0.06999	-0.07942	0.12022	0.10669	0.11927
	p-value	0.085	0.11	0.27	0.12	0.082	0.33	0.76	0.73	0.7	0.61	0.65	0.62
Lack of perseverance	r ²	0.02905	0.04103	0.05428	0.01352	0.10009	-0.1472	-0.12006	-0.19539	0.36055	-0.09484	-0.16215	-0.05758
	p-value	0.81	0.73	0.65	0.95	0.63	0.47	0.56	0.34	0.07	0.69	0.49	0.81
Sensation seeking	r ²	0.10114	0.07051	0.13134	0.35439	0.35309	0.45312	0.23373	0.13297	-0.06435	-0.06956	-0.0878	0.09276
	p-value	0.4	0.56	0.27	0.076	0.077	0.02	0.25	0.52	0.76	0.77	0.71	0.7

Abbreviations: OB: non-operative patients with obesity; SG: group with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass; EL: explicit liking; EW: explicit wanting; IW: implicit wanting. Data correspond to Pearson's coefficient of correlation and their p-value. Color coding vary from dark red (high positive correlation) to dark green (high negative correlation).

3.9.8 Comparison of food reward according to the follow-up periods

Comparing food preferences for all studied food categories, there was no significant difference in explicit liking, explicit and implicit wanting (all $p > 0.05$) between the operated patients (SG and RYGB), at 6, 12 and 24 mo follow-up ($n=20$, $n=17$ and $n=19$ respectively) (results not shown).

3.10 Discussion

The present research aimed to study food reward (liking and wanting) after bariatric surgery. The originality of this study relies on the use of a wide range of food categories varying in nutrition composition, appearance, taste and texture and on its comparative design between the two most common types of surgeries (SG and RYGB) and a non-operative state. That allowed us to investigate thoroughly associations between food reward and bariatric surgery using a computerized behavioral task.

We found that bariatric surgery patients had a lower liking and wanting for 'high fat – sweet foods. These findings are consistent with a longitudinal study that reported decreased hedonic ratings for calorically dense foods after SG when using a food preference questionnaire and a 2 (Fat: High Fat and Low Fat) \times 3 (Carbohydrates (CHO): High Simple Sugar, High Complex CHO, and Low CHO/High Protein) design (20). Another study using high- vs low-calorie food pictures showed lower hedonic ratings for high-calorie foods after both SG and RYGB compared to control group OB (38). Interestingly, in the fore-mentioned study, the Blood-Oxygen-Level Dependent (BOLD) response to high-calorie foods was significantly reduced among RYGB in the Ventral Tegmental Area (VTA), which is known to play a crucial role in the reward circuits in the brain. Of importance, a recent systematic review showed that food reward decreased during dietary, exercise, pharmacological, cognitive and behavioral/multidisciplinary weight loss interventions (39). This suggests that more than the bariatric surgery itself, the weight loss might have an impact on the motivation to eat and food choices. Most patients experience a "honeymoon" in the first post-operative year (12-18 months), where they have a reduced appetite, limiting portion sizes, and a disinterest in foods (40), which is concomitant with the great and rapid weight loss phase. After 12 to 18 months, most of the patients reach a plateau with a stable energy balance and a new body weight set point. Further research could explore long term-food reward (after 2 years of follow-up) to

better understand if those modifications are sustained and if they are related to the weight regain that occur in 20% of the patients within 1 to 3 years after surgery (41).

Beyond the observed modification in food reward for the highly palatable ‘high fat’ ‘with sauce’, our results showed that post-operative patients had lower liking scores for a large range of food categories compared to non-operative patients with obesity. This suggests that patients experience an overall decrease in the pleasure of eating after bariatric surgery. Consistently with our results, a cross-sectional study using pictures of high vs low-energy dense foods also reported lower overall liking and wanting among patients with a RYGB compared to control OB (21). The RYGB group had a lower brain activation of reward related areas and a higher activation of areas related to the visual, motor, cognitive control, memory, and gustatory regions (21), which might also play a role in food reward and consequently preferences after bariatric surgery. Given that liking has been demonstrated to be positively associated with food intake (42), we can hypothesize that the modification in the pleasure of eating could contribute to reduction of food intake induced by bariatric surgery.

We observed a higher preference for nutrient-dense foods, such as foods rich in fibers in the post-operative group. This is consistent with studies reporting an increase in fibers intake up to 24 months after bariatric surgery (5), as an increase in energy intake from fruits (6). It is also reported that vegetables and fruits were more often cited as favorite foods post than prior to surgery (8). The increased motivation to consume fibers might be the consequence of gastrointestinal symptoms that have been previously reported after bariatric surgery and could be related to avoiding dumping syndrome (43). In contrast, one study showed conflicting results with a decrease in the frequency of patients consuming fruits and vegetables after bariatric surgery (44). However, these results were different according to the fruit considered. The inconsistent results could be attributed to the fact that fruits and vegetables are a heterogeneous food category, with diverse and distinct sensory properties (taste, appearance, texture, etc.).

In our study, unadjusted liking scores for ‘dairy products – without color’ were significantly different between the groups of patients, with non-operative patients with obesity having the highest scores compared to post-operative patients. However, this difference was not significant after adjusting the results for hunger, fullness and time since the last meal. On the other hand, wanting scores for ‘dairy products – without color’ were significantly different between the patients, with non-operative patients having the lowest scores. In the incentive-sensitization model as described by Berridge and Robinson (45), repeated exposure to drug did

not change or decrease liking, while it increased wanting. Wanting is the motivational component of reward and is related to the drug seeking behavior. In our study we can speculate that 'wanting' for 'dairy products - without color', could be consciously or unconsciously oriented towards a goal of weight loss.

The current study is among the few using a distinct comparative design towards the two most common types of bariatric surgery. Findings suggest that there are only minor differences between the two types of surgery regarding liking for foods. This is in accordance with studies, showing a similar decrease in preference for fat (19) and liking for high calorie dense foods (38), as well as an increase in diet quality (46) and dietary intake (43) in both SG and RYGB. However, another study showed similar decrease in the hedonic rating for high fat between SG and RYGB but the liking of high sugar remained unchanged after RYGB (19). RYGB induces more dumping syndrome than SG (47), and thus the digestive discomfort caused by the consumption of foods rich in carbohydrates could have resulted in stronger conditioned taste avoidance in RYGB than in SG.

Considering the eating behavior of patients, binge eating disorder was found for 26.7% of pre-operative patients, which is in the usual range in bariatric candidates (48). There was a lower binge eating score among postoperative patients, which might be due to the effect of the surgery on improving eating behavior and / or to the selection of candidates without eating disorders that could benefit from bariatric surgery. Liking and wanting have already been shown to be related to trait binge eating (27,49). This is confirmed in our study, as binge eating scores were positively correlated with liking and wanting for '*high fat – sweet foods*'. Overall, most of our food reward outcomes did not correlate with food addiction scores, while a study performed on 374 women found a significant correlation between reward sensitivity and food addiction (50), as did a recent systematic review by Maxwell et al. (51). This discrepancy might be related to a lack of power to study these phenomena in our study. It could also be due to a difference in terms of studied population.

Our results showed a significant difference in age between OB, SG, and RYGB subjects. OB and SG were 38 years old while RYGB were 51 years old. Although the difference in age between the groups of patients is significant, it appears to be of small clinical relevance given that all patients belong to the same middle-age category.

Some limitations must be considered, especially the cross-sectional design of the study, which does not allow us to test the causal effect of bariatric surgery on the differences of food reward found between non- and post-operative patients. Nevertheless, we have tried to ensure that non-operative patients with obesity had the same characteristics than post-operative patients prior to their bariatric surgery. In particular, the healthcare unit in which the study was carried out only hosts patients with a BMI > 40 kg.m⁻² and patients with a BMI > 35kg.m⁻² who have at least two obesity comorbidities among hypertension, myocardial infarction, stroke, sleep apnea syndrome, diabetes and severe joint disease. These criteria are similar to those necessary to benefit from bariatric surgery and were verified before the admission of the patients using a questionnaire. Another limitation is the lack of controlled laboratory conditions when measuring food preferences as the visits and time of arrival of the patients were based on their pre-registered clinical consultancy, which prevented from standardizing fasting status, appetite levels and time since the last meal in patients. We cannot exclude that our results might have been impacted by this, given that the liking scores are higher in individuals in a hungry state, while they are lower in a fed state (29). However, in an attempt to mitigate this limitation, we compared liking and wanting scores between OB, SG and RYGB using ANOVAs adjusted for hunger level and time since the last meal. Finally, food preferences could have been influenced by the comorbid conditions and the ethnicity of the participants. Future research could explore the impact of excess weight loss on food reward and incorporate ethnicity and comorbidity as confounding factors.

3.11 Conclusion

We found that liking for a large range of food categories was lower among post-operative patients compared to non-operative patients with obesity. On the other hand, food choices, and implicit wanting were not significantly different between the groups of patients, except for *'dairy products – without color'*, *'low carbohydrates – fluid'* and those of higher palatability such as *'high fat – sweet foods'*. Moreover, similar food reward was observed following SG and RYGB, suggesting that a possible mechanism by which food reward is altered following bariatric surgery, might be common between the two major types of surgeries. The LFPQ could be clinically relevant to identify postoperative alterations in food reward and to guide caregivers to provide personalized advice to patients in the context of precision bariatric medicine.

3.12 References

1. Sjöström L, Narbro K, Sjöström CD, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med*. 2007 Aug 23;357(8):741–52.
2. Sjöström L, Peltonen M, Jacobson P, Sjöström CD, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. *JAMA - J Am Med Assoc*. 2012 Jan 4;307(1):56–65.
3. Sjöström L. Review of the key results from the Swedish Obese Subjects (SOS) trial - a prospective controlled intervention study of bariatric surgery. Vol. 273, *Journal of Internal Medicine*. 2013. p. 219–34.
4. Angrisani L, Santonicola A, Iovino P, Vitiello A, Zundel N, Buchwald H, et al. Bariatric Surgery and Endoluminal Procedures: IFSO Worldwide Survey 2014. *Obes Surg*. 2017 Sep 1;27(9):1–11.
5. Coluzzi I, Raparelli L, Guarnacci L, Paone E, Del Genio G, le Roux CW, et al. Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy. *Obes Surg*. 2016 Sep 7;26(9):2059–67.
6. Laurenus A, Larsson I, Melanson KJ, Lindroos AK, Lönroth H, Bosaeus I, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. *Eur J Clin Nutr*. 2013 Feb 9;67(2):168–73.
7. Thirlby RC, Bahiraei F, Randall J, Drewnoski A. Effect of Roux-en-Y gastric bypass on satiety and food likes: the role of genetics. *J Gastrointest Surg*. 2006 Feb;10(2):270–7.
8. Kittrell H, Graber W, Mariani E, Czaja K, Hajnal A, Di Lorenzo PM. Taste and odor preferences following Roux-en-Y surgery in humans. Covasa M, editor. *PLoS One*. 2018 Jul 5;13(7):e0199508.
9. Burge JC, Schaumburg JZ, Choban PS, DiSilvestro RA, Flancbaum L. Changes in patients' taste acuity after Roux-en-Y gastric bypass for clinically severe obesity. *J Am Diet Assoc*. 1995 Jun;95(6):666–70.
10. Miras AD, le Roux CW. Bariatric surgery and taste: novel mechanisms of weight loss. *Curr Opin Gastroenterol*. 2010 Mar;26(2):140–5.
11. Coveleskie K, Gupta A, Kilpatrick LA, Mayer ED, Ashe-Mcnalley C, Stains J, et al. Altered functional connectivity within the central reward network in overweight and obese women. *Nutr Diabetes*. 2015 Jan 19;5.
12. Stice E, Spoor S, Bohon C, Veldhuizen MG, Small DM. Relation of Reward From Food Intake and Anticipated Food Intake to Obesity: A Functional Magnetic Resonance Imaging Study. *J Abnorm Psychol*. 2008;117(4):924–35.
13. Berridge KC. Food reward: Brain substrates of wanting and liking. *Neurosci Biobehav Rev*. 1996;20(1):1–25.
14. Goldstone AP, Miras AD, Scholtz S, Jackson S, Neff KJ, Pénicaud L, et al. Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *J Clin Endocrinol Metab*. 2016 Feb 1;101(2):599–609.
15. Scholtz S, Miras AD, Chhina N, Prechtel CG, Sleeth ML, Daud NM, et al. Obese patients after gastric bypass surgery have lower brain-hedonic responses to food than after gastric banding. *Gut*. 2014 Jun;63(6):891–902.

16. Ochner CN, Kwok Y, Conceicao E, Pantazatos SP, Puma LM, Carnell S, et al. Selective reduction in neural responses to high calorie foods following gastric bypass surgery. *Ann Surg.* 2011 Mar;253(3):502–7.
17. Ochner CN, Stice E, Hutchins E, Afifi L, Geliebter A, Hirsch J, et al. Relation between changes in neural responsivity and reductions in desire to eat high-calorie foods following gastric bypass surgery. *Neuroscience.* 2012 May;209:128–35.
18. Frank S, Veit R, Sauer H, Enck P, Friederich HC, Unholzer T, et al. Dopamine depletion reduces food-related reward activity independent of BMI. *Neuropsychopharmacology.* 2016 May 1;41(6):1551–9.
19. Primeaux SD, Tzeng TH, Allerton TD, Chiang MC, Cosentino G, Dubin RL, et al. Differences in short-term food preferences following vertical sleeve gastrectomy and Roux-en-Y gastric bypass surgery. *Obes Res Clin Pract.* 2015 Nov 2;9(6):628–32.
20. Ammon BS, Bellanger DE, Geiselman PJ, Primeaux SD, Yu Y, Greenway FL. Short-Term Pilot Study of the Effect of Sleeve Gastrectomy on Food Preference. *Obes Surg.* 2015 Jun 26;25(6):1094–7.
21. Frank S, Heinze JM, Fritsche A, Linder K, von Feilitzsch M, Königsrainer A, et al. Neuronal Food Reward Activity in Patients With Type 2 Diabetes With Improved Glycemic Control After Bariatric Surgery. *Diabetes Care.* 2016 Aug;39(8):1311–7.
22. Sanjur D, Randall E, Sanjur D. Food preferences—Their conceptualization and relationship to consumption. *Ecol Food Nutr.* 1981 Dec 1;11(3):151–61.
23. Stano S, Alam F, Wu L, Dutia R, Ng SN, Sala M, et al. Effect of meal size and texture on gastric pouch emptying and glucagon-like peptide 1 after gastric bypass surgery. *Surg Obes Relat Dis.* 2017 Dec 1;13(12):1975–83.
24. Finlayson G, King N, Blundell JE. Is it possible to dissociate “liking” and “wanting” for foods in humans? A novel experimental procedure. *Physiol Behav.* 2007 Jan 30;90(1):36–42.
25. Griffioen-Roose S, Mars M, Siebelink E, Finlayson G, Tomé D, De Graaf C. Protein status elicits compensatory changes in food intake and food preferences. *Am J Clin Nutr.* 2012 Jan 1;95(1):32–8.
26. Griffioen-Roose S, Finlayson G, Mars M, Blundell JE, de Graaf C. Measuring food reward and the transfer effect of sensory specific satiety. *Appetite.* 2010 Dec;55(3):648–55.
27. Dalton M, Finlayson G. Psychobiological examination of liking and wanting for fat and sweet taste in trait binge eating females. *Physiol Behav.* 2014 Sep 1;136:128–34.
28. French SA, Mitchell NR, Finlayson G, Blundell JE, Jeffery RW. Questionnaire and laboratory measures of eating behavior: Associations with energy intake and BMI in a community sample of working adults. *Appetite.* 2014 Jan 1;72:50–8.
29. Oustric P, Thivel D, Dalton M, Beaulieu K, Gibbons C, Hopkins M, et al. Measuring food preference and reward: application and cross-cultural adaptation of the leeds food preference questionnaire in human experimental research. *Food Qual Prefer.* 2020 Oct;103824.
30. van der Meij BS, Wijnhoven HAH, Finlayson GS, Oosten BSH, Visser M. Specific food preferences of older adults with a poor appetite. A forced-choice test conducted in various care settings. *Appetite.* 2015 Jul 1;90:168–75.

31. Brunault P, Gaillard P, Ballon N, Couet C, Isnard P, Cook S, et al. Validation de la version française de la Binge Eating Scale : étude de sa structure factorielle, de sa consistance interne et de sa validité de construit en population clinique et non clinique. *Encephale*. 2016 Oct 1;42(5):426–33.
32. Gormally J, Black S, Daston S, Rardin D. The assessment of binge eating severity among obese persons. *Addict Behav*. 1982;7(1):47–55.
33. Grupski AE, Hood MM, Hall BJ, Azarbad L, Fitzpatrick SL, Corsica JA. Examining the binge eating scale in screening for binge eating disorder in bariatric surgery candidates. *Obes Surg*. 2013 Jan;23(1):1–6.
34. Brunault P, Courtois R, Gearhardt AN, Gaillard P, Journiac K, Cathelain S, et al. Validation of the French Version of the DSM-5 Yale Food Addiction Scale in a Nonclinical Sample. *Can J Psychiatry*. 2017 Mar 1;62(3):199–210.
35. Gearhardt AN, Corbin WR, Brownell KD. Development of the Yale Food Addiction Scale Version 2.0. *Psychol Addict Behav*. 2016 Feb 1;30(1):113–21.
36. Clark SM, Martens K, Smith-Mason CE, Hamann A, Miller-Matero LR. Validation of the Yale Food Addiction Scale 2.0 Among a Bariatric Surgery Population. *Obes Surg*. 2019 Sep 15;29(9):2923–8.
37. Billieux J, Rochat L, Ceschi G, Carré A, Offerlin-Meyer I, Defeldre AC, et al. Validation of a short French version of the UPPS-P Impulsive Behavior Scale. *Compr Psychiatry*. 2012 Jul;53(5):609–15.
38. Faulconbridge LF, Ruparel K, Loughhead J, Allison KC, Hesson LA, Fabricatore AN, et al. Changes in neural responsivity to highly palatable foods following roux-en-Y gastric bypass, sleeve gastrectomy, or weight stability: An fMRI study. *Obesity*. 2016 May;24(5):1054–60.
39. Oustric P, Gibbons C, Beaulieu K, Blundell J, Finlayson G. Changes in food reward during weight management interventions – a systematic review. Vol. 19, *Obesity Reviews*. Blackwell Publishing Ltd; 2018. p. 1642–58.
40. Lynch A. “When the honeymoon is over, the real work begins:” Gastric bypass patients’ weight loss trajectories and dietary change experiences. *Soc Sci Med*. 2016 Feb 1;151:241–9.
41. Sjöström L, Lindroos AK, Peltonen M, Torgerson J, Bouchard C, Carlsson B, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med*. 2004 Dec 23;351(26):2683–93.
42. Rogers PJ, Hardman CA. Food reward. What it is and how to measure it. *Appetite*. 2015;90:1–15.
43. El Labban S, Safadi B, Olabi A. The Effect of Roux-en-Y Gastric Bypass and Sleeve Gastrectomy Surgery on Dietary Intake, Food Preferences, and Gastrointestinal Symptoms in Post-Surgical Morbidly Obese Lebanese Subjects: A Cross-Sectional Pilot Study. *Obes Surg*. 2015 Dec 1;25(12):2393–9.
44. Molin Netto BDBD, Earthman CP, Farias G, Landi Masquio DC, Grotti Clemente AP, Peixoto P, et al. Eating patterns and food choice as determinant of weight loss and improvement of metabolic profile after RYGB. *Nutrition*. 2017 Jan;33:125–31.
45. Berridge KC, Robinson TE. Liking, wanting, and the incentive-sensitization theory of addiction. *Am Psychol*. 2016 Nov 1;71(8):670–9.

46. Hubert, Papasavas P, Stone, Swede, Huedo-Medina, Tishler, et al. Associations between Weight Loss, Food Likes, Dietary Behaviors, and Chemosensory Function in Bariatric Surgery: A Case-Control Analysis in Women. *Nutrients*. 2019 Apr 9;11(4):804.
47. Ramadan M, Loureiro M, Laughlan K, Caiazzo R, Iannelli A, Brunaud L, et al. Risk of Dumping Syndrome after Sleeve Gastrectomy and Roux-en-Y Gastric Bypass: Early Results of a Multicentre Prospective Study. *Gastroenterol Res Pract*. 2016;2016.
48. Niego SH, Kofman MD, Weiss JJ, Geliebter A. Binge eating in the bariatric surgery population: A review of the literature. Vol. 40, *International Journal of Eating Disorders*. 2007. p. 349–59.
49. Finlayson G, Arlotti A, Dalton M, King N, Blundell JE. Implicit wanting and explicit liking are markers for trait binge eating. A susceptible phenotype for overeating. *Appetite*. 2011 Dec;57(3):722–8.
50. Loxton NJ, Tipman RJ. Reward sensitivity and food addiction in women. *Appetite*. 2016;
51. Maxwell AL, Gardiner E, Loxton NJ. Investigating the relationship between reward sensitivity, impulsivity, and food addiction: A systematic review. *Eur Eat Disord Rev*. 2020 Jul 6;28(4):368–84.

Chapter V. Study of food preferences and eating behavior after bariatric surgery in a real context eating environment: conception and settings of the study

Guyot E, Balleydier S, Bagot S, Iceta S, Disse E, Nazare JA, Dougkas A. (In writing)

Abstract

Introduction: There is a consensus among most studies of a postoperative decrease in preferences for high-energy, high-fat and high-carbohydrate foods, that could contribute to the weight loss success of bariatric surgery. However, these findings have been based on self-reported surveys, which raises the question of their ecological relevance. Our goal was to adapt an ad-libitum buffet meal previously used by Alliot and al. (1), for a study aiming to compare food preferences and choices between adult women with a severe complicated or morbid obesity and adult women, who have had a bariatric surgery in the past 12 months, in an ecological environment.

Material and methods: To adapt the buffet-meal, we considered several methodological aspects including the specific nutritional requirement of our studied population, the French eating habits and nutritional guidelines, sensory aspects, appearance and texture of foods, seasonality and practicality, standardization and replicability of the dishes. A two-dimensional categorization paradigm based on lipid and carbohydrate content (high/low) was used for the ad-lib buffet. Food's high in lipids or carbohydrates contained at least 15g/100g of these nutrients. The low cut-off was fixed at 5g/100g. Seventeen food items meeting the requirements were selected. Two additional dimensions could also be considered: protein content (high/low) and energy density (high/low), based on the calculated median of the food items, 6.2g/100 g and 2.3kcal/g, respectively. The buffet meal will be recorded to assess the microstructure of the meal (e.g., number of bites per minute, time spent choosing, type of food).

Expected results: This buffet will allow us to assess food choices, total energy and specific macronutrient intake. We hope to confirm the results of previous studies in showing a significant difference in terms of food preferences between patients with obesity with or without bariatric surgery. The use of a real eating situation will give to the findings a high ecological relevance, which is important to generalize results to the real world. Furthermore, the study of the microstructure of the meal will give us clues on the underlying mechanisms of postoperative changes in food preferences.

Keywords: Food preferences; Eating behavior; Buffet meal; Energy density; Experimental restaurant; Bariatric surgery

5.1. Introduction

Bariatric surgery has a direct effect on appetite and food intake. Findings showed that in the postoperative period, the total energy intake and total volume ingested were reduced (2–4). Fasting hunger was also reduced after RYGB and postprandial satiety was prolonged (5). In addition to these quantitative modifications of food intake, qualitative changes have been previously reported. After RYGB, the consumption of foods of low nutritional quality was reduced in favor of foods of high nutritional quality (6). Moreover, the contribution of fat in the total energy intake was reduced and the contribution of low energy density foods in the total energy intake was increased (2). After SG the energy density was reduced and the quality of nutritional intake was improved (3). Several studies reported changes in favor of low energy density foods after bariatric surgery (5,7–9). Overall, this thesis work (Chapters II to IV) suggests that food preferences change after weight loss surgery.

By systematically reviewing the literature (see Chapter II), it was highlighted that most of the studies exploring modifications of food preferences were performed on cohort of patients using self-reported dietary intake. Despite the heterogeneity of the assessment tool used there were a predominance of food records, food recalls and food frequency questionnaires, typically found in observational studies (10). Although inexpensive and easy to set up, these methods are subjective and prone to biases, in particular of desirability (11–13). Additionally, the measure of food intake among patients with obesity is particularly complicated. A systematic review gathering the evidences of 34 scientific articles dealing with the accuracy of the self-reported measure of food intake among patients with obesity demonstrated that a BMI ≥ 30 was associated with a significant underreporting of food intake (14). Furthermore, patients with obesity are prone to selectively underreport the intake of certain types of foods (15), total protein (16) and fat intake (17). On the other hand, the studies, which explore possible mechanisms by which food preferences change following bariatric surgery (notably food reward and sensory abilities) were mainly performed in a laboratory setting (i.e., under strictly controlled condition). Those studies mainly used fMRI and explored the activation of the reward hotspots in the brain (7,9,18–27); and psychophysical testing to assess the gustatory (28–35) and olfactory (28,31,36,37) abilities of the bariatric patients pre- and post-operatively. Interestingly, a study showed that the value-based neural responses to health and taste attributes of foods of lean and overweight participants were similar under fMRI scanner, however their

patterns of food choices were different when assessed with an ad-libitum buffet meal in a real-world situation (38).

What we lack when studying food preferences following bariatric surgery is the ecological relevance of the findings.

The use of a laboratory setting is useful to measure food intake under controlled condition. Especially, it enables precise and accurate measures (39–41) and a better control of the confounding factors (42,43). However, the critical aspect of the external validity of the measures has been raised by several researchers, i.e., they questioned to what extent the results from the laboratory are generalizable to the real world. When studying the effect of context for measurements, a recent study found that serving size (large or small) had a greater effect on food intake when the study was conducted at home than when the measurements were carried out in the laboratory (44). There is the possibility to perform research in a more naturalistic context by controlling some key variables but incorporating a situation that patients would experiment in real life, as recommended by Meiselman (45) and by several narrative reviews on food preferences following bariatric surgery (46–48).

In experimental studies, ad libitum meals are classically used to assess the effect of an intervention on food intake (42). Nielsen et al. did not find any difference between pre- and post-operative food preferences when using a buffet-type meal in a laboratory setting (49). Especially, there were no modifications in relative intake of the studied food categories (high / low fat and sweet / savory) or macronutrients. This study also showed that taste sensitivity was unchanged between before and after bariatric surgery. Although using real foods, this unique prospective study was carried out under laboratory conditions. The patients received a standardized liquid meal at 10 AM and the buffet meal with typical Danish food was served at 4.30 PM. Furthermore, it did not explore the microstructure of meals (time spent eating, number of bites, speed of consumption, etc.) and the sensory evaluation was partial. Finally, it was carried out in Denmark and may not be repeatable in France given cultural differences in terms of diet and habits.

All in all, postoperative food preferences following bariatric surgery, needs to be further explored under ecological feeding conditions and be associated with a complete olfactory and gustatory phenotyping.

We therefore wish to set up study using objective measures of eating behavior, olfactory and taste capacities to better understand food preferences after bariatric surgery. We hypothesized that patients who had bariatric surgery in the past 12 months have different food preferences compared to a control group of patients with obesity, candidate for a bariatric surgery, in an ecological context of eating.

The main objective of this study is to compare the percentage energy from high-energy dense foods vs. low-energy dense foods, evaluated with a previously validated buffet type meal design, between the two groups. The secondary objectives are to compare food intake, nutritional quality, meal microstructure, sensory profile and eating behavior, between the groups. Additionally, we will further explore the link between food preferences and sensory profiles in these patients.

5.2. Subjects and methods

5.2.1. Study design

It is a single-center, comparative, non-randomized, balanced, open-label study, with 2 parallel groups (control and surgery groups).

5.2.2. Sample size

For this exploratory study, we cannot perform a strict power calculation because no previous study has assessed dietary preferences by comparing subjects with obesity who have or have not undergone bariatric surgery under the real-life conditions currently targeted. However, a previous study comparing 40 subjects with obesity who had either gastric bypass (n=20) or sleeve gastrectomy (n=20) showed a significant difference in the total energy intake between the two types of surgery (50). Similarly, in the current study we aim to include 20 subjects with obesity who had undergone bariatric surgery and 20 subjects with obesity who did not undergo bariatric surgery, i.e., 40 patients in total. To limit gender-related bias, only women are included, as they have a different eating behavior (51) and eating rates (52) than men. This could also assist the recruitment since women are overrepresented in cohorts of patients with bariatric surgery (53,54). In addition, when conducting the studies presented in Chapter IV and V, we targeted the same population and we enrolled a large majority of women 89.6 and 68.6%, respectively.

5.2.3. Subjects

The inclusion criteria are as follows: women between 18 to 65 years old, BMI ≥ 35 kg.m⁻² for the control group and a history of bariatric surgery (SG or RYGB only as they are the most commonly performed worldwide (55)). Chapter IV indicated that there was no major difference in food choices and food reward between SG and RYGB, which was consistent with findings showing that SG and RYGB similarly impact the diet quality (56) and dietary intake (57). We decided to include only patients who had a surgery in the past 12 months as this is a phase of early weight loss among bariatric patients. That was further supported by data from Chapter III pointing out that the duration of the follow-up might influence food preferences. Furthermore, although there was no difference in food reward outcomes comparing bariatric surgery patients at 6, 12 and 24 months, in Chapter IV, a systematic review found that food reward decreases during weight management (58).

Patients are excluded: if they suffer from a food allergy or food intolerance to at least one of the studied food items; or if they exclude the studied foods for religious or personal beliefs; with a history of pathology that may interfere with food preference or sensory measurements (neurological, digestive disorders, dysphagia, abdominal pain, etc.); habitual smokers; pregnant or breastfeeding women or women who do not take an effective contraception (declared to the investigator during the interview). Patients with revisional bariatric procedure will not be included.

Written informed consent for their participation and being video recorded will be obtained from all subjects before commencing the study. This study was approved by a national ethic Committee (2020-A00588-31, on July 2nd, 2020) and was registered in Clinical Trials.gov (NCT04511442).

5.2.4. Recruitment

Female volunteers will be recruited through information leaflets delivered by medical doctors during their consultations, and advertising at hospital departments and patient associations via posters and announcements in newspapers or on the websites and social networks of the CRNH Rhône-Alpes and the Institut Paul Bocuse Research Center (IPBR). Volunteers could complete an online pre-screening questionnaire hosted by the CRNH Rhône-Alpes to indicate their weight, height, and surgery status (operated or not). People will be

selected on the basis of these criteria and will be invited for the visit to the IPBR. This visit will take place in two parts, a part dedicated to the verification of the inclusion criteria and an investigation part.

The nutrition, diabetes, endocrinology department is hosting 200 patients per year. We want to include 20 subjects with obesity who did not undergo bariatric surgery with a BMI $\geq 35 \text{ kg}\cdot\text{m}^{-2}$ and 20 subjects with obesity who underwent bariatric surgery. It is planned to include 4 patients per month, i.e., a duration of inclusion of 10 months. We plan to recruit all patients over 14 months to take into account any difficulties with inclusion and periods when services are closed.

5.2.5. Primary and secondary endpoints

The primary endpoint of the study will be the proportion of total energy intake from high energy density foods versus low energy density foods assessed using a previously validated buffet meal design in a normal eating environment (1).

The secondary endpoints will be:

- the appetite levels (hunger, satiety, desire to eat, and prospective consumption) assessed before and after the buffet;
- the total energy intake, the intakes of macro- and micro-nutrients, the proportion of energy from macronutrients (proteins, lipids and carbohydrates) the proportion of total energy from high versus low fat, carbohydrate and protein foods, the microstructure of the meal (the time spent choosing the food items at the buffet, the duration of ingestion, the speed of ingestion, the total duration of the meal, the number of bites per minute, the total number of bites and by type of food, and the food choices), and the appreciation of the food items will be assessed during the buffet;
- the detection, identification, familiarity, intensity, agreeability, and edibility of tastes and odors will be recorded with Taste Strips and the European Test of Olfactory Capabilities (ETOC). Finally, eating behavior will be assessed with the Three-Factor Eating Questionnaire (TFEQ).

5.2.6. General organization of the study

Figure 5.1 and Table 5.1 show the study design and steps of the study respectively.

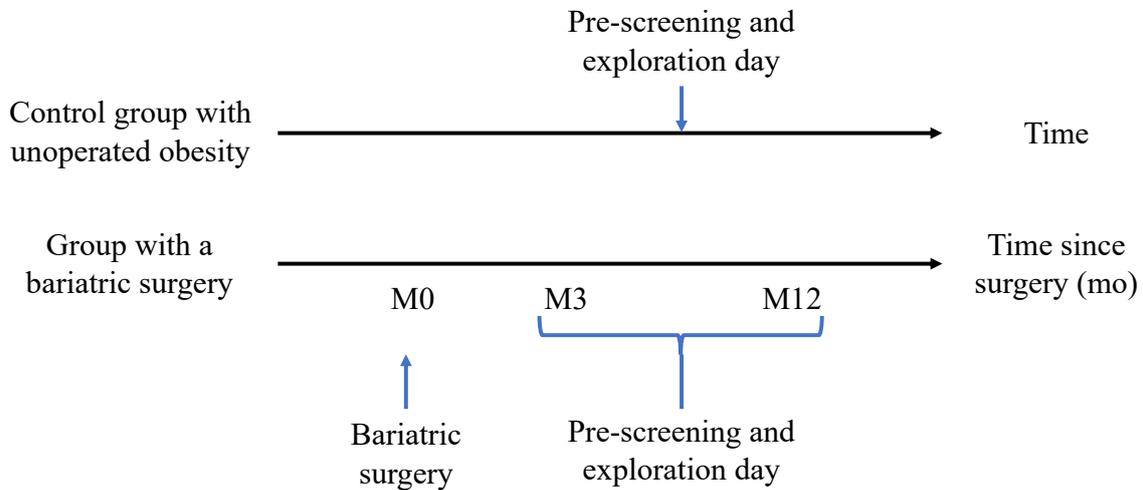


Figure 5.1. Study design. Abbreviation: M, Month.

Table 5.1. Steps of the study.

Steps	Pre-screening (online questionnaire)	Study day
Moment	M3 to M12 after bariatric surgery	M3 à M12 after bariatric surgery
Actions		
Verification of pre-screening criteria	X	
Information and recording of non-opposition ¹		X
Request of the image rights ¹		X
Medical history ¹		X
Verification of inclusion / non-inclusion criteria ¹		X
Paraclinical examination ^{1,2}		X
Sensory evaluation ²		X
Evaluation of eating behavior ³		X
Evaluation of food preferences ⁴		X
Evaluation of the microstructure of the meal ⁵		X

Method of assessment, which will be used: ¹ Interview and Case Report Form; ² Anthropometric measurements; ² ETOC, Taste Strips; ³ TFEQ; ⁴ Appetite ratings, food weighing's, video recording; ⁵ Video recording. M: month

The study day will take place at the IPBR, Bellecour Platform. The study provides compensation for travel expenses up to a limit of 30 Euros. Volunteers arrive between 9 a.m. and 10 a.m., having had breakfast before 9 a.m. At the start of the visit, the study will be explained in detail to the volunteers, the information notice will be given to them, the consent

form and the consent of the video image rights will be signed by the volunteer. The inclusion and non-inclusion criteria will be verified, and the final admission of the volunteer can be established. If they are not included, the reasons will be given and, if medical treatment is necessary, a letter will be written for the attention of their attending physician.

During the study day, there will be evaluation of their sensory abilities, appetite, food intake/food preferences using the buffet type meal and the microstructure of eating for assessment of their eating behavior. The appreciation of the studied food items will also be recorded. All the investigations will take place in an isolated room, without distraction or potential stimulus that could interfere with the measurements, with the exception of the buffet, which will be carried out in a domestic-type of kitchen at the IPBR (see Figure 5.2).



Figure 5.2. A domestic-type kitchen at the Institut Paul Bocuse restaurant.
© Santorini Dave.

Volunteers are asked to refrain from consuming any food, drinks other than water, chewing gum during the test session. During the test meals (buffet), they will be invited to eat without communicating with others. Each buffet meal will be individual and located close to each subject's table. During the morning, they are free to practice any sedentary activity of their choice (e.g., reading, music, film, etc.). Pre-testing has already been performed on a volunteer employee of the IPBR to verify the feasibility of the experimental procedure.

5.2.7. Data collection

Anthropometric data and medical history

Current weight, height, personal and family history, concomitant treatments and current comorbidities will be assessed during an interview and a paraclinical examination. During this occasion, patients should also indicate to the investigator what they consumed for breakfast. For the surgery group, the history of bariatric surgery, including the type and the date of surgery, and weight history will also be recorded.

Gustatory function

We will study the taste function with Taste Strips (Burghart Masstechnik GmbH, Wedel, Germany) (59,60). It is composed of 16 strips of filter paper impregnated with chemicals referring to the 4 primary tastes (sweet, salty, sour and bitter) at different concentrations administrated in a random order (61) (see Tables 5.2 and 5.3). The strips are 8 cm long and have an impregnated area of 2 cm². The solvent used is distilled water.

Table 5.2. Composition of the Taste Strips.

Taste	Chemical	Concentration 1 (g/ml)	Concentration 2 (g/ml)	Concentration 3 (g/ml)	Concentration 4 (g/ml)
Sweet	Sucrose	0.4	0.2	0.1	0.05
Sour	Citric acid	0.3	0.165	0.09	0.05
Salty	Sodium chloride	0.25	0.1	0.04	0.016
Bitter	Quinine hydrochloride	0.006	0.0024	0.0009	0.0004

Table 5.3. Randomization of the administration of the Taste Strips.

Taste	Lowest concentration	→	Highest concentration
Sweet	1	6	11
Sour	3	5	10
Salty	4	8	9
Bitter	2	7	12

Patients will have to rinse their mouth with water before each administration. They will then place a strip in the anterior region of their tongue, suck it for 20 seconds, say if they detect a taste and if so, identify the taste to which they have been exposed (see Figure 5.3). A forced choice task between 4 descriptors (sweet, sour, dirty, bitter) will be performed. A correct answer is worth 1 point, or 16 points at most. Patients will not be kept informed of success or failure in identifying tastes until the end of the study so as not to distort subsequent tests. Patients with a

score ≥ 9 are considered as normogeusic and patients with a score < 9 as hypogeusic. Moreover, 9-point Likert scales were used to assess i) familiarity, ii) intensity, iii) agreeability and iv) edibility, with the anchors i) “unknown” / “familiar”, ii) "no taste" / "intense", iii) "extremely unpleasant" / "extremely pleasant", and "inedible" / "edible". For each dimension, a score ranging from 1 to 9 will be calculated. The relative pleasantness will serve as an indicator of preference among the set of tastes offered in the Taste Strips.



Figure 5.3. Use of the Taste Strips.

Olfactory function

We initially planned to assess the odor detection and identification, familiarity, pleasantness, intensity, edibility and trigeminal perception with the ETOC (62). It consists of first presenting 16 blocks of 4 bottles, only one of which contains an odor, and asking the patients to determine which bottle is odorous and then to identify the odor by choosing an answer among 4 (see Figure 5.4). Sixteen odors, food and non-food items, are therefore presented (vanilla, cloves, apple, eucalyptus, cinnamon, fuel oil, pine, garlic, grass, anise, orange, fish, rose, thyme, lemon, mint). As for the taste strips, the perceptual dimensions will be measured from these odors: familiarity, intensity, agreeability and edibility of the presented odors. In a second step, 8 smells (menthol, vegetable, floral, fruity, woody, spicy, perspiration, gas) are presented to the patient who will have to identify them and assess their familiarity, intensity, agreeability, edibility, and to characterize the odor as cool, hot, irritating or pungent (this last part is referring to the trigeminal sensitivity). The ETOC allows to evaluate the olfactory status (anosmia, hyposmia or normosmia) of the patients, on the basis of predefined cut-off values (63). The patients are considered anosmic when they have a complete loss of smell. They are considered hyposmic when they have reduced smell abilities. Finally, the patients without smell alteration are considered normosmic.



Figure 5.4. Use of the ETOC.

The ETOC test was designed to be used by 40 to 50 patients over a period of up to 6 months. Given the COVID-19 epidemic, it was no longer possible to share the ETOC test between several patients. Therefore, it will be replaced by 14 single-use olfactory cards, which can be easily manipulated by the patients themselves. The patients will have to open the blister, take out the card, scrape the yellow circle on the card with a stick to release the odor, and to smell it (see Figure 5.5). Then they can perform the identification task and rate the familiarity, pleasantness, intensity, and edibility of the odor. However, as each card contains an odor, it is impossible to obtain a detection score. Moreover, the probability table used to evaluate the olfactory function of the patients based on the results of the ETOC is not appropriate for this tool.



Figure 5.5. Use of the olfactory cards to assess the identification smell capacity of the patients.

Eating behaviors assessment using TFEQ

The TFEQ is composed of 51 questions measuring 3 factors (40). The ‘cognitive restraint of eating’ factor ranges from 0 to 21 and measures the control of the diet in a restrictive mode to achieve a weight goal (example of item: I count calories as a conscious means of controlling my weight). The ‘disinhibition’ factor ranging from 0 to 16. It measures the loss of control overeating and refers to emotionality and / or externality related to food consumption (example of item: I usually eat too much at social occasions, like parties and picnics). The ‘hunger’ factor measures the ability to feel this sensation with a 0 to 14 score (example of item: I am usually so hungry that I eat more than three times a day).

Assessment of levels of hunger, desire to eat, prospective consumption and satiation

Appetite sensations (feelings of hunger, desire to eat, fullness and prospective consumption) will be assessed before and after the buffet by using 100 mm visual analog scales (0 mm corresponds to ‘not at all’ and 100 mm corresponds to ‘extremely’) and the following questions: ‘How hungry are you?’, ‘How full are you?’, ‘How strong is your desire to eat?’, and ‘How much food do you think you could eat right now?’ (64). These measurements will allow us to calculate a composite appetite score according to the following formula: composite appetite (mm) = (hunger + desire to eat + (100 – fullness) + prospective consumption)/4 (65).

Assessment of food preferences

Meiselman recommended that research on eating behavior should re-focus on real eating situations, with real foods (45). To stay along these lines, we decided to assess food preferences, in a controlled but ecological (i.e., more realistic) environment, in the domestic kitchens of the Institut Paul Bocuse. The type of meal may influence the meal parameters (66). Patients’ food preferences will be collected by direct measurement of eating behavior through a dedicated and standardized ad-libitum buffet configuration. We decided to use real foods, in a buffet type meal as Alliot et al. demonstrated that an ad-libitum buffet meal in a controlled but more naturalistic environment, had a good reproducibility and sensitivity to differences in hunger level, energy intake and eating behaviors, including the microstructure of the meal (meal duration, time spent at the buffet, number of bites, mean energy content of bites) (1). Interestingly, one study showed that the quantities presented during an ad-libitum buffet and the size of the containers would encourage volunteers to consume larger proportions than they usually consume (67). However, another study showed that food intake was not influenced by the size of the containers, even when the participants served themselves (68). A series of important considerations were taken in order to design the new buffet-type configuration particular for our studied population and the primary aim of the study as explained in the section below.

⇒ Design of the buffet

In Chapter IV, we used the Leeds Food Preference Questionnaire, a behavioral computerized task and we found a lower liking and wanting for ‘high fat – sweet foods’ among

bariatric surgery patients compared to patients with unoperated obesity. These findings were coherent with findings from the literature demonstrating postoperative decreased hedonic ratings for energy dense (69) and high-calorie foods in bariatric surgery patients compared to patients with obesity (7). By designing this study, we wish to verify if these results are reproducible under an ecological eating environment. Thus, we chose food items varying in fat (high / low), and carbohydrate content (high / low). Foods' high in fat and carbohydrate were defined as having at least 15% of fat and carbohydrate per 100 g of food items, respectively. Foods low in fat and carbohydrate were defined as having less than 5% of fat and carbohydrate per 100 g of food items, respectively. Two additional dimensions were also considered: protein content (high / low) and energy density (high / low), 6.2g/100 g and 2.3kcal/g based on the calculated median of the food items, respectively. The design of the buffet and the selected food items are presented in Table 5.4. The nutritional composition of the selected foods is available in Appendix 5.A and was either determined on the packaging of the industrial products, or calculated using the general Centre d'Information sur la QUalité des ALiments (CIQUAL) food directory, which is the reference food composition table in France (70).

Table 5.4. Studied food items and composition of the buffet meal.

	HF > 15%	LF ≤ 5%
HC ≥ 15%	Chocolate cake Dauphine potatoes Rice salad with tuna * Breaded chicken fries *	Compote Ketchup Bread * Pasta
LC < 5%	Comté cheese * Country terrine * Minced steak * Mayonnaise	Cottage cheese * Tomato basil Parsley green beans Pollock with sorrel *

*Foods with the highest content of proteins

⇒ Choice of the food items

In addition to these criteria, we selected food items that could typically be eaten at lunchtime, to avoid any occasional consumption. We also ensured that patients with bariatric surgery could consume the foods, by reviewing postoperative nutritional guidelines (71,72). We ensured that foods could be combined and consumed together considering the esthetic of the plate and the food pairing that are usual for French consumers. We also took into account the seasonality and we selected products that are available all year round. Finally, the choice of foods was in relation to the feasibility, reproducibility and the skills and time needed during the

culinary preparations. We worked closely with the Research and Innovation team of the IPBR to develop recipes that meet all these criteria, while keeping good organoleptic qualities (the recipes are available in Appendix 5.B). Technical datasheets in order to standardize the preparation of buffet meals were produced. Importantly, the buffet test food display will be fixed and identical to all the volunteers and there will be no randomization in the display between the patients. Photos of the buffet have been taken to ensure the reproducibility of the presentation between patients (see Figure 5.6). Finally, the location of the various elements on the site of the investigation were defined on plans (see Appendix 5.C).



Figure 5.6. Ad-libitum buffet meal.

⇒ Adaptation of the quantities

Concerning the quantities, we used as a basis the guidelines of the Groupement d'Etude des Marchés en Restauration Collective et de Nutrition (GEMRCN) (73), which gives recommendations concerning the weight of the portions served in collective catering. We multiplied these quantities by 3 to ensure that the buffet will be ad-libitum. Given that the characteristics of the 1879 patients with bariatric surgery in the Swedish Obese Subjects (SOS) cohort (57), were similar to those of bariatric surgery patients in France (53), the mean (\pm SD) energy intake consumed preoperatively by women participating in the SOS study (2749 ± 1186 kcal) (54) was used. Considering that the lunch corresponds to 40% of the daily intake, we estimated that preoperative patients approximately eat 1100 kcal for lunch. Thus, the total energy intake of the buffet had to reach at least 3 times this value, i.e., 3300 kcal.

⇒ Safety of the patients

All the precautions necessary for the use and preparation of food will be implemented (hygiene, respect for the cold chain, First In First Out (FIFO), labeling of opened products, etc.) to ensure the food safety of the buffet products.

⇒ Measurements

Patients will take their buffet-meal in one of the domestic-type kitchens of the Institut Paul Bocuse. They will have their own individual buffet and will be separated by screens so that there will be no interactions or disturbances during the meal. During the buffet meal, patients will be filmed to study their food choices and the microstructure of their meal (see Figure 5.7). A systematic review showed that obesity is associated with high eating rate (74) and a study conducted in a cafeteria setting demonstrated that participants with obesity have higher bite size in comparison to participants with normal BMI and overweight (75).



Figure 5.7. Video recordings will be performed to study the microstructure of the meal.

The weight of each food item will be measured before and after consumption, and the total energy and macronutrient intake will be calculated using the general CIQUAL food directory (70). This will also allow us to calculate the percentage energy intake at the buffet from proteins, fats and carbohydrates. A test buffet has been carried out to take into account the evaporation coefficient of the hot dishes (see Table 5.5). Finally, appreciation of the food items will be recoded using 100-mm VAS rating.

Table 5.5. Calculation of the evaporation coefficient.

	Weight after cooking (g)	Weight before consumption (g)	Evaporation coefficient (%)
Parsley green beans	805	798	0.87
Pasta	968	968	0.00
Dauphine potatoes	930	921	0.97
Minced steak	1008	995	1.29
Pollock with sorrel	1059	1041	1.70
Breaded chicken fries	982	959	2.34

5.2.1. Summary of the course of the experiment (see Figure 5.8)

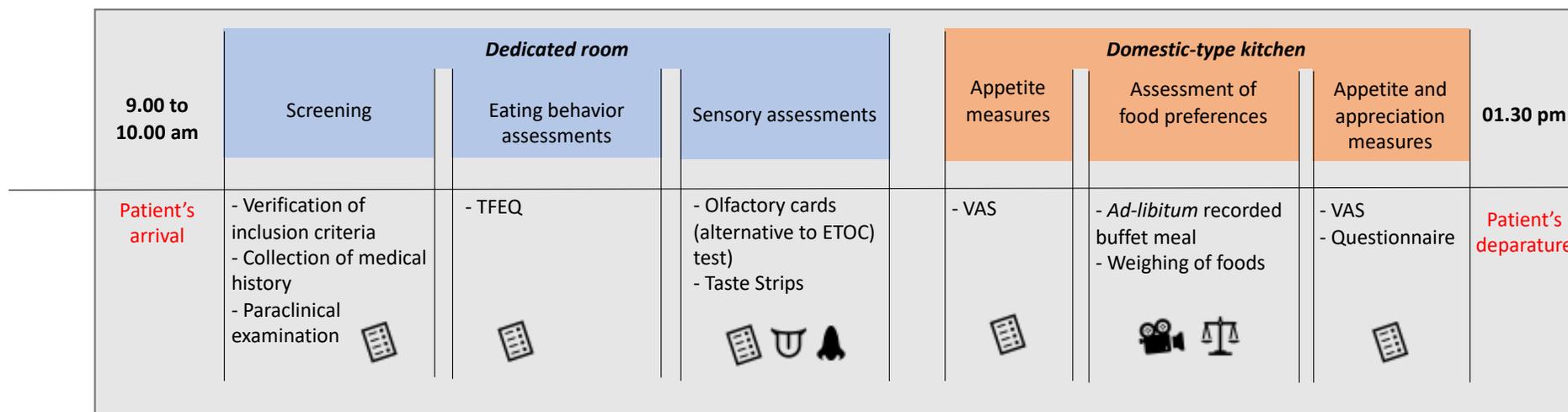


Figure 5.8. Summary of the course of the experiment.

Abbreviations: TFEQ, Three Eating Factor Questionnaire; ETOC, European Test of Olfactory Capabilities; VAS, Visual Analog Scale.

5.2.2. *Statistical analyses*

Treatment of missing subjects

Missing or invalid data on the primary endpoint will be replaced with new inclusions.

Descriptive statistics

A descriptive analysis of the characteristics and endpoints will be performed for the entire sample and by group. The quantitative data will be described using the following descriptive statistics: enumeration, number of missing values, mean and standard deviation, median and first and third quartile as well as range. The quantitative variables can be categorized using their median or a cut-off (threshold) known from the literature.

The qualitative variables will be summarized using the following descriptive statistics: frequencies and percentages for each level of the variable and missing values (missing values will be counted and will be included in the denominator of the frequency calculation).

Analytical statistics

The comparisons of the primary and secondary endpoints between the control and the surgery groups will be performed using Student's tests, Wilcoxon tests, Chi-square or Kruskal and Wallis tests as appropriate. Food preferences will be mapped for the entire population and for each group using Principal Component Analysis (PCA). The links between food preferences and sensory changes will be analyzed using regression models the with least absolute shrinkage and selection operator (LASSO) (76). Correlation analyses will be performed to study the relationships between parameters of food preferences and sensory evaluation. The analyses will be carried out considering an alpha threshold fixed at 5% with a Holm Bonferroni correction for multiple tests if necessary.

5.3. Expected results

To our knowledge this is the first study assessing food preferences and eating behavior using a buffet-type design in a more natural eating environment in patients with obesity who had or not yet bariatric surgery. This study design will allow us to assess food preferences and choices, total energy and macronutrient intake, and link the eating behavior with any changes observed in their sensory abilities as a major driver of food choice and intake.

A significant difference in terms of food preferences, between patients with obesity with or without bariatric surgery is expected. The use of a real eating situation will provide a higher ecological relevance, which is important to generalize results to the real world. Especially, the research design has been thought to conserve to the extent is possible the usual dietary habits of the patients. For instance, patients will have their usual breakfast and test buffet meal is at lunchtime. This research will use video recordings and analyses of the microstructure of the meal, which could provide some insight on the underlying mechanisms of postoperative changes in food preferences. Also, this is the first study to relate these parameters to the sensory abilities of the patients assessed with psychophysical testing, which could complement the understanding of postoperative food preferences.

The findings of this research could also provide practical tools for healthcare professionals who follow patients who undergo bariatric surgery in order to detect and address their eating difficulties and sensory alterations. Ultimately, the results of this research could help improve the pre- and post-operative management of bariatric surgery patients through advice on tasting, preparation, recipe sheets, and nutritional information. New dietary strategies could help patients adapt more easily to the dietary changes induced by bariatric surgery and thus, promote a tailored dietary plan to limit the risk of undernutrition and maintain the weight loss induced by the surgery over time.

5.4. Conclusion

We designed a buffet meal for a study aiming at comparing food preferences and choices, and meal microstructure between patients with obesity with or without bariatric surgery. This study will increase the knowledge about changes in food preferences after bariatric surgery as it is the first to use a real context eating environment and to study parameters at the level of the microstructure of the meal.

5.5. References

1. Alliot X, Saulais L, Disse E, Roth H, Cazal C, Laville M. Validation of a buffet meal design in an experimental restaurant. *Appetite*. 2012 Jun 1;58(3):889–97.
2. Laurenus A, Larsson I, Melanson KJ, Lindroos AK, Lönroth H, Bosaeus I, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. *Eur J Clin Nutr*. 2013 Feb 9;67(2):168–73.
3. Coluzzi I, Raparelli L, Guarnacci L, Paone E, Del Genio G, le Roux CW, et al. Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy. *Obes Surg*. 2016 Sep 7;26(9):2059–67.
4. Makaronidis JM, Neilson S, Cheung W-H, Tymoszuk U, Pucci A, Finer N, et al. Reported appetite, taste and smell changes following Roux-en-Y gastric bypass and sleeve gastrectomy: Effect of gender, type 2 diabetes and relationship to post-operative weight loss. *Appetite*. 2016 Dec;107:93–105.
5. Thirlby RC, Bahiraei F, Randall J, Drewnoski A. Effect of Roux-en-Y gastric bypass on satiety and food likes: the role of genetics. *J Gastrointest Surg*. 2006 Feb;10(2):270–7.
6. Molin Netto BDBD, Earthman CP, Farias G, Landi Masquio DC, Grotti Clemente AP, Peixoto P, et al. Eating patterns and food choice as determinant of weight loss and improvement of metabolic profile after RYGB. *Nutrition*. 2017 Jan;33:125–31.
7. Faulconbridge LF, Ruparel K, Loughhead J, Allison KC, Hesson LA, Fabricatore AN, et al. Changes in neural responsivity to highly palatable foods following roux-en-Y gastric bypass, sleeve gastrectomy, or weight stability: An fMRI study. *Obesity*. 2016 May;24(5):1054–60.
8. Kittrell H, Graber W, Mariani E, Czaja K, Hajnal A, Di Lorenzo PM. Taste and odor preferences following Roux-en-Y surgery in humans. Covasa M, editor. *PLoS One*. 2018 Jul 5;13(7):e0199508.
9. Zoon HFA, de Bruijn SEM, Jager G, Smeets PAM, de Graaf C, Janssen IMC, et al. Altered neural inhibition responses to food cues after Roux-en-Y Gastric Bypass. *Biol Psychol*. 2018 Sep;137:34–41.
10. Tucker KL. Assessment of usual dietary intake in population studies of gene-diet interaction. Vol. 17, *Nutrition, Metabolism and Cardiovascular Diseases*. *Nutr Metab Cardiovasc Dis*; 2007. p. 74–81.
11. Klesges LM, Baranowski T, Beech B, Cullen K, Murray DM, Rochon J, et al. Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8- to 10-year-old African-American girls: Results from the Girls health Enrichment Multisite Studies (GEMS). *Prev Med (Baltim)*. 2004;38(SUPPL.):78–87.
12. Herbet JR, Clemow L, Pbert L, Ockene IS, Ockene JK. Social Desirability Bias in Dietary Self-Report May Compromise the Validity of Dietary Intake Measures. *Int J Epidemiol*. 1995 Apr 1;24(2):389–98.
13. Kristal AR, Andrilla CHA, Koepsell TD, Diehr PH, Cheadle A. Dietary assessment instruments are susceptible to intervention- associated response set bias. *J Am Diet Assoc*. 1998 Jan 1;98(1):40–3.
14. Wehling H, Lusher J. People with a body mass index ≥ 30 under-report their dietary intake: A systematic review. Vol. 24, *Journal of Health Psychology*. SAGE Publications

- Ltd; 2019. p. 2042–59.
15. Lissner L. Measuring food intake in studies of obesity. *Public Health Nutr.* 2002 Dec;5(6a):889–92.
 16. Heitmann BL, Lissner L. Dietary underreporting by obese individuals—is it specific or non-specific? *BMJ.* 1995 Oct 14;311(7011):986.
 17. Goris AH, Westerterp-Plantenga MS, Westerterp KR. Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. *Am J Clin Nutr.* 2000 Jan 1;71(1):130–4.
 18. Olivo G, Zhou W, Sundbom M, Zhukovsky C, Hogenkamp P, Nikontovic L, et al. Resting-state brain connectivity changes in obese women after Roux-en-Y gastric bypass surgery: A longitudinal study. *Sci Rep.* 2017 Dec 26;7(1):6616.
 19. Wang J-L, Yang Q, Hajnal A, Rogers AM. A pilot functional MRI study in Roux-en-Y gastric bypass patients to study alteration in taste functions after surgery. *Surg Endosc.* 2016;30(3):892–8.
 20. Frank S, Veit R, Sauer H, Enck P, Friederich HC, Unholzer T, et al. Dopamine depletion reduces food-related reward activity independent of BMI. *Neuropsychopharmacology.* 2016 May 1;41(6):1551–9.
 21. Goldstone AP, Miras AD, Scholtz S, Jackson S, Neff KJ, Pénicaud L, et al. Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *J Clin Endocrinol Metab.* 2016 Feb 1;101(2):599–609.
 22. Scholtz S, Miras AD, Chhina N, Prechtel CG, Sleeth ML, Daud NM, et al. Obese patients after gastric bypass surgery have lower brain-hedonic responses to food than after gastric banding. *Gut.* 2014 Jun;63(6):891–902.
 23. Ochner CN, Kwok Y, Conceicao E, Pantazatos SP, Puma LM, Carnell S, et al. Selective reduction in neural responses to high calorie foods following gastric bypass surgery. *Ann Surg.* 2011 Mar;253(3):502–7.
 24. Giel KE, Rieber N, Enck P, Friederich H-C, Meile T, Zipfel S, et al. Effects of laparoscopic sleeve gastrectomy on attentional processing of food-related information: evidence from eye-tracking. *Surg Obes Relat Dis.* 2014;10(2):277–82.
 25. Holsen LM, Davidson P, Cerit H, Hye T, Moondra P, Haimovici F, et al. Neural predictors of 12-month weight loss outcomes following bariatric surgery. *Int J Obes (Lond).* 2018;42(4):785–93.
 26. Ochner CN, Laferrère B, Afifi L, Atalayer D, Geliebter A, Teixeira J. Neural responsivity to food cues in fasted and fed states pre and post gastric bypass surgery. *Neurosci Res.* 2012 Oct;74(2):138–43.
 27. Miras AD, Jackson RN, Jackson SN, Goldstone AP, Olbers T, Hackenberg T, et al. Gastric bypass surgery for obesity decreases the reward value of a sweet-fat stimulus as assessed in a progressive ratio task. *Am J Clin Nutr.* 2012 Sep 1;96(3):467–73.
 28. Hanci D, Altun HH, Altun HH, Batman B, Karip AB, Serin KR, et al. Laparoscopic Sleeve Gastrectomy Improves Olfaction Sensitivity in Morbidly Obese Patients. *Obes Surg.* 2016 Mar 1;26(3):558–62.
 29. Bueter M, Miras AD, Chichger H, Fenske W, Ghatei MA, Bloom SR, et al. Alterations of sucrose preference after Roux-en-Y gastric bypass. *Physiol Behav.* 2011

- Oct;104(5):709–21.
30. Burge JC, Schaumburg JZ, Choban PS, DiSilvestro RA, Flancbaum L. Changes in patients' taste acuity after Roux-en-Y gastric bypass for clinically severe obesity. *J Am Diet Assoc.* 1995 Jun;95(6):666–70.
 31. Holinski F, Menenakos C, Haber G, Olze H, Ordemann J. Olfactory and Gustatory Function After Bariatric Surgery. *Obes Surg.* 2015 Dec;25(12):2314–20.
 32. Nance K, Eagon JC, Klein S, Pepino MY. Effects of Sleeve Gastrectomy vs. Roux-en-Y Gastric Bypass on Eating Behavior and Sweet Taste Perception in Subjects with Obesity. *Nutrients.* 2017 Dec;10(1).
 33. Pepino MY, Bradley D, Eagon JC, Sullivan S, Abumrad NA, Klein S. Changes in taste perception and eating behavior after bariatric surgery-induced weight loss in women. *Obesity (Silver Spring).* 2014 May;22(5):E13-20.
 34. Scruggs, Buffington, Jr C. Taste Acuity of the Morbidly Obese before and after Gastric Bypass Surgery. *Obes Surg.* 1994 Feb;4(1):24–8.
 35. Nielsen MS, Andersen INSKK, Lange B, Ritz C, le Roux CW, Schmidt JB, et al. Bariatric Surgery Leads to Short-Term Effects on Sweet Taste Sensitivity and Hedonic Evaluation of Fatty Food Stimuli. *Obesity.* 2019 Sep;
 36. Jurowich CF, Seyfried F, Miras AD, Bueter M, Deckelmann J, Fassnacht M, et al. Does bariatric surgery change olfactory perception? Results of the early postoperative course. *Int J Colorectal Dis.* 2014;29(2):253–60.
 37. Enck P, Rieber N, Sauer H, Klosterhalfen S, Mack I, Zipfel S, et al. Almost Nothing - Not Even Bariatric Surgery for Obesity - Changes Olfactory Sensitivity. *J Res Obes.* 2014 Apr 1;1:1–13.
 38. Medic N, Ziauddeen H, Forwood SE, Davies KM, Ahern AL, Jebb SA, et al. The presence of real food usurps hypothetical health value judgment in overweight people. *eNeuro.* 2016;3(2):412–27.
 39. Gregersen NT, Flint A, Bitz C, Blundell JE, Raben A, Astrup A. Reproducibility and power of ad libitum energy intake assessed by repeated single meals. *Am J Clin Nutr.* 2008 May 1;87(5):1277–81.
 40. Martin CK, Williamson DA, Geiselman PJ, Walden H, Smeets M, Morales S, et al. Consistency of food intake over four eating sessions in the laboratory. *Eat Behav.* 2005 Dec;6(4):365–72.
 41. Robinson E, Haynes A, Hardman CA, Kempes E, Higgs S, Jones A. The bogus taste test: Validity as a measure of laboratory food intake. *Appetite.* 2017 Sep 1;116:223–31.
 42. Blundell J, De Graaf C, Hulshof T, Jebb S, Livingstone B, Lluch A, et al. Appetite control: Methodological aspects of the evaluation of foods. Vol. 11, *Obesity Reviews.* *Obes Rev;* 2010. p. 251–70.
 43. Blundell J, de Graaf K, Finlayson G, Halford JCG, Hetherington M, King N SJ. Measuring food intake, hunger satiety, and satiation in the laboratory. In *Handbook of Assessment Methods for Eating Behaviours and Weight-related Problems: Measures, Theory and Research.* Baskin DA& M, editor. Thousand oaks, California, USA: SAGE Publications Inc.; 2009. 283–326 p.
 44. Gough T, Haynes A, Clarke K, Hansell A, Kaimkhani M, Price B, et al. Out of the lab

- and into the wild: the influence of portion size on food intake in laboratory vs. real-world settings. *Appetite*. 2021 Feb 6;105:160.
45. Meiselman HL. Methodology and theory in human eating research. *Appetite*. 1992 Aug 1;19(1):49–55.
 46. Kapoor N, Al-Najim W, le Roux CW, Docherty NG. Shifts in Food Preferences After Bariatric Surgery: Observational Reports and Proposed Mechanisms. *Curr Obes Rep*. 2017 Sep;6(3):246–52.
 47. Gero D, Steinert RE, le Roux CW, Bueter M. Do Food Preferences Change After Bariatric Surgery? *Curr Atheroscler Rep*. 2017 Sep;19(9):38.
 48. Mathes CM, Spector AC. Food selection and taste changes in humans after Roux-en-Y gastric bypass surgery: a direct-measures approach. *Physiol Behav*. 2012 Nov;107(4):476–83.
 49. Nielsen MS, Christensen BJ, Ritz C, Rasmussen S, Hansen TT, Bredie WLPP, et al. Roux-En-Y Gastric Bypass and Sleeve Gastrectomy Does Not Affect Food Preferences When Assessed by an Ad libitum Buffet Meal. *Obes Surg*. 2017 Oct 14;27(10):2599–605.
 50. Søndergaard Nielsen M, Rasmussen S, Just Christensen B, Ritz C, le Roux CW, Berg Schmidt J, et al. Bariatric Surgery Does Not Affect Food Preferences, but Individual Changes in Food Preferences May Predict Weight Loss. *Obesity*. 2018 Dec;26(12):1879–87.
 51. Herman CP, Polivy J. Sex and Gender Differences in Eating Behavior. In: *Handbook of Gender Research in Psychology*. Springer New York; 2010. p. 455–69.
 52. Hill SW, McCutcheon NB. Contributions of obesity, gender, hunger, food preference, and body size to bite size, bite speed, and rate of eating. *Appetite*. 1984 Jun 1;5(2):73–83.
 53. Martincic C, Balcaen T, Georges A, Baro E, Ficheur G, Chazard E. La chirurgie bariatrique en France de 2008 à 2014 : triplement de l'activité et fort recul de l'anneau gastrique. *Rev Epidemiol Sante Publique*. 2017 Mar 1;65:S20.
 54. Kanerva N, Larsson I, Peltonen M, Lindroos AK, Carlsson LM. Changes in total energy intake and macronutrient composition after bariatric surgery predict long-term weight outcome: Findings from the Swedish Obese Subjects (SOS) study. *Am J Clin Nutr*. 2017 Jul 1;106(1):136–45.
 55. Angrisani L, Santonicola A, Iovino P, Ramos A, Shikora S, Kow L. Bariatric Surgery Survey 2018: Similarities and Disparities Among the 5 IFSO Chapters. *Obes Surg*. 2021 Jan 12;1–12.
 56. Hubert, Papasavas P, Stone, Swede, Huedo-Medina, Tishler, et al. Associations between Weight Loss, Food Likes, Dietary Behaviors, and Chemosensory Function in Bariatric Surgery: A Case-Control Analysis in Women. *Nutrients*. 2019 Apr 9;11(4):804.
 57. El Labban S, Safadi B, Olabi A. The Effect of Roux-en-Y Gastric Bypass and Sleeve Gastrectomy Surgery on Dietary Intake, Food Preferences, and Gastrointestinal Symptoms in Post-Surgical Morbidly Obese Lebanese Subjects: A Cross-Sectional Pilot Study. *Obes Surg*. 2015 Dec 1;25(12):2393–9.
 58. Oustric P, Gibbons C, Beaulieu K, Blundell J, Finlayson G. Changes in food reward during weight management interventions – a systematic review. Vol. 19, *Obesity*

- Reviews. Blackwell Publishing Ltd; 2018. p. 1642–58.
59. Landis BN, Welge-Luessen A, Brämerson A, Bende M, Mueller CA, Nordin S, et al. “taste Strips” - A rapid, lateralized, gustatory bedside identification test based on impregnated filter papers. *J Neurol*. 2009 Feb;256(2):242–8.
 60. Mueller C, Kallert S, Renner B, Stiassny K, Temmel AFP, Hummel T, et al. Quantitative assessment of gustatory function in a clinical context using impregnated “taste strips.” *Rhinology*. 2003 Mar 1;41(1):2–6.
 61. Altun HHH, Hanci D, Altun HHH, Batman B, Serin RK, Karip AB, et al. Improved Gustatory Sensitivity in Morbidly Obese Patients After Laparoscopic Sleeve Gastrectomy. *Ann Otol Rhinol Laryngol*. 2016 Jul 1;125(7):536–40.
 62. Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, et al. Development of the ETOC: A European Test of Olfactory Capabilities. *Rhinology*. 2003;41(3):142–51.
 63. Jousain P, Bessy M, Fournel A, Ferdenzi C, Rouby C, Delphin-Combe F, et al. Altered affective evaluations of smells in Alzheimer’s disease. *J Alzheimer’s Dis*. 2015 Oct 9;49(2):433–41.
 64. Flint A, Raben A, Blundell JE, Astrup A. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *Int J Obes*. 2000 Mar 2;24(1):38–48.
 65. Samra RA, Anderson GH. Insoluble cereal fiber reduces appetite and short-term food intake and glycemic response to food consumed 75 min later by healthy men. *Am J Clin Nutr*. 2007 Oct 1;86(4):972–9.
 66. Bellisle F, Guy-Grand B, Le Magnen J. Chewing and swallowing as indices of the stimulation to eat during meals in humans: Effects revealed by the edogram method and video recordings. Vol. 24, *Neuroscience and Biobehavioral Reviews*. *Neurosci Biobehav Rev*; 2000. p. 223–8.
 67. Hollands GJ, Shemilt I, Marteau TM, Jebb SA, Lewis HB, Wei Y, et al. Portion, package or tableware size for changing selection and consumption of food, alcohol and tobacco. Vol. 2017, *Cochrane Database of Systematic Reviews*. John Wiley and Sons Ltd; 2015.
 68. Kosite D, König LM, De-Loyde K, Lee I, Pechey E, Clarke N, et al. Plate size and food consumption: A pre-registered experimental study in a general population sample. *Int J Behav Nutr Phys Act*. 2019 Aug 28;16(1).
 69. Ammon BS, Bellanger DE, Geiselman PJ, Primeaux SD, Yu Y, Greenway FL. Short-Term Pilot Study of the Effect of Sleeve Gastrectomy on Food Preference. *Obes Surg*. 2015 Jun 26;25(6):1094–7.
 70. ANSES. Ciqual Table de composition nutritionnelle des aliments [Internet]. [cited 2021 Feb 17]. Available from: <https://ciqual.anses.fr/>
 71. Leahy CR, Luning A. Review of Nutritional Guidelines for Patients Undergoing Bariatric Surgery. *AORN J*. 2015 Aug 1;102(2):153–60.
 72. Dagan SS, Goldenshluger A, Globus I, Schweiger C, Kessler Y, Sandbank GK, et al. Nutritional Recommendations for Adult Bariatric Surgery Patients: Clinical Practice. *Adv Nutr An Int Rev J*. 2017 Mar 1;8(2):382–94.
 73. GEMRCN. Recommandation nutrition | economie.gouv.fr [Internet]. Version 2.0 -

- Juillet 2015. [cited 2021 Feb 17]. Available from: <https://www.economie.gouv.fr/daj/recommandation-nutrition>
74. Ohkuma T, Hirakawa Y, Nakamura U, Kiyohara Y, Kitazono T, Ninomiya T. Association between eating rate and obesity: A systematic review and meta-analysis. Vol. 39, *International Journal of Obesity*. Nature Publishing Group; 2015. p. 1589–96.
 75. Mattfeld RS, Muth ER, Hoover A. A comparison of bite size and BMI in a cafeteria setting. *Physiol Behav*. 2017 Nov 1;181:38–42.
 76. Tibshirani R. Regression Shrinkage and Selection Via the Lasso. *J R Stat Soc Ser B*. 1996;58(1):267–88.

Chapter VI. General discussion and conclusion

The research presented in this doctoral work explores the influence of bariatric surgery on the hedonic regulation of appetite (sensory and reward domain) and its phenotypic expression (i.e., food preferences), which are altered in obesity. A better understanding of these phenomena is of prime importance for managing weight loss success and nutritional side effects. First, a systematic review and meta-analysis were conducted investigating the effect of bariatric surgery on food preferences, considering various methods and time points during patients' weight loss trajectory. The identification of gaps in the literature prompted us to conduct new research. In particular we intended to combine approaches from the nutrition, sensory and neuroscience fields, which are complementary for a comprehensive understanding of postoperative hedonic regulation of appetite and food preferences. An observational cross-sectional study was therefore performed in a second step. This study aimed to characterize and compare postoperative food preferences based on the presence or absence of taste and smell alterations, the duration of the follow-up (< 2 or ≥ 2 y) and the success or failure of bariatric surgery. Since our results highlighted a duality between two main types of food: high-fat and high-sweet foods, which are usually considered palatable, and healthier food options, we decided to further explore food reward in the context of bariatric surgery. In a third part, we then adapted and used a behavioral computerized task to compare food reward between patients with a SG, a RYGB and non-operative patients with obesity in a clinical setting. Finally, the lack of measurements of food preferences in a real context of consumption led us to design a clinical study to compare food preferences between non-operative patients with obesity and patients who had bariatric surgery in the past 12 months using a buffet meal in an ecological setting. This study, which get ethical and regulatory agreement will start mid-May 2021 and will also enable to explore the link between food preferences and the sensory profile of the patients.

The first part of this chapter summarizes the results describing food preferences after bariatric surgery and their link with the sensory and reward domain. The second part discusses the findings with regards to the theoretical model of appetite control. The third part consists of a methodological reflection about the tools and experimental designs used to measure food preferences in the context of bariatric surgery, before discussing strengths and limitations of this doctoral work. The last part will address the perspectives of this work from two different angles: the directions for future research and the recommendations for clinical practice and public health.

8.1 Main results

Overall, this thesis supports previous research, which found that changes in food preferences occur after bariatric surgery, with patients preferring less highly palatable foods (high-fat sweet foods) (Chapter II, III and IV). This low preference towards highly palatable foods results in a decreased contribution of fat to the total energy intake but not of carbohydrates after bariatric surgery (Chapter II). In addition, post-operative patients prefer healthy foods (Chapter II and III), especially fruits and vegetables, which improves diet quality (Chapter II). Our results however revealed an attenuation of these changes in the longer term after bariatric surgery (Chapter II and III) and indicated that changes of food preferences were different among those patients characterized as having a successful weight loss trajectory than those who did not (Chapter III).

This thesis linked the postoperative food preferences with modifications of the sensory (Chapter III) and the reward domain (liking and wanting) (Chapter II and IV). While most patients declared having taste alteration, a small number of patients did not encounter any smell alteration. In both cases, sensory alterations were characterized mainly by an increase in sensitivity to tastes and smells (Chapter III). Interestingly, postoperative food preferences differed between patients with and without sensory alterations (Chapter III). Moreover, food reward patterns differed between patients with obesity, with and without bariatric surgery (Chapter IV). Overall, there was a low liking score for most food groups accompanied by a low wanting score for some food categories including highly palatable foods.

This doctoral work highlighted the various methods and designs used to assess food preference in the context of bariatric surgery, and that there is a paucity of data on real foods in a normal eating environment (Chapter II). In order to improve the ecological validity of our research, we designed a study using objective measurements of eating behavior, olfactory and taste capacities (Chapter IV). This study will enable the comparison of food preferences and microstructure of the meal evaluated by a standardized and validated buffet, between adult women with obesity, and those with bariatric surgery in the past 12 months.

8.2 Reflection about the model of homeostatic and hedonic regulation of appetite following bariatric surgery

Chapter II highlighted that most of the research related to food preferences were conducted in patients with RYGB, which prevented us from performing sub-group meta-analyses according to the type of surgery. There are anatomical differences between RYGB and SG, which in turn impact upon the mechanisms underlying the weight-reducing effects of these two procedures. Furthermore, RYGB and SG have different post-ingestive effects. Especially, the prevalence of dumping syndrome is higher after RYGB than SG (1), which could induce a more pronounced taste avoidance for high carbohydrate foods among patients with RYGB compared to patients with SG. However, in our comparative study design between these two types of surgery (Chapter IV), results showed a similar pattern of food reward (liking and wanting) and food choices between patients with RYGB and SG. These findings showed that the postoperative modifications of the hedonic appetite might be explained by common mechanisms between the two types of surgeries.

Changes in appetite signaling that occur in both RYGB and SG could explain the postoperative modifications of liking and wanting and ultimately of food preferences and choices. Considering the episodic appetite signals, both types of surgery induce similar decrease in ghrelin and increase in CCK, PYY and GLP-1 levels (2). In addition to its role in the homeostatic regulation of appetite (3), ghrelin is involved in both liking and wanting pathways (i.e., opioid and endocannabinoid systems and dopamine pathway respectively) (4). Results from preclinical studies demonstrated that ghrelin modulates food reward. It increases the food anticipatory activity (FFA) in rodents (5), which corresponds to an increase in arousal, locomotor activity and body temperature, in anticipation of the meal (6–9). On the other hand, inhibition of ghrelin signaling decreases FFA (5). Interestingly, ghrelin has been shown to increase the rewarding value of high-sugar (10–12), and high fat diet (13). Moreover, a study showed that when injected in the ventral tegmental area (VTA), ghrelin increased energy intake in mice fed with a highly palatable diet, and not in mice fed with regular chow (10). Furthermore, inhibition of ghrelin signaling suppressed the intake of highly palatable food in a free choice paradigm between regular low and highly palatable foods (10). Interestingly, chronic delivery of ghrelin increases intake in rats fed with palatable foods only (not chow) (14). On the other hand, acute injection of ghrelin seemed to redirect intake towards a healthier diet in rodents, which initially ate a large proportion of their caloric intake from highly palatable

foods (14,15). Overall, although current evidence supports that ghrelin play a role in food preferences, the exact underlying mechanisms possibly being related to the interaction between appetite signaling and energy balance remain to be elucidated. Satiety signals might also play a role in food reward and preferences. Notably, Goldstone et al. found that the suppression of the enhanced response of satiety hormones after RYGB increases food reward when assessed with a progressive ratio task, which is a behavioral task measuring the willingness to work (i.e., increasing number of mouse clicks) to obtain a high-fat sweet food (16). It also increased the food appeal ratings in a fMRI paradigm as well as the Blood-Oxygen-Level Dependent (BOLD) signal in reward brain areas (16).

Individuals with obesity have a higher plasma leptin levels compared to their counterparts without obesity, and leptin levels were associated with the activation of reward-related brain area (right ventral striatum) in response to visual cue (17). There is only a slight difference in weight loss in favor of RYGB compared to SG (18). This almost similar weight loss might result in the same decrease in fasting leptin levels found in both SG and RYGB (19), which might be a sign of a leptin resensitization (20). Interestingly, leptin levels are also decreased after weight loss interventions (21) and a recent systematic review showed that food reward is modified after weight management interventions being reflected in a decrease in liking and wanting for highly palatable foods (22). Altogether, these findings suggest that a possible mechanism by which the attribution of a hedonic value to food change after bariatric surgery might be related to weight loss itself through the improvement of leptin resistance.

We found in Chapter III that patients perceived sensory alterations after bariatric surgery, which could in turn have an effect on the appreciation of specific foods. The hypothesis of a postoperative endocrine modulation of the hedonic value to foods would be plausible since ghrelin and leptin have shown their role in the modulation of taste (23–25) and olfaction (26).

Overall, the framework of appetite regulation by both homeostatic and hedonic processes as it was initially proposed in the introduction of this doctoral work seems relevant for a better understanding of changes in food preferences after bariatric surgery. However, more research is needed given that underlying mechanisms of these changes are not yet fully elucidated. More broadly, bariatric surgery is an interesting model to explore eating behavior

given that the changes on the homeostatic and hedonic levels of regulation of appetite are more evident in a short duration of time.

8.3 Methodological considerations related to the measure of food preferences in the context of bariatric surgery

In biopsychology, food preferences can be considered as a phenotypic expression of hedonic regulation of food intake, which has two major domains: the sensory and reward domains. It can also be viewed as a relative choice between foods in the nutrition field or as a hedonic rating of foods in the sensory field. This doctoral work crossed these different approaches and their specific tools for a comprehensive understanding of food preferences after bariatric surgery. We found a high degree of heterogeneity on food preferences after bariatric surgery which varied by the study outcomes and time point of assessment in the existing literature (Chapter II). Most of the existing literature use food recalls, food records and food frequency questionnaires. While these tools are inexpensive and easy to set up, they are subject to desirability bias (27–29). We further explored food preference after bariatric surgery using an online questionnaire (Chapter III), and a behavioral computerized task (Chapter IV), which will soon be supplemented by real context measurements and psychophysical testing of sensory abilities (Chapter V). The reasoning of selecting each methodological tool corresponding to the research question raised and the advantages and disadvantages of each are explained below. Our intention was also to see to what extent certain methodological tools could be used in clinical practice for phenotyping patients and receiving tailored medical recommendations.

In Chapter III we used an online questionnaire on food preferences that it was adapted based on existing questionnaires (30,31). We worked closely with scientists from different fields and patients' associations to discuss the relevance of the questions and the clarity of the questionnaire. Importantly, the questionnaire was designed to have a short completion time and not to be too demanding for the patients. The use of an online platform and advertisement in social media facilitated the enrollment of the patients. However, some challenges concerning the choice of the online platform became apparent, since the platform had to be aligned with the laws related to data protection and the requirements of the study promotor. The WEPI 1.0 © Epiconcept 1996-2013 (www.wepi.org) was chosen as it was safe, user-friendly and free at this time, yet with limited functionalities. For instance, WEPI did not allow the use of visual analog scales. In general, the use of questionnaire is subject to bias, including desirability bias

(27–29). In our study, we also suspect the possibility of memory bias since the completion after surgery was long for some of them (> 2 years).

In Chapter IV we used the LFPQ (32), which demonstrated its reliability against actual food selection (33–36). The LFPQ assess explicit liking, explicit and implicit wanting, food choices and taste and sweet appeal bias within one task. Explicit measures are assessed with VAS, while implicit measures are computed based on relative food choices and reaction time of the participants. In the original LFPQ the food items vary along two dimensions: fat (high and low) and taste (sweet and taste). In our study we used the version of Van der Meij et al. (37) to have a broader range of food categories varying along other dimensions related to their nutritional composition sensory properties, including taste or appearance. Before using it, we had to adapt the tool for its use in French language and culture. This was a critical aspect as the guidelines for the cross-cultural adaptation of the LFPQ (38) were not published by the time we conducted the study. These guidelines are related only to the original task of the LFPQ and not the extensive version. However, we could have carried out test measurements to check the properties of the tool before using it in our French cohort, while we verified its properties post-hoc by verifying whether the measures correlated with behavioral outcomes such as the binge eating score calculated with the Binge Eating Scale (39). As expected, we found that the binge eating score positively correlated with liking and wanting for *'high fat – sweet foods'*. Conversely, we did not find a correlation between food reward outcomes food addiction scores.

Some advantages of this tool, include the fact that it was inexpensive and user-friendly for both the investigator and the patient. Additionally, the use of implicit measure of wanting enables to get an intuitive response from patients based on their relative choices and reaction times, which we assume to be a more reliable insight into this partly unconscious process. However, the environment needs to be quiet, and the patient needs to be focused on the task performance. We found that the measures of explicit liking and wanting gave similar results, and that measures of explicit and implicit wanting were contradicting. A possible explanation might be that it was difficult for the patient to capture the difference between explicit liking and wanting based on the questions asked, which might be viewed as similar. Explicit liking was assessed with the question “how much would It pleasant to taste some of this food now?”, while explicit wanting was assessed with the question “how much would you eat some of this food now”. The wording of the questions is very important and needs to be carefully considered

when translated into another language. This difficulty in distinguishing the pleasantness of the taste of food versus the pleasantness of eating has been previously raised by Rogers et al. They finally considered that ratings of desire to eat a portion of a food, which is actually tasted by the participants is a reliable measure of food reward (40).

In Chapter V, we designed a buffet meal for the study of food preferences in our experimental restaurant. We used as a basis the work of Alliot et al. (41), who validated the methodology of the buffet to assess eating behavior at the Institut Paul Bocuse experimental restaurant. As this buffet was intended to be used among normal weight or overweight participants, we adapted it for the dietary constraints (e.g., types of foods, quantities, texture, etc.) of patients with obesity with or without a bariatric surgery. The positive aspect of this type of experiment is the high ecological validity of the measures (42) as it uses situation that patients would experience in more natural eating environment in their real life. Contrary to the questionnaires, which capture subjective responses with a high risk of reporting bias, ad-libitum buffet meal is considered more objective and is typically used to assess the effect of an intervention on food intake and selection of foods (43). However, certain points of vigilance must be raised. Especially, this type of methods is expensive as it requires specific equipment, including cameras, kitchens, dedicated rooms and foods. Furthermore, the analysis of video recordings is time-consuming. Finally, the food products need to be carefully chosen to avoid occasional eating.

Overall, there is a wide range of methodological tools, that could be used to assess food preferences and more generally eating behavior after bariatric surgery. Each of them has pros and cons that needs to be carefully considered depending on the question that needs to be addressed and the available resources. Among the tools used in this work, it seems that the LFPQ is the one that comes closest to these characteristics because it is inexpensive and easy to implement, it combines measures of food preferences/choices with food reward and has been previously validated against actual food selection (33–36). However, it remains time consuming in its version composed of 6 tasks and should ideally be performed without distraction.

8.4 Strengths and limitation

The strengths of this work are related to the reasonable number of patients it involved so as the various and original approaches it uses to advance knowledge on the complex phenomenon of food preferences in the context of bariatric surgery. It notably involved a

systematic review and meta-analyses, concerning overall 2271 patients with RYGB and 903 patients with SG; an online questionnaire performed on 220 patients with a bariatric surgery, a computerized cognitive task performed on 30 patients with OB, 30 with SG and 26 patients with RYGB. Moreover, an ad-libitum buffet meal added to psychophysical sensory testing will be performed on 20 patients with unoperated obesity and 20 patients with SG to enrich the current findings. This diversity of assessment tools, which have been adapted for their use in patients with bariatric surgery, and points of view at the crossroads of several disciplines make the richness of this thesis work. Another strength is the interpretation of the results according to different covariates such as type of surgery, follow-up period, and success or failure of weight loss. This allowed us to take into account the different profiles of the patients and to better characterize postoperative food preferences. Finally, the results of this work have been put into perspective with the existing literature to date, taking mostly into account clinical studies but also including some preclinical studies. It also contributed to discussions around the theoretical framework of appetite control, which are of capital importance for a better understanding of obesity physiopathology and ultimately for proposing adapted treatments that will mimic certain effects of bariatric surgery.

This thesis has also some limitations. All the studies performed in this work were using a cross sectional design, which prevent us from drawing solid conclusions in terms of causality between the surgery intervention and food preference modifications and in terms of mechanistic insight. However, the systematic review and meta-analyses (Chapter II) involved mainly prospective studies, the results of which are overall consistent with our findings, which gives us good confidence in the general interpretation of the findings presented in this thesis. When studying food reward in a clinical setting, the control group was patients with obesity (Chapter IV). The study design did not allow us to control for fasting status and time of the LFPQ assessment in the clinical setting due to be part of the routine medical care of those patients, which another limitation. However, we attempt to mitigate this weakness by performing adjustment on some confounding factors assessed, including appetite levels and behavioral outcomes. The awareness of those limitations allowed us to improve the study design of the buffet meal considering more parameters that could confound the results (Chapter V). We for instance assessed eating behavior with the TFEQ and we standardized the buffet meal. Other parameters such as the socio-cultural background and the ethnicity should however be taken into account in further research given their influence on food choices (44,45).

8.5 Perspectives and recommendations

2.4.5. *Direction for future research*

Study food preferences in an ecological setting

The first perspective of this doctoral work will be to complete the study comparing food preferences between patients with obesity with or without bariatric surgery using a buffet meal in an experimental restaurant (Chapter V). This research will enable a better understanding of food preferences and choices when patients are faced with real visual and olfactory food cues. It will also provide additional data among the very limited studies assessing food preferences of patients with bariatric surgery with real foods such as Nielsen et al., who found no difference in food preferences before and after bariatric surgery when using a buffet type meal in a laboratory setting (46). Our study will additionally enable the characterization of the microstructure of the meal among patients with obesity and with bariatric surgery using video recording. It is known that the total duration of the meal has an effect on the total energy intake (47). Moreover, a pre-clinical study showed that conditioned taste aversion was manifested by a smaller meal size, a longer meal duration, and a decreased ingestion rate (48). Gaining insight on the meal microstructure will allow us to better understand the mechanisms involved in food preferences and choices after bariatric surgery. Furthermore, while this thesis used subjective measures of sensory ability, the upcoming study will use psychophysical testing to assess more accurately the sensory abilities of the patients. Furthermore pleasantness, intensity, familiarity and edibility will be rated for each tastes and odors to study other dimensions of gustation and olfaction in relation to patients' food preferences.

Study other determinants of food preferences

Food preferences have various determinants, including factors related to the individual himself, to the food and to the environment (49). It was beyond the scope of this thesis to cover all these determinants. However, it would be of great interest to study some of them in future research. For instance, the role of learning (i.e., predictive associations and cognitions), which is another component of food reward (50), needs to be clarified in the theoretical framework of the hedonic regulation of appetite after bariatric surgery. It should also be noted that in addition to the homeostatic and hedonic regulation pathways, the cognitive regulation of food intake involves higher cognitive functions, such as executive memory or inhibitory processes (51). It

has been demonstrated that bariatric surgery recovers some brain structures and functions, which are impaired in obesity (52,53). More precisely, a systematic review demonstrated that the weight loss induced by bariatric surgery is associated with improved cognitive functions of the patients (54). Thus, exploring the role of cognitive function in relation to food preferences and overall dietary habits in this specific context seems prudent.

Build a predictive model of weight loss success and failure

In Chapter III, we explored the link between food preferences and the weight loss success of bariatric surgery as a secondary outcome. The results suggested that patients in weight loss success or failure of their surgery had different food preferences, which might be interesting to explore further. Especially, the use of a cohort and a predictive model could identify variables of interest, which would predict the success of the surgery. Ribeiro et al. recently published a study (55), which aimed to investigate whether gustatory abilities assessed with taste strips (56) and food reward assessed with the power of food scale (57) are predictors of weight loss induced by bariatric surgery. In their study involving 116 patients with bariatric surgery and 96 unoperated controls, there were 10% or less missing data (55), which demonstrated that it would be possible to constitute such a cohort with a good adherence to the protocol. They found that the sweet intensity ratings and the hedonic hunger scores predict the percentage of weight loss between 11 and 18 months after bariatric surgery. These promising findings indicates that some variables, which could be easily assessed in clinical routine would be able to predict the weight loss success of bariatric surgery. It would be interesting to replicate these results and take into account the excess weight loss at 2 years, which is a commonly accepted indicator of the weight loss success. Moreover, it would be interesting to use a food preference questionnaire in addition to psychophysical testing and assessment of food reward to see whether simple questions about eating habits might as well predict the effect of surgery on weight loss. To implement this type of study on a large scale in France, it would be possible to build on and enrich the registry created in 2018 in which 79 bariatric surgery centers already record their interventions (58). We could also rely on the French Obesity Research Center of Excellence (FORCE) network, which is a national clinical research network specializing in the study of obesity and associated metabolic diseases (59). The ultimate goal of this type of study would be to propose an initial phenotyping of patients in order to provide decision-making tools to clinicians during their medical management of the patients.

A consumer study to improve acceptance of healthy products

Chapter III also suggests a role of sensory perception in food preferences among patients with bariatric surgery and Chapter IV suggests that specific properties of the foods would impact the wanting for these foods. Interestingly, a systematic review demonstrated that nudging is a good strategy to promote healthy food choices in the context of take away, including when it comes to increase the salience of a healthy food (60). It would then be interesting to perform a consumer study with a comparative design towards healthy products with different properties (shapes, colors, sizes, overall presentations, qualities and intensities of tastes and aromas) to determine which properties are best liked by patients. All in all, the results of such studies could lead to the development of cooking advice for the patients and catering as well as well-accepted culinary innovation, that could help patients to maintain a balance diet in the longer term after bariatric surgery. For example, this was recently done following the doctoral work carried out at the Research Center of the Paul Bocuse Institute by Drareni, who studied sensory alteration in the context of chemotherapy. Her work led to the development of a guide with culinary advice, which is now to be tested in an interventional study.

2.4.6. *Recommendations for clinical practice and public health*

Prevent protein energy malnutrition after bariatric surgery

Most of the patients do not eat enough proteins to reach the daily recommendations of 60 g of proteins per day (61). Chapter II demonstrated that there is an increased proportion of proteins in the total energy intake of the patients after bariatric surgery, which is not necessarily contradictory with the data of the literature as it might not be enough in terms of quantities to cover patients' needs. Chapter III showed that the increased preference for proteins is however accompanied by a low preference, and even an aversion towards red meat. Interestingly, other high protein foods are well appreciated by the patients after the surgery, for instance white meat, fish and seafoods (Chapter III). Also, while milk seems to be least preferred after the surgery, other dairy products seem to be appreciated and should be considered as a great source of proteins. Importantly, proteins were proposed as a good strategy in reducing appetite as it is the most satiating macronutrient (62). In bariatric population, it would then be important to split protein intake into several small portions to cover the nutritional needs of the patients, without promoting the satietogenic effect of proteins. Overall, our research supports that preventing protein-energy malnutrition is still an important issue after weight loss surgery. This could be

reversed by the selection of certain products rich in proteins well appreciated by the patient, while taking into account the current environmental considerations around animal proteins.

Adherence to nutritional recommendations, barriers and facilitators for the longer-term follow-up

By exploring food preferences at specific times after surgery in Chapter II, we found that food preferences might not be significantly different from the preoperative state after some time. Additionally, we saw in Chapter III signs that the low preference for highly palatable was less present in patients with a longer-term follow-up (> 2 years) compared to those in a shorter term follow up (< 2 years). This was coherent with qualitative data showing that patients find it more difficult to adopt a balanced diet when the “honeymoon” is over (i.e., after the phase of rapid weight loss related to decreased appetite) (63). These findings are of importance because poor and maladaptive eating habits are common causes for weight regain (64,65). It would therefore be important to optimize follow-up at this pivotal period following bariatric surgery.

Overall, patients have a good understanding of postoperative recommendations, which they find useful for their long-term weight loss (66). But while follow-up is recommended for life, Radvinsky et al. found that the percentage of patients who are followed by the bariatric team drops to 43%, 1 year after surgery (67). Similarly, findings from the SOS study indicate that only 47,6% of the patients are regularly follow-up 10 years after the surgery (68). This number drops to 9% after 15 years (68). A study reported that among the reasons patients gave for the lack of follow-up, were that patients were "too busy" or "forgot" their appointments (67). A detailed qualitative study composed of 9 focus groups bringing together a total of 76 patients and which covered many aspects of the postoperative experience indicated that the barriers to follow-up care included the insurance coverage, emotional and situational challenges, and physical pain limiting mobility (69). On the other hand, the facilitators are linked to the self-care action, including the follow-up of the guidelines, the follow-up of mental treatment and the entourage (69).

When focusing on the specific case of France, where 37 Specialized Centers for Obesity / Centre Spécialisé de l'Obésité (CSO) operate for the multidisciplinary care of obesity and the organization of the care at regional level since 2011 (70), the postoperative follow-up still seems insufficient for more than a third of patients (71,72). In 2017, these findings led the Academy

of Medicine to make recommendations: 1) to clearly inform the patients on the need for a lifetime follow-up; 2) to involve general practitioners in the follow-up of patients with bariatric surgery; 3) to involve the high authority of health / Haute Autorité de Santé (HAS) and to the national health insurance / Caisse Nationale d'Assurance Maladie (CNAM) in order to promote the use of a share medical folder, to diffuse guides and sensitize healthcare givers and to promote the reimbursement of certain surgical acts (73). In this context the new guidelines of the HAS in patients with bariatric surgery, the last edition of which dates from 2009 (74), are being drawn up as well as the new specifications for CSO.

The findings of the present thesis are of importance in relation to the patients' difficulties to adopt an adapted balanced diet in the long term after bariatric surgery as it emphasized the diversity of the patient's profiles and the need to a personalized follow-up. In this context, it would be interesting to put forward paramedical professions, such as dieticians (75,76) and psychologists (77,78), who could provide local care and support patients, but whose consultations might not be affordable if they are not included in a therapeutic education program for the patient. A possible facilitator would be to offer tariff exemptions as it has just been done by the decree of December 20, 2020 in the context of support after cancer treatment (79).

8.6 Conclusion

Taking a holistic approach, this work provides new and valuable information concerning the influence of bariatric surgery on food preferences. Although the evidence showed some inconstancies, the majority of data indicates that changes in food preferences occur after bariatric surgery. This manifests as a high appreciation for healthy foods and a low preference towards highly palatable foods (high in fat and/or sweet), which does not seem to last in the long term. This translates into a lower proportion of fat in the energy intake, offsets by a higher proportion of protein. Importantly this work also highlighted the possible role of the sensory and reward domain in changes in food preferences in a broader framework of appetite regulation where homeostatic and hedonic pathways interplay. Patients with or without sensory and / or food reward alterations seem to have different food preferences after bariatric surgery. While this research suggests that patients in success and failure of their bariatric surgery have different food preferences, the role of food preference in postoperative weight loss remains to be fully elucidated. All in all, this work leads us to think that not all patients are sensitive to the effects of surgery in the same way in terms of food preferences, food reward, and sensory alterations.

It would therefore be important to take into account the specificities of each patient in order to offer precision bariatric medicine in the future, as much as an adapted food offer and dietary/culinary recommendation, which must be part of a comprehensive adapted health policy.

8.7 References

1. Ramadan M, Loureiro M, Laughlan K, Caiazzo R, Iannelli A, Brunaud L, et al. Risk of Dumping Syndrome after Sleeve Gastrectomy and Roux-en-Y Gastric Bypass: Early Results of a Multicentre Prospective Study. *Gastroenterol Res Pract.* 2016;2016.
2. Meek CL, Lewis HB, Reimann F, Gribble FM, Park AJ. The effect of bariatric surgery on gastrointestinal and pancreatic peptide hormones. Vol. 77, *Peptides.* Elsevier Inc.; 2016. p. 28–37.
3. Al Massadi O, López M, Tschöp M, Diéguez C, Nogueiras R. Current Understanding of the Hypothalamic Ghrelin Pathways Inducing Appetite and Adiposity. Vol. 40, *Trends in Neurosciences.* Elsevier Ltd; 2017. p. 167–80.
4. Al Massadi O, Nogueiras R, Dieguez C, Girault JA. Ghrelin and food reward. Vol. 148, *Neuropharmacology.* Elsevier Ltd; 2019. p. 131–8.
5. Merkestein M, Brans MAD, Luijendijk MCM, De Jong JW, Egecioglu E, Dickson SL, et al. Ghrelin mediates anticipation to a palatable meal in rats. *Obesity.* 2012 May;20(5):963–71.
6. Bolles RC, De Lorge J. The rat's adjustment to a-diurnal feeding cycles. *J Comp Physiol Psychol.* 1962 Oct;55(5):760–2.
7. Krieger DT. Food and water restriction shifts corticosterone, temperature, activity and brain amine periodicity. *Endocrinology.* 1974;95(5):1195–201.
8. Escobar C, Díaz-Muñoz M, Encinas F, Aguilar-Roblero R. Persistence of metabolic rhythmicity during fasting and its entrainment by restricted feeding schedules in rats. *Am J Physiol - Regul Integr Comp Physiol.* 1998;274(5 43-5).
9. Mistlberger RE. Circadian food-anticipatory activity: Formal models and physiological mechanisms. *Neurosci Biobehav Rev.* 1994;18(2):171–95.
10. Egecioglu E, Jerlhag E, Salomé N, Skibicka KP, Haage D, Bohlooly-Y M, et al. Ghrelin increases intake of rewarding food in rodents. *Addict Biol.* 2010;15(3):304–11.
11. Skibicka KP, Hansson C, Alvarez-Crespo M, Friberg PA, Dickson SL. Ghrelin directly targets the ventral tegmental area to increase food motivation. *Neuroscience.* 2011 Apr 28;180:129–37.
12. Skibicka KP, Hansson C, Egecioglu E, Dickson SL. Role of ghrelin in food reward: Impact of ghrelin on sucrose self-administration and mesolimbic dopamine and acetylcholine receptor gene expression. *Addict Biol.* 2012 Jan;17(1):95–107.
13. Perello M, Sakata I, Birnbaum S, Chuang JC, Osborne-Lawrence S, Rovinsky SA, et al. Ghrelin Increases the Rewarding Value of High-Fat Diet in an Orexin-Dependent

- Manner. *Biol Psychiatry*. 2010 May 1;67(9):880–6.
14. Bake T, Hellgren KT, Dickson SL. Acute ghrelin changes food preference from a high-fat diet to chow during binge-like eating in rodents. *J Neuroendocrinol*. 2017 Apr 1;29(4):1.
 15. Schéle E, Bake T, Rabasa C, Dickson SL. Centrally Administered Ghrelin Acutely Influences Food Choice in Rodents. López M, editor. *PLoS One*. 2016 Feb 29;11(2):e0149456.
 16. Goldstone AP, Miras AD, Scholtz S, Jackson S, Neff KJ, Pénicaud L, et al. Link between increased satiety gut hormones and reduced food reward after gastric bypass surgery for obesity. *J Clin Endocrinol Metab*. 2016 Feb 1;101(2):599–609.
 17. Grosshans M, Vollmert C, Dt-Klein SV, Tost H, Leber S, Bach P, et al. Association of leptin with food cue-induced activation in human reward pathways. *Arch Gen Psychiatry*. 2012 May 1;69(5):529–37.
 18. Pucci A, Batterham RL. Mechanisms underlying the weight loss effects of RYGB and SG: similar, yet different. Vol. 42, *Journal of Endocrinological Investigation*. Springer International Publishing; 2019. p. 117–28.
 19. Kalinowski P, Paluszkiwicz R, Wróblewski T, Remiszewski P, Grodzicki M, Bartoszewicz Z, et al. Ghrelin, leptin, and glycemic control after sleeve gastrectomy versus Roux-en-Y gastric bypass—results of a randomized clinical trial. *Surg Obes Relat Dis*. 2017 Feb 1;13(2):181–8.
 20. Andreoli MF, Donato J, Cakir I, Perello M. Leptin resensitisation: A reversion of leptin-resistant states. Vol. 241, *Journal of Endocrinology*. BioScientifica Ltd.; 2019. p. R81–96.
 21. Abbenhardt C, McTiernan A, Alfano CM, Wener MH, Campbell KL, Duggan C, et al. Effects of individual and combined dietary weight loss and exercise interventions in postmenopausal women on adiponectin and leptin levels. *J Intern Med*. 2013 Aug 1;274(2):163–75.
 22. Oustric P, Gibbons C, Beaulieu K, Blundell J, Finlayson G. Changes in food reward during weight management interventions – a systematic review. Vol. 19, *Obesity Reviews*. Blackwell Publishing Ltd; 2018. p. 1642–58.
 23. Kawai K, Sugimoto K, Nakashima K, Miura H, Ninomiya Y. Leptin as a modulator of sweet taste sensitivities in mice. *Proc Natl Acad Sci U S A*. 2000 Sep 26;97(20):11044–9.
 24. Shigemura N, Ohta R, Kusakabe Y, Miura H, Hino A, Koyano K, et al. Leptin Modulates Behavioral Responses to Sweet Substances by Influencing Peripheral Taste Structures. *Endocrinology*. 2004 Feb;145(2):839–47.
 25. Disse E, Bussier AL, Veyrat-Durebex C, Deblon N, Pfluger PT, Tschöp MH, et al. Peripheral ghrelin enhances sweet taste food consumption and preference, regardless of its caloric content. *Physiol Behav*. 2010;101(2):277–81.
 26. Palouzier-paulignan B, Lacroix MC, Aimé P, Baly C, Caillol M, Congar P, et al. Olfaction under metabolic influences. *Chem Senses*. 2012 Nov;37(9):769–97.
 27. Klesges LM, Baranowski T, Beech B, Cullen K, Murray DM, Rochon J, et al. Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8- to 10-year-old African-American girls: Results from the Girls health Enrichment

- Multisite Studies (GEMS). *Prev Med (Baltim)*. 2004;38(SUPPL.):78–87.
28. Herbet JR, Clemow L, Pbert L, Ockene IS, Ockene JK. Social Desirability Bias in Dietary Self-Report May Compromise the Validity of Dietary Intake Measures. *Int J Epidemiol*. 1995 Apr 1;24(2):389–98.
 29. Kristal AR, Andrilla CHA, Koepsell TD, Diehr PH, Cheadle A. Dietary assessment instruments are susceptible to intervention-associated response set bias. *J Am Diet Assoc*. 1998 Jan 1;98(1):40–3.
 30. Rawal S, Hoffman HJ, Honda M, Huedo-Medina TB, Duffy VB. The Taste and Smell Protocol in the 2011–2014 US National Health and Nutrition Examination Survey (NHANES): Test–Retest Reliability and Validity Testing. *Chemosens Percept*. 2015 Sep 3;8(3):138–48.
 31. Lim J. Hedonic scaling: A review of methods and theory. Vol. 22, *Food Quality and Preference*. Elsevier; 2011. p. 733–47.
 32. Finlayson G, King N, Blundell JE. Is it possible to dissociate “liking” and “wanting” for foods in humans? A novel experimental procedure. *Physiol Behav*. 2007 Jan 30;90(1):36–42.
 33. Griffioen-Roose S, Mars M, Siebelink E, Finlayson G, Tomé D, De Graaf C. Protein status elicits compensatory changes in food intake and food preferences. *Am J Clin Nutr*. 2012 Jan 1;95(1):32–8.
 34. Griffioen-Roose S, Finlayson G, Mars M, Blundell JE, de Graaf C. Measuring food reward and the transfer effect of sensory specific satiety. *Appetite*. 2010 Dec;55(3):648–55.
 35. Dalton M, Finlayson G. Psychobiological examination of liking and wanting for fat and sweet taste in trait binge eating females. *Physiol Behav*. 2014 Sep 1;136:128–34.
 36. French SA, Mitchell NR, Finlayson G, Blundell JE, Jeffery RW. Questionnaire and laboratory measures of eating behavior: Associations with energy intake and BMI in a community sample of working adults. *Appetite*. 2014 Jan 1;72:50–8.
 37. van der Meij BS, Wijnhoven HAH, Finlayson GS, Oosten BSH, Visser M. Specific food preferences of older adults with a poor appetite. A forced-choice test conducted in various care settings. *Appetite*. 2015 Jul 1;90:168–75.
 38. Oustric P, Thivel D, Dalton M, Beaulieu K, Gibbons C, Hopkins M, et al. Measuring food preference and reward: application and cross-cultural adaptation of the leeds food preference questionnaire in human experimental research. *Food Qual Prefer*. 2020 Oct;103824.
 39. Gormally J, Black S, Daston S, Rardin D. The assessment of binge eating severity among obese persons. *Addict Behav*. 1982;7(1):47–55.
 40. Rogers PJ, Hardman CA. Food reward. What it is and how to measure it. *Appetite*. 2015;90:1–15.
 41. Allirox X, Saulais L, Disse E, Roth H, Cazal C, Laville M. Validation of a buffet meal design in an experimental restaurant. *Appetite*. 2012 Jun 1;58(3):889–97.
 42. Meiselman HL. Methodology and theory in human eating research. *Appetite*. 1992 Aug

- 1;19(1):49–55.
43. Blundell J, De Graaf C, Hulshof T, Jebb S, Livingstone B, Lluch A, et al. Appetite control: Methodological aspects of the evaluation of foods. Vol. 11, Obesity Reviews. *Obes Rev*; 2010. p. 251–70.
 44. Rozin P. The socio-cultural context of eating and food choice. In: *Food Choice, Acceptance and Consumption*. Springer US; 1996. p. 83–104.
 45. Enriquez JP, Archila-Godinez JC. Social and cultural influences on food choices: A review. *Critical Reviews in Food Science and Nutrition*. Bellwether Publishing, Ltd.; 2021.
 46. Nielsen MS, Christensen BJ, Ritz C, Rasmussen S, Hansen TT, Bredie WLPP, et al. Roux-En-Y Gastric Bypass and Sleeve Gastrectomy Does Not Affect Food Preferences When Assessed by an Ad libitum Buffet Meal. *Obes Surg*. 2017 Oct 14;27(10):2599–605.
 47. Pliner P, Bell R, Hirsch ES, Kinchla M. Meal duration mediates the effect of “social facilitation” on eating in humans. *Appetite*. 2006 Mar;46(2):189–98.
 48. Feurté S, Tomé D, Gietzen DW, Even PC, Nicolaïdis S, Fromentin G. Feeding patterns and meal microstructure during development of a taste aversion to a threonine devoid diet. *Nutr Neurosci*. 2002;5(4):269–78.
 49. Sanjur D, Randall E, Sanjur D. Food preferences—Their conceptualization and relationship to consumption. *Ecol Food Nutr*. 1981 Dec 1;11(3):151–61.
 50. Berridge KC, Robinson TE, Aldridge JW. Dissecting components of reward: “liking”, “wanting”, and learning. Vol. 9, *Current Opinion in Pharmacology*. 2009. p. 65–73.
 51. Alonso-Alonso M, Woods SC, Pelchat M, Grigson PS, Stice E, Farooqi S, et al. Food reward system: Current perspectives and future research needs. *Nutr Rev*. 2015 May 1;73(5):296–307.
 52. Nota MHC, Vreeken D, Wiesmann M, Aarts EO, Hazebroek EJ, Kiliaan AJ. Obesity affects brain structure and function- rescue by bariatric surgery? Vol. 108, *Neuroscience and Biobehavioral Reviews*. Elsevier Ltd; 2020. p. 646–57.
 53. Zhang Y, Ji G, Xu M, Cai W, Zhu Q, Qian L, et al. Recovery of brain structural abnormalities in morbidly obese patients after bariatric surgery. *Int J Obes*. 2016 Oct 1;40(10):1558–65.
 54. Handley JD, Williams DM, Caplin S, Stephens JW, Barry J. Changes in Cognitive Function Following Bariatric Surgery: a Systematic Review. *Obes Surg*. 2016 Oct 28;26(10):2530–7.
 55. Ribeiro G, Camacho M, Fernandes AB, Cotovio G, Torres S, Oliveira-Maia AJ. Reward-related gustatory and psychometric predictors of weight loss following bariatric surgery: a multicenter cohort study. *Am J Clin Nutr*. 2021 Mar 11;113(3):751–61.
 56. Landis BN, Welge-Luessen A, Brämerson A, Bende M, Mueller CA, Nordin S, et al. “taste Strips” - A rapid, lateralized, gustatory bedside identification test based on impregnated filter papers. *J Neurol*. 2009 Feb;256(2):242–8.
 57. Lowe MR, Butryn ML. Hedonic hunger: A new dimension of appetite? *Physiol Behav*. 2007 Jul 24;91(4):432–9.
 58. Communiqué n°1: Registre de la SOFFCO.MM concernant les interventions

- bariatriques en France - SOFFCO.MM [Internet]. [cited 2021 Mar 28]. Available from: <https://soffcomm.org/communiquer-ndegl1-registre-de-la-soffcomm-concernant-les-interventions-bariatriques-en-france>
59. Accueil | FORCE - French Obesity Research Centre of Excellence [Internet]. [cited 2021 Mar 29]. Available from: <https://www.force-obesity.org/fr/accueil>
 60. Cheung TTL, Gillebaart M, Kroese FM, Marchiori D, Fennis BM, De Ridder DTD. Cueing healthier alternatives for take-away: A field experiment on the effects of (disclosing) three nudges on food choices. *BMC Public Health*. 2019 Jul 22;19(1):974.
 61. Steenackers N, Gesquiere I, Matthys C. The relevance of dietary protein after bariatric surgery: What do we know? Vol. 21, *Current Opinion in Clinical Nutrition and Metabolic Care*. Lippincott Williams and Wilkins; 2018. p. 58–63.
 62. Morell P, Fiszman S. Revisiting the role of protein-induced satiation and satiety. *Food Hydrocoll*. 2017 Jul 1;68:199–210.
 63. Lynch A. “When the honeymoon is over, the real work begins:” Gastric bypass patients’ weight loss trajectories and dietary change experiences. *Soc Sci Med*. 2016 Feb 1;151:241–9.
 64. Thompson CC, Slattery J, Bundga ME, Lautz DB. Peroral endoscopic reduction of dilated gastrojejunal anastomosis after Roux-en-Y gastric bypass: A possible new option for patients with weight regain. *Surg Endosc Other Interv Tech*. 2006 Nov;20(11):1744–8.
 65. Masnyj S V., Shea BJ, Khaitan L. Predictors of Success in Bariatric Surgery. Vol. 14, *Current Cardiovascular Risk Reports*. Springer; 2020. p. 1–9.
 66. Ariel-Donges AH, Oyama CK, Hood MM. Patient-reported Short-term Barriers to and Facilitators of Adherence to Behavioral Recommendations Following Bariatric Surgery : *Bariatric Times*. *Bariatric Times*. 2020;17(7):5–17.
 67. Radvinsky D, Iskander M, Ferzli G. Barriers to compliance with long-term follow-up after bariatric surgery. In: *Surgical Endoscopy and Other Interventional Techniques*. 2017. p. S295.
 68. Sjöström L, Narbro K, Sjöström CD, Karason K, Larsson B, Wedel H, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med*. 2007 Aug 23;357(8):741–52.
 69. Coleman KJ, Schlundt DG, Bonnet KR, Holmquist KJ, Dunne J, Crull E, et al. Understanding the Bariatric Patient Perspective in the National Patient-Centered Clinical Research Network (PCORnet) Bariatric Study. *Obes Surg*. 2020 May 1;30(5):1837–47.
 70. Les centres spécialisés d’obésité - Ministère des Solidarités et de la Santé [Internet]. [cited 2021 Mar 30]. Available from: <https://solidarites-sante.gouv.fr/soins-et-maladies/prises-en-charge-specialisees/obesite/article/les-centres-specialises-d-obesite>
 71. Thereaux J, Lesuffleur T, Païta M, Czernichow S, Basdevant A, Msika S, et al. Long-term follow-up after bariatric surgery in a national cohort. *Br J Surg*. 2017 Sep 1;104(10):1362–71.
 72. Vidal P, Ramón JM, Goday A, Parri A, Crous X, Trillo L, et al. Lack of adherence to follow-up visits after bariatric surgery: Reasons and outcome. *Obes Surg*. 2014

- Feb;24(2):179–83.
73. Jaffiol C, Bringer J, Laplac JP, Buffet C. Améliorer le suivi des patients après chirurgie bariatrique. *Bull Acad Natl Med.* 2017 Sep 1;201(7–9):973–82.
 74. Haute Autorité de Santé - Obésité : prise en charge chirurgicale chez l'adulte [Internet]. [cited 2021 Mar 29]. Available from: https://www.has-sante.fr/jcms/c_765529/fr/obesite-prise-en-charge-chirurgicale-chez-l-adulte#toc_1_5
 75. Osland E, Powlesland H, Guthrie T, Lewis C-A, Memon MA. Micronutrient management following bariatric surgery: the role of the dietitian in the postoperative period. *Ann Transl Med.* 2020 Mar;8(S1):S9–S9.
 76. Kulick D, Hark L, Deen D. The Bariatric Surgery Patient: A Growing Role for Registered Dietitians. *J Am Diet Assoc.* 2010 Apr;110(4):593–9.
 77. Ristanto A, Caltabiano ML. Psychological Support and Well-being in Post-Bariatric Surgery Patients. *Obes Surg.* 2019 Feb 15;29(2):739–43.
 78. Van Zyl N, Andrews L, Williamson H, Meyrick J. The effectiveness of psychosocial interventions to support psychological well-being in post-operative bariatric patients: A systematic review of evidence. Vol. 14, *Obesity Research and Clinical Practice.* Elsevier Ltd; 2020. p. 404–20.
 79. Arrêté du 24 décembre 2020 relatif au parcours de soins global après le traitement d'un cancer - Légifrance [Internet]. [cited 2021 Mar 30]. Available from: <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000042845710>

Thesis valorisation

Publications in peer-review journals

Guyot E, Dougkas A, Bagot S, Nazare JA, Disse E, Iceta S. A systematic review of food preference modifications after bariatric surgery. (Submitted)

Guyot E, Dougkas A, Robert M, Nazare JA, Iceta S, Disse E. Food preferences and their perceived changes before and after bariatric surgery: a cross-sectional study. *Obes Surg*. 2021.

Guyot E, Disse E, Nazare JA, Oustric P, Robert M, Dougkas A, et al. Alterations in food reward following bariatric surgery. (Submitted)

Oral communications

Guyot E, Dougkas A, Bagot S, Nazare JA, Disse E & Iceta S. A systematic review of food preference modifications after bariatric surgery. European Congress on Obesity, 10th-13rd May 2021, Online

Guyot E, Dougkas A, Nazare JA, Iceta S, Disse E. Changements de préférences alimentaires et de goût après chirurgie bariatrique : étude transversale française chez 220 patients. Société Francophone du Diabète, 23rd-26th March 2021, Online

Guyot E, Dougkas A, Nazare JA, Iceta S, Disse E. Is there a link between sensory alterations and modification in food preference following bariatric surgery? Nutrition Society Live, 14th-15th July 2020, Online

Guyot E, Iceta S, Dougkas A, Nazare JA, Disse E. Studying the food preferences after bariatric surgery: The BariaTaste Pilot Study. 16th Conference on Trans-Pyrenean Investigations in Obesity and Diabetes, Common session of Société Française de Nutrition and Sociedad Española de Nutrición, 20th-21st June 2019, Soria, Spain

Posters

Guyot E, Dougkas A, Nazare JA, Iceta S, Disse E. Evolution des préférences alimentaires post-opératoires : Et si c'était un élément clé du succès pondéral de la chirurgie bariatrique ? Association Française d'Étude et de Recherche sur l'Obésité, 28th-29th January 2021, Online

Guyot E, Dougkas A, Nazare JA, Iceta S, Disse E. Are food preference modifications towards healthier options the key to success for bariatric surgery? European and International Congress on Obesity, 1st-4th September 2020, Online

Guyot E, Iceta S, Nazare JA, Disse E, Dougkas A. Comparing the impact of two types of bariatric surgery on food preferences: The BARIATASTE pilot study. 13th European Nutrition Conference, Federation of European Nutrition Societies, 15th-18th October 2019, Dublin, Ireland

Guyot E, Disse E, Nazare JA, Dougkas A, Iceta S. Quel est l'impact de la chirurgie bariatrique sur les préférences alimentaires ? Annual congress of the Société Française et Francophone de Chirurgie de l'Obésité et des Maladies Métaboliques, 24th-26th May, Nancy, France

Dissemination to industry, institutional & general public

Guyot E. BariaTaste. Study of food preferences and eating behaviour after bariatric surgery. CarMeN laboratory seminar, 4th January 2021, Lyon, France

Guyot E. Are changes in food preferences towards healthier options and sensory alterations the key to success for bariatric surgery? Institut Paul Bocuse Research Center Seminar, 5th November 2020, Ecully, France

Guyot E. Why and how to study food preferences after bariatric surgery? Innovation and Research Committee of Institut Paul Bocuse Research Center, 3rd October 2019 (English) and 10th October 2019 (French), Ecully, France

Guyot E. D'une problématique de terrain à une thèse en recherche clinique : une diététicienne étudie le comportement et les préférences alimentaires après une chirurgie bariatrique. Invited lecture, Association Française des Diététiciens Nutritionnistes. 23rd-25th May 2019, Dijon, France

Guyot E. Ecrire un protocole de recherche clinique. Workshop, Association Française des Diététiciens Nutritionnistes. 23rd-25th May 2019, Dijon, France

Guyot E, Drareni K. L'analyse sensorielle comment et pourquoi ? Quand nos sens sont perturbés : cas du cancer et de l'obésité. Pint of Science, 21st May 2019, Lyon, France

Guyot E. From hamburgers to veggies. Exploring food preference changes after a weight loss surgery. Workshops on weight management and appetite, Leeds University, 1st November 2018, Leeds, United Kingdom

Guyot E. Exploration of the evolution of eating behavior in patients who underwent bariatric surgery (weight loss). Institut Paul Bocuse Research Center Seminar, 12nd July 2018, Ecully, France

Guyot E. Exploration observationnelle et interventionnelle de l'évolution du comportement alimentaire chez les patients ayant subi une chirurgie bariatrique (perte de poids). Conférence « Manger bien, Portez-vous bien », 29th May 2018, Lyon, Fr

Price

Research project price, Institut Benjamin Delessert, 2018

List of appendices

Chapter II. A systematic review of food preference modifications after bariatric surgery

Appendix 2.A. Search equations and results at the date of last search (01/06/2020).....	V
Appendix 2.B. Forest plots means [95% confidence intervals (CI)] weighted differences in total energy intake coming from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.....	VII
Appendix 2.C. Relative choices between foods or food categories in comparison with preoperative measures (prospective studies, N=19) or measures on control groups of subjects with obesity (cross-sectional studies, N=3).	XI
Appendix 2.D. Hedonic rating of food categories in comparison with preoperative measures (prospective studies, N=10) or measures on control groups of subjects with obesity (cross-sectional studies, N=6).....	XVI
Appendix 2.E. Traffic light plot representing the risk of bias in each domain of the ‘Quality assessment tool for quantitative studies’ for each study included in the systematic review.	XIX
Appendix 2.F. Funnel plots for means weighted differences in total energy intake coming from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.....	XX
Appendix 2.G. Key findings from pre-clinical studies in relation to changes in food preferences after bariatric surgery.....	XXI

Chapter III. Food preferences and their perceived modifications before and after a bariatric surgery: a cross sectional study

Appendix 3.A. Summary table of the outcomes assessed with the online questionnaire....	XXV
Appendix 3.B. Translated online questionnaire used in the study.....	XXVI
Appendix 3.C. Perceived taste and smell alterations after bariatric surgery among 220 participants.....	XXXI

Chapter IV. Alterations in food reward following bariatric surgery

Appendix 4.A. Food items used in the LFPQ.....	XXXII
Appendix 4.B. Liking scores according to the operative status of the 86 included patients (2018-2019).	XXXIV

Chapter V. Study of food preferences and eating behavior after bariatric surgery in a real context environment: conception and settings of the study

Appendix 5.A. Nutritional values of the ad-libitum buffet meal.....	XXXIX
Appendix 5.B. Receipts used for the ad-libitum bufffet meal.	XL
Appendix 5.C. Map of the domestic kitchens of Institut Paul Bocuse.	XLVIII

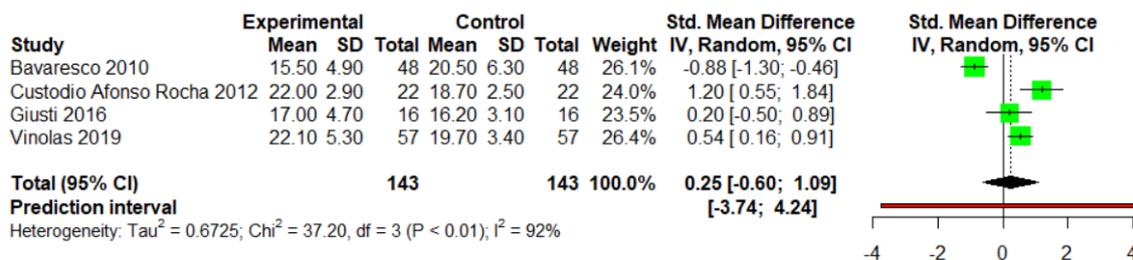
Appendix 2.A. Search equations and results at the date of last search (01/06/2020).

Database	Set	Search string	Results
MEDLINE	1	("Bariatric surger*" or "Weight loss surger*" or "Obesity surger*" or "Metabolic surger*" or "Bariatric surgical procedure*" or "Bariatric procedure*" or "Bariatric operation*" or "Gastric bypass" or "Stomach bypass" or RYGB or RYGBP or "Sleeve gastrectomy" or "Gastric sleeve" or LSG).ab,hw,kf,ti.	29455
	2	"Bariatric Surgery"/ or "Gastric Bypass"/ or Gastrectomy/	51776
	3	1 OR 2	60991
	4	("Food preferenc*" or "Food choic*" or "Food reward" or "Reward system" or Liking or Wanting or "Food intake" or "Diet* record*" or "Diet* assessment*" or "Diet* survey*" or "Nutrition* record*" or "Nutrition* assessment*" or "Nutrition* survey*").ab,hw,kf,ti.	119597
	5	Food preferences/	14230
	6	4 OR 5	119597
	7	3 AND 6	1186
Cochrane	#1	'Bariatric surger*':ti,ab,kw OR 'Weight loss surger*':ti,ab,kw OR 'Obesity surger*':ti,ab,kw OR 'Metabolic surger*':ti,ab,kw OR 'Bariatric surgical procedure*':ti,ab,kw OR 'Bariatric procedure*':ti,ab,kw OR 'Bariatric operation*':ti,ab,kw OR 'Gastric bypass':ti,ab,kw OR 'Stomach bypass':ti,ab,kw OR RYGB OR RYGBP OR 'Sleeve gastrectomy':ti,ab,kw OR 'Gastric sleeve':ti,ab,kw OR LSG	10116
	#2	MeSH descriptor: [Bariatric Surgery] explode all trees	953
	#3	MeSH descriptor: [Gastric Bypass] explode all trees	459
	#4	MeSH descriptor: [Gastrectomy] explode all trees	987
	#5	#1 OR #2 OR #3 OR #4	10977
	#6	'food preferenc*':ti,ab,kw OR 'food choic*':ti,ab,kw OR 'food reward':ti,ab,kw OR 'reward system':ti,ab,kw OR liking:ti,ab,kw OR wanting:ti,ab,kw OR 'food intake':ti,ab,kw OR 'diet* record*':ti,ab,kw OR 'diet* assessment*':ti,ab,kw OR 'diet* survey*':ti,ab,kw OR 'nutrition* record*':ti,ab,kw OR 'nutrition* assessment*':ti,ab,kw OR 'nutrition* survey*':ti,ab,kw	47279
	#7	MeSH descriptor: [Food preferences] explode all trees	839
	#8	#6 OR #7	47279
	#9	#5 AND #8	1005
	#10	Only Trial	925
Web of Science	S1	ALL=("Bariatric surger*" OR "Weight loss surger*" OR "Obesity surger*" OR "Metabolic surger*" OR "Bariatric surgical procedure*" OR "Bariatric procedure*" OR "Bariatric operation*" OR "Gastric bypass" OR "Stomach bypass" OR "RYGB" OR "RYGBP" OR "Sleeve gastrectomy" OR "Gastric sleeve" OR "LSG")	50815
	S2	("Food preferenc*" OR "Food choic*" OR "Food reward" OR "Reward system" OR "Liking" OR "Wanting" OR "Food intake" OR "Diet* record*" OR "Diet* assessment*" OR "Diet* survey*" OR "Nutrition* record*" OR "Nutrition* assessment*" OR "Nutrition* survey*")	112932
	S3	#1 AND #2	1560
Cinahl	S1	(MH "Bariatric Surgery") OR (MH "Gastric Bypass") OR (MH "Gastrectomy")	10719
	S2	"Bariatric surger*" OR "Weight loss surger*" OR "Obesity surger*" OR "Metabolic surger*" OR "Bariatric surgical procedure*" OR "Bariatric procedure*" OR "Bariatric operation*" OR "Gastric bypass" OR "Stomach bypass" OR RYGB OR RYGBP OR "Sleeve gastrectomy" OR "Gastric sleeve" OR LSG	14230
	S3	S1 or S2	16635

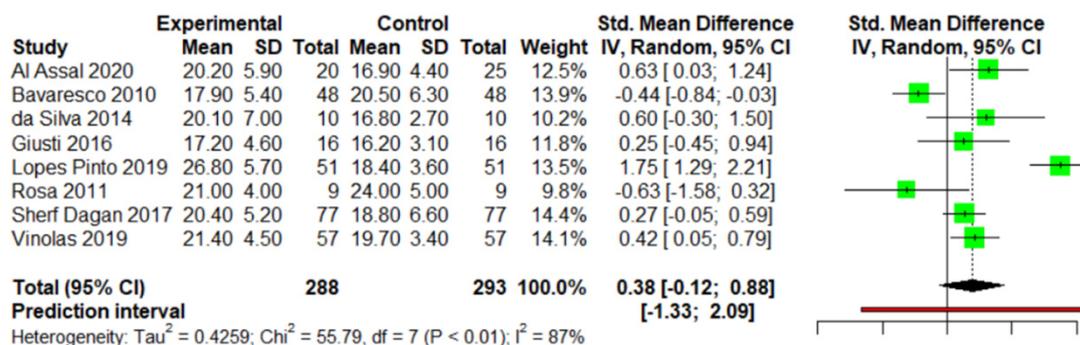
	S4	(MH "Food preferences")	6376
	S5	"Food preferenc*" OR "Food choic*" OR "Food reward" OR "Reward system" OR Liking OR Wanting OR "Food intake" OR "Diet* record*" OR "Diet* assessment*" OR "Diet* survey*" OR "Nutrition* record*" OR "Nutrition* assessment*" OR "Nutrition* survey*"	59920
	S6	S4 OR S5	59920
	S7	S3 AND S6	394
PsycInfo	1	("Bariatric surger*" or "Weight loss surger*" or "Obesity surger*" or "Metabolic surger*" or "Bariatric surgical procedure*" or "Bariatric procedure*" or "Bariatric operation*" or "Gastric bypass" or "Stomach bypass" or RYGB or RYGBP or "Sleeve gastrectomy" or "Gastric sleeve" or LSG).ab,hw,id,ti.	1635
	2	"Bariatric Surgery"/ or "Gastric Bypass"/ or Gastrectomy/	1131
	3	1 or 2	1635
	4	("Food preferenc*" or "Food choic*" or "Food reward" or "Reward system" or Liking or Wanting or "Food intake" or "Diet* record*" or "Diet* assessment*" or "Diet* survey*" or "Nutrition* record*" or "Nutrition* assessment*" or "Nutrition* survey*").ab,hw,id,ti.	40047
	5	Food preferences/	4940
	6	4 OR 5	40047
	7	3 AND 6	100
ProQuest	S1	diskw.Exact("Bariatric surgery" OR "Gastric bypass" OR "Gastrectomy")	251
	S2	noft("bariatric surger*") OR noft("weight loss surger*") OR noft("obesity surger*") OR noft("metabolic surger*") OR noft("bariatric surgical procedure*") OR noft("bariatric procedure*") OR noft("bariatric operation*") OR noft("gastric bypass") OR noft("stomach bypass") OR noft(RYGB) OR noft(RYGBP) OR noft("sleeve gastrectomy") OR noft("gastric sleeve") OR noft(LSG) OR noft("") OR noft("")	639
	S3	S1 or S2	648
	S4	diskw.Exact("Food preferences")	33
	S5	noft("food preferenc") OR noft("food choic*") OR noft("food reward") OR noft("reward system") OR noft("liking") OR noft("wanting") OR noft("food intake") OR noft("diet* record*") OR noft("diet* assessment*") OR noft("diet* survey*") OR noft("nutrition* record*") OR noft("nutrition* assessment*") OR noft("nutrition* survey*")	11020
	S6	S4 OR S5	11043
	S7	S3 AND S6	31
OpenGrey	S1	"Bariatric surger*" OR "Weight loss surger*" OR "Obesity surger*" OR "Metabolic surger*" OR "Bariatric surgical procedure*" OR "Bariatric procedure*" OR "Bariatric operation*" OR "Gastric bypass" OR "Stomach bypass" OR RYGB OR RYGBP OR "Sleeve gastrectomy" OR "Gastric sleeve" OR LSG	59
	S2	"Food preferenc*" OR "Food choic*" OR "Food reward" OR "Reward system" OR Liking OR Wanting OR "Food intake" OR "Diet* record*" OR "Diet* assessment*" OR "Diet* survey*" OR "Nutrition* record*" OR "Nutrition* assessment*" OR "Nutrition* survey*"	354
	S3	S1 AND S2	1
	S4	Filter : English	1

Appendix 2.B. Forest plots means [95% confidence intervals (CI)] weighted differences in total energy intake coming from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.

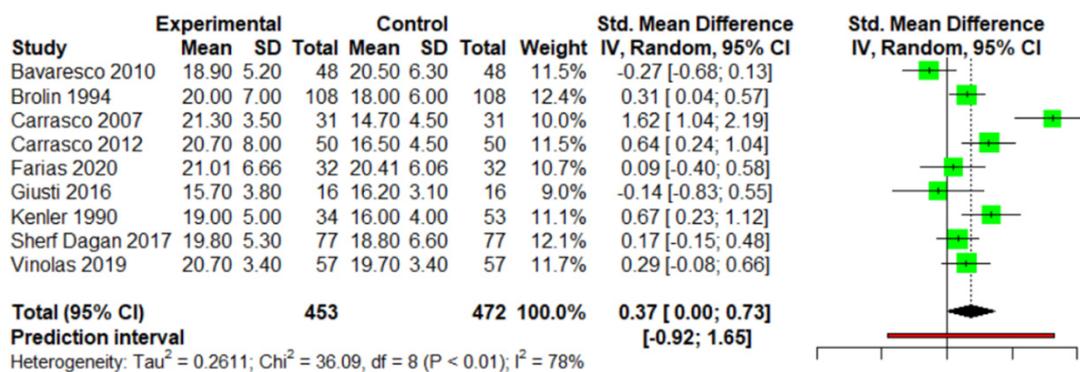
Proteins – 1 month



Proteins – 3 months



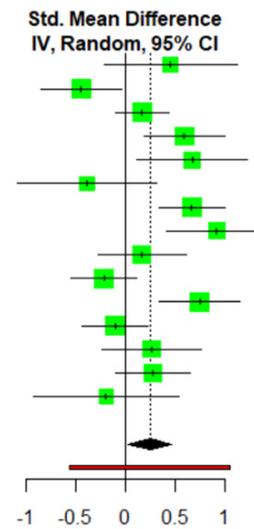
Proteins – 6 months



Proteins – 12 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Al Assal 2020	19.10	5.40	14	16.90	4.40	25	5.0%	0.45 [-0.21; 1.11]
Bavaresco 2010	17.80	5.80	48	20.50	6.30	48	7.1%	-0.44 [-0.85; -0.04]
Brolin 1994	19.00	6.00	108	18.00	6.00	108	8.3%	0.17 [-0.10; 0.43]
Carrasco 2012	20.00	7.00	50	16.50	4.50	50	7.1%	0.59 [0.19; 0.99]
Casagrande 2012	22.40	6.80	22	18.70	4.40	33	5.8%	0.67 [0.11; 1.22]
Giusti 2016	14.80	3.90	16	16.20	3.10	16	4.7%	-0.39 [-1.09; 0.31]
Johnson 2013	19.00	3.00	76	17.00	3.00	76	7.8%	0.66 [0.34; 0.99]
Kenler 1990	20.00	5.00	25	16.00	4.00	53	6.3%	0.91 [0.41; 1.41]
Molin Netto 2017	21.10	6.20	39	20.10	5.70	41	6.8%	0.17 [-0.27; 0.61]
Nonino 2019	18.10	5.60	72	19.50	7.30	72	7.8%	-0.21 [-0.54; 0.11]
Lopes Pinto 2019	21.20	3.90	50	18.40	3.60	51	7.1%	0.74 [0.34; 1.14]
Sherf Dagan 2017	18.20	4.60	68	18.80	6.60	77	7.8%	-0.10 [-0.43; 0.22]
Søvik 2013	17.60	6.70	31	16.10	4.40	31	6.3%	0.26 [-0.24; 0.76]
Vinolas 2019	20.70	3.90	57	19.70	3.40	57	7.4%	0.27 [-0.10; 0.64]
Trosler 1995	17.80	12.80	12	21.20	19.30	19	4.6%	-0.19 [-0.92; 0.53]
Total (95% CI)			688			757	100.0%	0.24 [0.03; 0.46]
Prediction interval								[-0.56; 1.05]

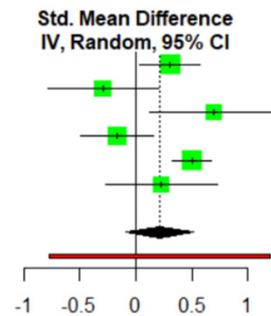
Heterogeneity: Tau² = 0.1265; Chi² = 52.34, df = 14 (P < 0.01); I² = 73%



Proteins – 24 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Brolin 1994	20.00	7.00	108	18.00	6.00	108	19.5%	0.31 [0.04; 0.57]
Farias 2020	19.10	1.20	32	20.41	6.06	32	14.2%	-0.30 [-0.79; 0.20]
Kenler 1990	19.00	5.00	16	16.00	4.00	53	12.6%	0.70 [0.13; 1.27]
Nonino 2019	18.30	6.60	72	19.50	7.30	72	18.1%	-0.17 [-0.50; 0.16]
Ruiz-Lozano 2016	20.70	9.90	270	16.90	4.20	270	21.5%	0.50 [0.33; 0.67]
Søvik 2013	17.50	7.40	31	16.10	4.40	31	14.1%	0.23 [-0.27; 0.73]
Total (95% CI)			529			566	100.0%	0.21 [-0.09; 0.51]
Prediction interval								[-0.77; 1.20]

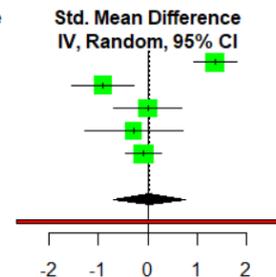
Heterogeneity: Tau² = 0.1022; Chi² = 20.69, df = 5 (P < 0.01); I² = 76%



Carbohydrates – 1 month

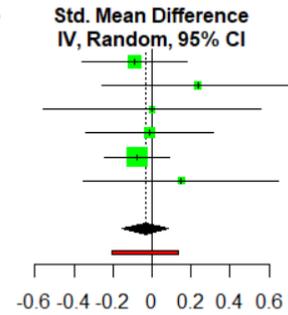
Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bavaresco 2010	59.70	9.50	48	46.10	10.20	48	21.7%	1.37 [0.92; 1.82]
Custodio Afonso Rocha 2012	42.40	8.20	22	50.10	8.40	22	20.1%	-0.91 [-1.53; -0.29]
Giusti 2016	44.60	18.80	16	44.60	8.50	16	19.4%	0.00 [-0.69; 0.69]
Sanmiguel 2017	38.80	27.00	8	45.20	13.60	8	16.5%	-0.28 [-1.27; 0.70]
Vinolas 2019	44.70	9.40	57	45.40	5.80	57	22.3%	-0.09 [-0.46; 0.28]
Total (95% CI)			151			151	100.0%	0.05 [-0.68; 0.78]
Prediction interval								[-2.66; 2.75]

Heterogeneity: Tau² = 0.5842; Chi² = 42.16, df = 4 (P < 0.01); I² = 91%



Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Brolin 1994	45.00	13.00	108	46.00	9.00	108	20.1%	-0.09 [-0.36; 0.18]
Farias 2020	52.90	18.70	32	49.31	10.34	32	5.9%	0.23 [-0.26; 0.73]
Kenler 1990	43.00	10.00	16	43.00	8.00	53	4.6%	0.00 [-0.56; 0.56]
Nonino 2019	53.10	22.50	72	53.40	24.00	72	13.4%	-0.01 [-0.34; 0.31]
Ruiz-Lozano 2016	38.50	9.40	270	39.20	9.00	270	50.2%	-0.08 [-0.24; 0.09]
Søvik 2013	45.10	17.80	31	42.70	13.70	31	5.8%	0.15 [-0.35; 0.65]
Total (95% CI)			529			566	100.0%	-0.04 [-0.15; 0.08]
Prediction interval								[-0.20; 0.13]

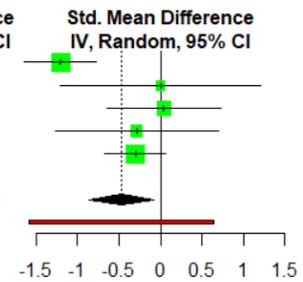
Heterogeneity: $\tau^2 = 0$; $\chi^2 = 2.10$, $df = 5$ ($P = 0.84$); $I^2 = 0\%$



Lipids – 1 month

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bavaresco 2010	24.70	7.30	48	33.20	6.70	48	29.0%	-1.20 [-1.64; -0.77]
Custodio Afonso Rocha 2012	31.30	38.20	3	31.30	6.30	22	8.4%	0.00 [-1.21; 1.21]
Giusti 2016	38.30	50.70	16	36.70	12.20	16	18.6%	0.04 [-0.65; 0.74]
Sanmiguel 2017	29.80	25.00	8	35.90	14.00	8	11.5%	-0.28 [-1.27; 0.70]
Vinolas 2019	33.20	8.30	57	35.30	5.30	57	32.4%	-0.30 [-0.67; 0.07]
Total (95% CI)			132			151	100.0%	-0.47 [-0.86; -0.09]
Prediction interval								[-1.59; 0.65]

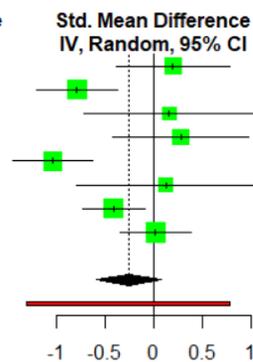
Heterogeneity: $\tau^2 = 0.0845$; $\chi^2 = 14.25$, $df = 4$ ($P < 0.01$); $I^2 = 72\%$



Lipids – 3 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Al Assal 2020	36.30	9.70	20	34.10	11.80	25	12.0%	0.20 [-0.39; 0.79]
Bavaresco 2010	27.10	8.50	48	33.20	6.70	48	14.8%	-0.79 [-1.21; -0.37]
da Silva 2014	34.00	9.60	10	32.50	8.80	10	8.3%	0.16 [-0.72; 1.03]
Giusti 2016	40.40	13.80	16	36.70	12.20	16	10.5%	0.28 [-0.42; 0.97]
Lopes Pinto 2019	26.70	6.30	51	33.10	5.90	51	14.8%	-1.04 [-1.46; -0.63]
Rosa 2011	32.00	10.00	9	31.00	4.00	9	7.8%	0.13 [-0.80; 1.05]
Sherf Dagan 2017	35.20	8.10	77	38.50	7.70	77	16.3%	-0.42 [-0.73; -0.10]
Vinolas 2019	35.40	7.30	57	35.30	5.30	57	15.6%	0.02 [-0.35; 0.38]
Total (95% CI)			288			293	100.0%	-0.26 [-0.60; 0.07]
Prediction interval								[-1.31; 0.78]

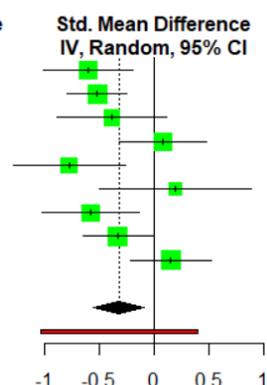
Heterogeneity: $\tau^2 = 0.1532$; $\chi^2 = 27.64$, $df = 7$ ($P < 0.01$); $I^2 = 75\%$



Lipids – 6 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bavaresco 2010	29.00	7.20	48	33.20	6.70	48	11.4%	-0.60 [-1.01; -0.19]
Brolin 1994	31.00	11.00	108	36.00	8.00	108	14.3%	-0.52 [-0.79; -0.25]
Carrasco 2007	33.40	3.20	31	35.50	6.90	31	9.7%	-0.39 [-0.89; 0.12]
Carrasco 2012	30.70	16.50	50	29.50	13.60	50	11.8%	0.08 [-0.31; 0.47]
Farias 2020	23.45	5.24	32	28.15	6.67	32	9.5%	-0.77 [-1.28; -0.26]
Giusti 2016	41.10	29.10	16	36.70	12.20	16	6.8%	0.19 [-0.50; 0.89]
Kenler 1990	36.00	8.00	34	40.00	6.00	53	10.8%	-0.58 [-1.02; -0.14]
Sherf Dagan 2017	35.90	7.90	77	38.50	7.70	77	13.3%	-0.33 [-0.65; -0.01]
Vinolas 2019	36.20	6.40	57	35.30	5.30	57	12.3%	0.15 [-0.22; 0.52]
Total (95% CI)			453			472	100.0%	-0.32 [-0.55; -0.09]
Prediction interval								[-1.03; 0.39]

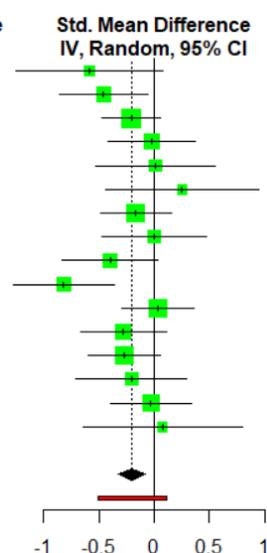
Heterogeneity: Tau² = 0.0771; Chi² = 20.66, df = 8 (P < 0.01); I² = 61%



Lipids – 12 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Al Assal 2020	28.00	5.90	14	34.10	11.80	25	3.0%	-0.59 [-1.26; 0.08]
Bavaresco 2010	30.20	6.30	48	33.20	6.70	48	6.6%	-0.46 [-0.86; -0.05]
Brolin 1994	34.00	11.00	108	36.00	8.00	108	11.1%	-0.21 [-0.47; 0.06]
Carrasco 2012	29.20	10.70	50	29.50	13.60	50	6.9%	-0.02 [-0.42; 0.37]
Casagrande 2012	33.20	8.60	22	33.10	6.10	33	4.3%	0.01 [-0.53; 0.55]
Giusti 2016	40.60	17.40	16	36.70	12.20	16	2.8%	0.25 [-0.44; 0.95]
Johnson 2013	36.00	6.00	76	37.00	6.00	76	9.1%	-0.17 [-0.48; 0.15]
Kenler 1990	40.00	9.00	25	40.00	6.00	53	5.2%	0.00 [-0.48; 0.48]
Laurenus 2013	34.30	5.40	41	37.00	7.70	43	6.0%	-0.40 [-0.83; 0.03]
Molin Netto 2017	23.30	5.00	39	27.90	6.00	41	5.5%	-0.82 [-1.28; -0.37]
Nonino 2019	28.70	10.30	72	28.30	13.10	72	8.8%	0.03 [-0.29; 0.36]
Lopes Pinto 2019	31.40	6.20	50	33.10	5.90	51	6.9%	-0.28 [-0.67; 0.11]
Sherf Dagan 2017	36.60	6.20	68	38.50	7.70	77	8.8%	-0.27 [-0.60; 0.06]
Søvik 2013	37.00	19.30	31	40.70	15.60	31	4.8%	-0.21 [-0.71; 0.29]
Vinolas 2019	35.10	7.10	57	35.30	5.30	57	7.6%	-0.03 [-0.40; 0.34]
Trosler 1995	35.70	30.60	12	33.10	34.80	19	2.6%	0.08 [-0.65; 0.80]
Total (95% CI)			729			800	100.0%	-0.20 [-0.32; -0.08]
Prediction interval								[-0.51; 0.11]

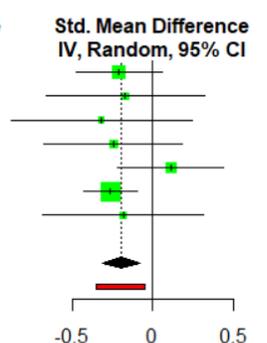
Heterogeneity: Tau² = 0.0172; Chi² = 18.19, df = 15 (P = 0.25); I² = 18%



Lipids – 24 months

Study	Experimental			Control			Weight	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Brolin 1994	34.00	11.00	108	36.00	8.00	108	18.6%	-0.21 [-0.47; 0.06]
Farias 2020	26.60	11.10	32	28.15	6.67	32	5.5%	-0.17 [-0.66; 0.32]
Kenler 1990	38.00	7.00	16	40.00	6.00	53	4.2%	-0.32 [-0.88; 0.24]
Laurenus 2013	35.30	6.00	42	37.00	7.70	43	7.3%	-0.24 [-0.67; 0.18]
Nonino 2019	29.80	13.30	72	28.30	13.10	72	12.5%	0.11 [-0.21; 0.44]
Ruiz-Lozano 2016	41.50	8.30	270	43.80	9.30	270	46.5%	-0.26 [-0.43; -0.09]
Søvik 2013	37.20	22.30	31	40.70	15.60	31	5.4%	-0.18 [-0.68; 0.32]
Total (95% CI)			571			609	100.0%	-0.20 [-0.31; -0.08]
Prediction interval								[-0.35; -0.04]

Heterogeneity: Tau² = 0; Chi² = 4.24, df = 6 (P = 0.64); I² = 0%



Appendix 2.C. Relative choices between foods or food categories in comparison with preoperative measures (prospective studies, N=19) or measures on control groups of subjects with obesity (cross-sectional studies, N=3).

First author, year	Method of assessment (unit)	Time points	Post-operative decrease OR Less in operative group than others	No modification OR No difference between the groups	Post-operative increase OR Greater in operative group than others
--------------------	-----------------------------	-------------	--	---	---

Aron-Wisniewsky 2016	Food record - 24h (serving / d)	Preop, 1 mo, 3 mo	Starchy food Meat and fish Fruits and vegetables (at 1 mo)	Dairy products	N/A
Brolin 1994	Food recall - 24h (percentage of energy intake)	Preop, 6 mo, 12 mo, 18 mo, 24 mo, 36 mo	Sweets/soda (at 6, 12, 18 and 24 mo) Milk and ice cream products High calorie liquids (at 12, 18 and 24 mo) Non-liquid sweets	N/A	N/A
Buzga 2014	Food frequency questionnaire - 24 items (frequency of consumption)	Preop, 6 mo, 12 mo	Smoked meat products with high fat contents Fatty meat (at 6 mo) Bread dumplings (at 6 mo) White flour baked goods (at 6 mo) Distillates (at 12 mo)	N/A	Fish (at 6 mo)
Delin 1997	Food frequency questionnaire - 37 items (frequency of consumption)	32 ± 11 mo	Cereals Fruit juice Ice-cream Milk Steak Chips (vs. OB) Fizzy drinks (vs. OB)	N/A	Chips (vs. NW) Fizzy drinks (vs. NW)
Ernst 2009	Food frequency questionnaire - 24 items (frequency of consumption)	> 12 mo	Chocolate Cake biscuits and cookies Soda (vs. OB) White bread and toast (vs. OB) Whole-grain bread (vs. OB) Cereals (vs. NO)	N/A	Poultry Cooked vegetables Eggs Fish (vs. OB) Meat (vs. NO) Diet soft (vs. NO) Drinks (vs. NO)
Farias 2020 ^f	Food frequency questionnaire and NOVA classification (percentage of energy intake)	Preop, 6 mo, 24 mo	Processed + ultraprocessed foods	N/A	Unprocessed or minimally processed foods
Freeman 2014	Food recall - 24h Qualitative Dietary Assessment form (serving sizes)	RYGB: 34.0 ± 12 mo SG: 26.5 ± 10 mo	Extras Breads and cereals (SG vs. OB)	Fruits Vegetables Meat and meat alternatives Dairy foods	N/A
Garla 2019	Food record - 7d and food frequency questionnaire (intake per day or week)	Preop, 3 mo, 12 mo	Polyunsaturated fatty acids Fish Soybean oil	N/A	N/A
Giusti 2016	Food records - 4 and 7d (intake per d)	Preop, 1 mo, 3 mo,	Meat (at 1mo) Cheese (at 1 and 3 mo)	Fish	N/A

		6 mo, 12 mo, 36 mo	Other dairy (at 3, 6 and 12 mo) Vegetal (at 1mo)		
Hubert 2019	Liking survey - 100 items and dietary quality index (scale from -100 to 100)	12 mo	N/A	N/A	Dietary quality index
Johnson 2013	Food frequency questionnaire - 180 items (intake per day)	Preop, 12 mo	Vegetables (vs. ILI) Whole grain (vs. ILI) Yogurt (vs. ILI)	N/A	N/A
Kenler 1990	Food recall - 24h (percentage of energy intake)	Preop, 6 mo, 12 mo, 18 mo, 24 mo	Sweets and high-calorie beverages Milk and ice cream High calorie liquids Non liquid sweets (at 12 and 18 mo)	N/A	N/A
Kvehaugen 2018	Food frequency questionnaire (percentage of energy intake or intake)	Preop, 6 mo	Sugar (%EI) Fibers Water	N/A	N/A
Laurenius 2013	SOS study dietary questionnaire - 51 questions (percentage of energy intake)	Preop, 6 wk, 12 mo, 24 mo	Nonalcoholic drinks (at 12 mo) Cooked meals Desserts (at 24 mo) Fast foods (at 6 wk and 12 mo) Cakes and cookies (at 6 wk) Candies and chocolate (at 6 wk and 12 mo) Snacks (at 6 wk) Alcohol (at 6 wk) - Sum of high dietary energy density (at 6 wk)	Light meals Egg Cereals Sandwiches Ham and cheese - Sum of low and medium dietary energy density	Milk (at 6 wk) Fruits - Sum of very low dietary energy density (at 6 wk and 12 mo)
Lopes Pinto 2019	Food record - 3d and NOVA classification (intake per day)	Preop, 3 mo, 12 mo	Unprocessed or minimally processed foods Processed foods Ultra-processed foods Processed culinary ingredients (at 3 mo)	N/A	N/A
Moizé 2013 ^s	Food record - 3d and Food recall - 24h (percentage of energy intake)	Preop, 6 mo, 12 mo, 24 mo, 48 mo, 60 mo	Saturated fat Monounsaturated fat Polyunsaturated fat		N/A
Molin Netto 2017	Food frequency questionnaire (percentage of patients consuming ≥ 4 d/wk)	Preop, 6 mo	Chicken or beef fried pastry Pizza Hot dog Hamburger	N/A	Fish (grilled or cooked) Yogurt, plain Yogurt, fruit Fresh orange juice

			<p>Finger foods (deep fried pastry)</p> <p>Banana (breaded, fried) Potato chips (i.e., crips), French, cassava Dulche de leche</p> <p>Guava jam</p> <p>Chocolates, truffles</p> <p>Ice cream, sundae</p> <p>Mayonnaise</p> <p>Soft drinks</p> <p>Hot chocolate</p> <p>Sausage</p> <p>Lean beef (breaded, roasted) barbecue</p> <p>Chicken breast (cooked, shredded)</p> <p>Beans, green peas, lentils (cooked)</p> <p>Whole milk</p> <p>Ricotta cheese</p> <p>Fruits</p> <p>Fruit salad</p>		
Murphy 2015	Food record - 3d (intake)	Preop, 12 mo	N/A	Saturated fat* Fiber*	N/A
Nielsen 2017	Ad libitum buffet meal (percentage of energy intake)	Preop, 6 mo, 18 mo	N/A	High fat sweet High fat savory Low fat sweet Low fat savory Sweet Savory High fat Low fat	N/A
Ruiz-Tovar 2018	Alimentary Frequency Questionnaire 1991-2002 (frequency of consumption)	Preop, 12 mo	<p>Processed foods</p> <p>Fried fish</p> <p>Sweets</p> <p>Fried potatoes</p> <p>Rice and pasta</p> <p>Dairy products</p> <p>Red meat</p> <p>Deli meat products</p> <p>Shellfish</p> <p>Nuts</p> <p>Soft drinks</p> <p>Beer</p>	<p>Eggs</p> <p>White meat</p> <p>Fish</p> <p>Fruits</p> <p>Bread</p> <p>Wine</p>	Vegetables and legumes
Trostler 1995	Food record - 7d, food recall - 24h, Food Frequency Questionnaire (proportion of energy intake)	Preop, 1 mo, 2 mo, 3 mo, 4 mo, 5 mo, 6 mo, 9 mo, 12 mo, 15 mo	<p>Starches (at 1 to 5 mo)</p> <p>Red meat</p>	N/A	Eggs (at 1 to 6 mo) Low fat milk products (1 to 3 mo)
Ullrich 2013	Food frequency questionnaire - 24 items (frequency of consumption)	Preop, 16 mo	<p>Chocolate</p> <p>Cake, biscuits, cookies</p> <p>Fruit juice, soft drinks</p>	<p>Meat</p> <p>Sausage product, ham</p> <p>Pasta</p> <p>Rice</p> <p>Salad or raw vegetables</p>	<p>Poultry</p> <p>Fish</p> <p>Eggs</p> <p>Potatoes</p> <p>Cooked vegetables</p>

				Fresh fruits Sweets (candies...) Salted snacks (potato chips, peanuts...) Bread (white, rye- wheat), toast Bread (whole grain, dark-rye, crisp) Cereals Curd cheese, yogurt, soured milk Cheese - milk, buttermilk Soda Diet soft drinks, other diet beverages	
Verger 2016	Food record - 3d (serving / d)	Preop, 3 mo, 12 mo	Starchy foods Fruits and vegetables (at 3 mo) Meat and fish (at 3mo)	Dairy products	N/A
Zaparolli 2018	Food recall - 24h (prevalence of consumption, %)	Preop, 3 mo, 6 mo, 12 mo	Soft drinks Alcoholic beverages	N/A	N/A

* preoperative measures were under very low-calorie diet. [‡] The significance of the results was not clearly mentioned, there were a decrease in contribution of processed and ultra-processed foods accompanied by an increase in the contribution of the unprocessed or minimally processed foods. [§] The significance of the results was not indicated, there were a progressive decrease in the contribution to energy intake from all types of fats, especially for saturated fats. N/A indicates that the results were either not assessed by the authors or not reported in the papers.

Appendix 2.D. Hedonic rating of food categories in comparison with preoperative measures (prospective studies, N=10) or measures on control groups of subjects with obesity (cross-sectional studies, N=6).

First author, year	Method of assessment (unit)	Time points	Post-operative decrease OR Less in operative group than others	No modification OR No difference between the groups
Ammon 2015	Food Preference questionnaire / hedonic (liking) ratings - 72 items (9-points Likert scale)	Preop, 6 wk	High fat / high sugar High fat / high complexe carbohydrate Fat preference score	High sugar High complexe carbohydrate High protein High fat Low fat Low fat / high sugar Low fat / high complexe carbohydrate High fat / low complexe carbohydrate / high protein Low fat / low complexe carbohydrate / high protein
Faulconbridge 2016	Liking - 10 items (11 points Likert scale)	Preop, 6mo	Liking for high calorie foods	Low calorie foods
Frank 2016	Liking and wanting - 40 items (5-points Lickert scale) Desire to eat - Power of Food Scale	7.73 ± 2.68 mo	Liking Wanting Tasted food domain of the PFS Aggregated PFS score	
Gero 2017	Food preference questionnaire / distgusting, appetizing - 10 items (5-point Likert scale)	Preop, 6 d, 6 mo	Bitter (grappefruit) Salty (potatoe chips) Umami (cheese) Fatty (hamburger and french fries) Sour (pickled cucumber) Spicy (curry dish) Sweet (chocolate cake and ice cream) Red wine (at 6 d) Cigarette (at 6d)	Water
Hubert 2019	Liking survey - 100 items (scale from -100 to 100)	12 mo	High fat proteins Sweet foods Salty Sweet drinks Alcohol	Fruit Low-fat-protein Fiber Fat Vegetables Refined carbohydrates Sour Bitter Spicy / flavorful

Kittrell 2018	Questionnaire - 15 food related pictures and 4 odor related pictures (preference rating from 0=high to 9=low) (Self Assessment Manikin)	35.7 ± 3.1 mo	Ice cream Cookies French fries (< 12 mo)	Strawberries Chips Pretzels Lemon Vinegar Sauerkraut Coffee Dark chocolate Guinness Steak Chicken Cheese Rose (odor) Banana (odor) Coffee (odor) Gasoline (odor)
Miras 2015	Food reward - Progressive ratio task	Preop, 8 wk	Reward value of chocolate sweets	Reward value of vegetables
Nielsen 2019	Hedonic rating - 4 items (translated and adapted 9-point hedonic scale)	-3 mo (before WL), -2 wk (preop), 6 wk, 6 mo, 18 mo	Fat, cocoa drink (fat 0.6, 1.5, 2.9, 8.5 and 36.1%) (36.1% at 6 wk) (36.1% and 18 mo, SG)	Savory, tomato soup (monosodium glutamate 0, 4 and 8 g/L) Sweet, tomato soup (sucrose 12 and 24 g/L) Sweet, apple juice (sucrose 0, 5, 10, 15 and 20 g/L)
Ochner 2011	Desire to eat (scale from 0 to 100)	Preop, 1 mo	High energy dense foods	Low energy dense foods
Ochner 2012	Liking and desire to eat (scale from 0 to 100)	Preop, 1 mo	Desire to eat high calorie foods	Liking high calorie foods Liking and desire to eat low calorie foods
Primeaux 2015	Geiselman Food Preference Questionnaire - 72 items - Dislike / like (9-point Likert scale)	Preop, 49.8 ± 4.6 d (RYGB) or 60.0 ± 6.9 d (SG)	High complex carbohydrate High fat Low fat / high complex carbohydrate High sugar (SG) Low fat (SG) Low fat / high protein (SG) High fat / high sugar (SG)	N/A
Sanmiguel 2017	Desire to eat (scale from 0 to 100)	Preop, 1 mo	High calorie foods	Low calorie foods

Scholtz 2014	Food appeal - 6 items (visual analog scale 0-10 cm)	8.1 (2.6-26.2) mo	Food High calorie (chocolate, other sweet and non-sweet)	Low calorie
Schultes 2010	Desire to eat - Power of Food Scale	22.5 ± 17.2 mo	Food available (RYGB vs. OB) Food present (RYGB vs. OB) Food tasted (RYGB vs. OB and NO) Aggregated PFS score (RYGB vs. OB)	
Thirlby 2006	Liking - high fat vs. low-fat potato chips (9-point Likert scale)	Preop, 32 mo	High fat potato chips (high obesity risk index patients)	
Ullrich 2013	Desire to eat - Power of food scale	Preop, 16 mo	Food available Food present Food tasted Aggregated PFS score	

Abbreviations: NO: patients without obesity; OB: patients with obesity; PFS: Power of Food Scale; RYGB: roux-en-Y gastric bypass; SG: sleeve gastrectomy. N/A indicates that the results were either not assessed by the authors or not reported in the papers.

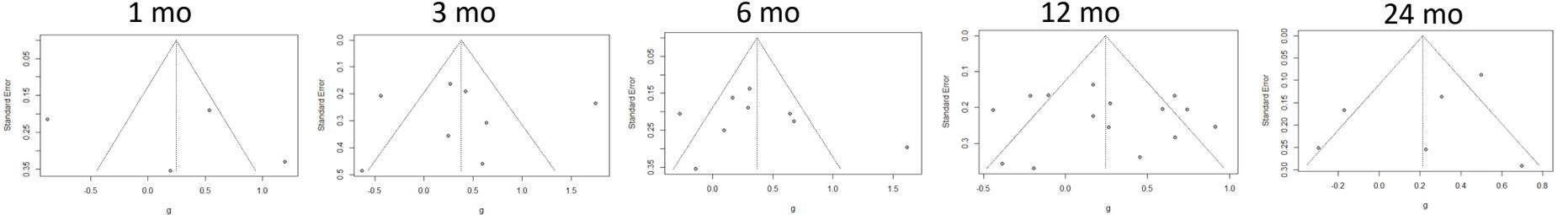
Appendix 2.E. Traffic light plot representing the risk of bias in each domain of the ‘Quality assessment tool for quantitative studies’ for each study included in the systematic review.

Study ID	A Selection bias	B Study design	C Confounders	D Blinding	E Data collection method	F Withdrawals and dropouts	Global rating for this paper
AlAssal 2020	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Ammon 2015	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Aron-Wisnewsky 2016	⚠️	⚠️	✅	⚠️	✅	✅	✅
Bavaresco 2010	⚠️	⚠️	✅	⚠️	✅	✅	✅
Brolin 1994	⚠️	⚠️	✅	⚠️	✅	✅	✅
Buzga 2014	⚠️	⚠️	✅	⚠️	✅	✅	✅
Carrasco 2007	⚠️	⚠️	✅	⚠️	✅	✅	✅
Carrasco 2012	⚠️	⚠️	✅	⚠️	✅	⚠️	✅
Casagrande 2012	⚠️	⚠️	✅	⚠️	✅	⚠️	✅
Coluzzi 2016	⚠️	⚠️	✅	⚠️	✅	✅	✅
Coupaye 2020	⚠️	⚠️	✅	⚠️	✅	✅	✅
CustodioAfonsoRocha 2012	⚠️	⚠️	✅	⚠️	✅	✅	✅
daSilva 2014	⚠️	⚠️	✅	⚠️	✅	✅	✅
Davies 2020	⚠️	✅	✅	✅	✅	✅	✅
Delin 1997	⚠️	⚠️	❌	⚠️	✅	⚠️	⚠️
Ernst 2009	⚠️	⚠️	❌	⚠️	✅	⚠️	⚠️
Farias 2020	⚠️	⚠️	✅	❌	✅	❌	❌
Faulconbridge 2016	⚠️	⚠️	⚠️	⚠️	✅	✅	✅
Frank 2016	⚠️	⚠️	⚠️	⚠️	✅	⚠️	⚠️
Freeman 2014	❌	⚠️	❌	⚠️	❌	⚠️	❌
Garla 2019	⚠️	⚠️	✅	⚠️	✅	✅	✅
Gero 2017	✅	⚠️	✅	⚠️	❌	✅	⚠️
Giusti 2016	⚠️	⚠️	✅	⚠️	✅	⚠️	✅
Hubert 2019	⚠️	⚠️	❌	⚠️	✅	⚠️	⚠️
Johnson 2013	⚠️	✅	⚠️	❌	✅	✅	⚠️
Kenler 1990	⚠️	⚠️	✅	⚠️	✅	✅	✅
Kittrell 2018	⚠️	⚠️	❌	⚠️	❌	⚠️	❌
Kvehaugen 2018	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Laurenius 2013	✅	⚠️	✅	⚠️	✅	✅	✅
LopesPinto 2019	⚠️	⚠️	✅	⚠️	✅	✅	✅
Miras 2013	⚠️	⚠️	❌	⚠️	⚠️	⚠️	⚠️
Miras 2015	⚠️	⚠️	✅	⚠️	⚠️	⚠️	⚠️
Moizé 2013	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
MolinNetto 2017	⚠️	⚠️	✅	⚠️	✅	✅	✅
Murphy 2015	⚠️	✅	✅	✅	✅	✅	✅
Nielsen 2017	⚠️	⚠️	✅	⚠️	✅	⚠️	✅
Nielsen 2019	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Nonino 2019	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Ochner 2011	⚠️	⚠️	✅	⚠️	✅	✅	✅
Ochner 2012	⚠️	⚠️	✅	⚠️	✅	✅	✅
Odstrcil 2010	⚠️	⚠️	✅	⚠️	✅	✅	✅
Primeaux 2015	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Robinson 2019	✅	⚠️	✅	⚠️	✅	✅	✅
Rosa 2011	⚠️	⚠️	✅	⚠️	✅	✅	✅
Ruiz-Lozano 2016	✅	⚠️	✅	⚠️	✅	✅	✅
Ruiz-Tovar 2018	✅	⚠️	✅	⚠️	✅	⚠️	✅
Sanmiguel 2017	⚠️	⚠️	✅	⚠️	✅	✅	✅
Schultes 2010	⚠️	⚠️	❌	⚠️	✅	⚠️	⚠️
SherfDagan 2017	⚠️	⚠️	✅	⚠️	✅	✅	✅
Søvik 2013	⚠️	✅	✅	⚠️	✅	✅	✅
Thirlby 2006	⚠️	⚠️	✅	⚠️	✅	✅	✅
Trostler 1995	⚠️	⚠️	✅	⚠️	✅	❌	⚠️
Ullrich 2013	⚠️	⚠️	✅	⚠️	✅	✅	✅
Verger 2016	⚠️	⚠️	✅	⚠️	✅	⚠️	✅
Vieira 2019	⚠️	⚠️	❌	⚠️	✅	⚠️	⚠️
Vinolas 2019	⚠️	⚠️	✅	⚠️	✅	✅	✅
Zaparolli 2018	⚠️	⚠️	✅	⚠️	✅	✅	✅

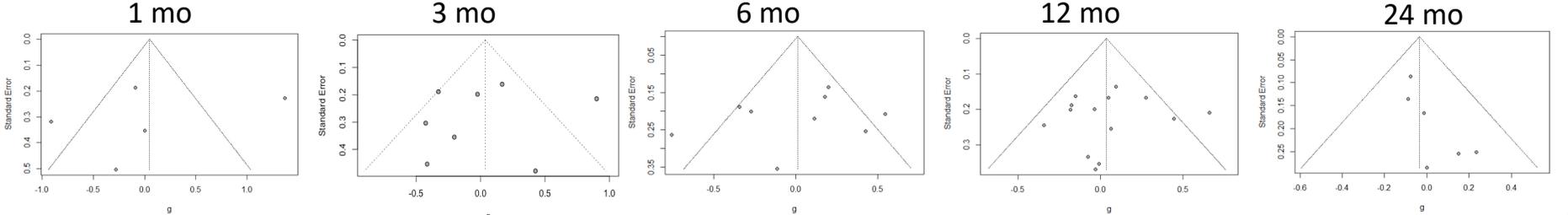


Appendix 2.F. Funnel plots for means weighted differences in total energy intake coming from proteins, carbohydrates and lipids between preoperative and postoperative measure (1, 3, 6, 12, and 24 mo) using random effect models.

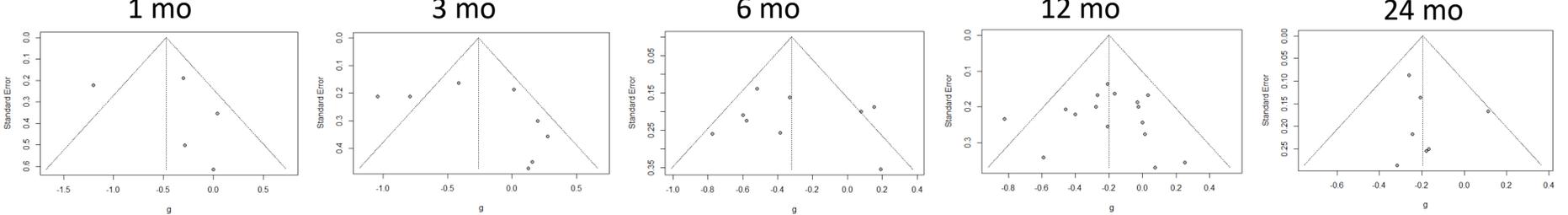
Proteins



Carbohydrates



Lipids



Egger’s regression test did not detect a significant bias, but there were a lack of power (N<10 studies) for the meta-analyses performed at 1, 3 and 24 mo.

Appendix 2.G. Key findings from pre-clinical studies in relation to changes in food preferences after bariatric surgery.

First author, year (reference number)*	Intervention	Control	Type of outcome	Method of assessment	Post-operative modification OR Difference between intervention group and controls
Arble, 2016 (1)	SG	Sham operation	Macronutrient preference	Macronutrient selection paradigm (P, L, C)	Decreased preference for fat
Bueter, 2011 (2)	RYGB	Sham operation	Taste preference	Two-bottle test (sucrose)	Lower preference for sucrose at the highest concentrations
Goncalves, 2015 (3)	Bile diversion from the bile duct to the mid-ileum (as in RYGB)	Bile diversions from the bile duct to the mid-jejunum	Food preference	Two-choice diet (standard and HFHS)	Lower preference for HFHS diet compared to controls
Hajnal, 2010 (4)	RYGB	Sham operation	Taste preference	Brief access test (sucrose)	Reduction of the preference for sucrose
Hankir, 2017 (5)	RYGB	Sham operation	Food preference	Two-choice diet (HF and LF)	Decreased preference for HF
Hao, 2014 (6)	RYGB ± celiac branch vagotomy	Sham operation ± celiac branch vagotomy	Food preference (for fat)	Two-choice diet (standard and HF)	Lower preference for HF over LF post RYGB ± celiac vagotomy
Joram D Mul, 2012 (7)	SG	Sham operation	Food preference	Macronutrient selection paradigm (P, L, C)	Shift preference away from fat and towards carbohydrates
Le Roux, 2011 (8)	RYGB		Food preference	Three choice diet (HF, HF-Bistro (gravy-type flavor) and LF-Bistro)	Decreased preference for HF towards LF
				---	---
				Two-bottle preference test (intralipid)	Progressive decreased preference for HF liquid
				---	---
				Rood reward	No effect on the licking response
---				Brief access test (intralipid)	Decreased preference for HS after HF gavage
---				Taste aversion paradigm (corn oil)	

Mathes, 2012 (9)	RYGB	Sham operation	Food reward	Brief access test (sucrose)	Increased appetitive behavior and increased reward (under undeprived condition and presurgical exposure to sucrose)
Mathes, 2015 (10)	RYGB	Sham operation	Taste preference	Two-bottle test (intralipid)	Decreased preference for fat
Mathes, 2016 (11)	RYGB	Sham operation	Food preference	Cafeteria diet (chow, beans (LFHS), yogurt (LFHS), peanut butter (HFHS) and sugar-fat whip (HFHS))	Progressive decreased preference for fat
Saeidi, 2012 (12)	RYGB and SG	Sham operation	Food preference	Two-choice diet (HF and LF)	Decreased food preferences for HF among RYGB rats only
Seyfried, 2013 (13)	RYGB	Sham operation	Food preference	Two-choice drink (vegetable and HC) Two-choice diet (standard and HF)	Increased preference for a vegetable drink over LS and LF liquids Decreased preference for HF
Shin, 2011 (14)	RYGB	Sham operation and lean	Food reward --- Food preference	The brief-access lick test (sucrose and corn oil emulsion) --- Two-choice diet (standard and HF)	Decreased liking for HF and HS Wanting initially reduced was restored to the same level of lean controls --- Decreased preference for HF
Thanos, 2012 (15)	RYGB	OB and lean	Food reward	Two-bottle test (ethanol and water), under HF diet	Higher alcohol intake (i.e., higher reward)
Tichanski, 2011 (16)	RYGB	Sham operation	Taste preference	Brief access test (sucrose)	Decreased preference for the highest concentrations of sucrose, no modification for low concentration of sucrose or water
Wilson-Perez, 2013 (17)	RYGB and SG	Sham operation	Food preference --- Food reward --- Taste aversion	Three-choice diet (nutritionally complete, HFHS and LF) ---	Shifted preference towards lower energy-dense foods --- No change in food reward for fat or sweet --- Aversion for high fat among SG rats only

		Progressive ratio task (sucrose and peanut oil)		---		Taste aversion paradigm (corn oil)	
Zheng, 2009 (18)	RYGB	Sham operation	Food preference	Two-choice diet (HF and LF)	Increased preference for LF over HF		

Abbreviations: C: carbohydrates; HC: high calorie; HF: high fat; HFHS: high fat - high sugar; HFSL: high fat - low sugar; L: lipid; LF: low fat; LFHS: low fat - high sugar; LFSL: low fat - low sugar; LS: low sugar; P: protein; RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy. *Correspond to the following references:

1. Arble DM, Pressler JW, Sorrell J, Wevrick R, Sandoval DA. Sleeve gastrectomy leads to weight loss in the Magel2 knockout mouse. *Surg Obes Relat Dis.* 2016 Dec 1;12(10):1795–802.
2. Bueter M, Miras AD, Chichger H, Fenske W, Ghatei MA, Bloom SR, et al. Alterations of sucrose preference after Roux-en-Y gastric bypass. *Physiol Behav.* 2011 Oct;104(5):709–21.
3. Goncalves D, Barataud A, De Vadder F, Vinera J, Zitoun C, Duchamp A, et al. Bile Routing Modification Reproduces Key Features of Gastric Bypass in Rat. *Ann Surg.* 2015 Dec;262(6):1006–15.
4. Hajnal A, Kovacs P, Ahmed T, Meirelles K, Lynch CJ, Cooney RN. Gastric bypass surgery alters behavioral and neural taste functions for sweet taste in obese rats. *Am J Physiol Gastrointest Liver Physiol.* 2010 Oct;299(4):G967-79.
5. Hankir MK, Seyfried F, Hintschich CA, Diep T-A, Kleberg K, Kranz M, et al. Gastric Bypass Surgery Recruits a Gut PPAR-alpha-Striatal D1R Pathway to Reduce Fat Appetite in Obese Rats. *Cell Metab.* 2017 Feb;25(2):335–44.
6. Hao Z, Townsend RL, Mumphrey MB, Patterson LM, Ye J, Berthoud HR. Vagal Innervation of Intestine Contributes to Weight Loss After Roux-en-Y Gastric Bypass Surgery in Rats. *Obes Surg.* 2014 Dec 1;24(12):2145–51.
7. Mul JD, Begg DP, Alsters SIM, van Haaften G, Duran KJ, D'Alessio DA, et al. Effect of vertical sleeve gastrectomy in melanocortin receptor 4-deficient rats. *Am J Physiol Endocrinol Metab.* 2012 Jul;303(1):E103-10.
8. le Roux CW, Bueter M, Theis N, Werling M, Ashrafian H, Lowenstein C, et al. Gastric bypass reduces fat intake and preference. *Am J Physiol Regul Integr Comp Physiol.* 2011 Oct;301(4):R1057-66.
9. Mathes CM, Bueter M, Smith KR, Lutz TA, le Roux CW, Spector AC. Roux-en-Y gastric bypass in rats increases sucrose taste-related motivated behavior independent of pharmacological GLP-1-receptor modulation. *Am J Physiol - Regul Integr Comp Physiol.* 2012 Mar;302(6):751–67.
10. Mathes CM, Bohnenkamp RA, le Roux CW, Spector AC. Reduced sweet and fatty fluid intake after Roux-en-Y gastric bypass in rats is dependent on experience without change in stimulus motivational potency. *Am J Physiol Regul Integr Comp Physiol.* 2015 Oct;309(8):R864-74.
11. Mathes CM, Letourneau C, Blonde GD, Roux CWL, Spector AC. Roux-en-y gastric bypass in rats progressively decreases the proportion of fat calories selected from a palatable cafeteria diet. *Am J Physiol - Regul Integr Comp Physiol.* 2016 May 1;310(10):R952–9.
12. Saeidi N, Nestoridi E, Kucharczyk J, Uygun MK, Yarmush ML, Stylopoulos N. Sleeve gastrectomy and Roux-en-Y gastric bypass exhibit differential effects on food preferences, nutrient absorption and energy expenditure in obese rats. *Int J Obes (Lond).* 2012 Nov;36(11):1396–402.
13. Seyfried F, Miras AD, Bueter M, Prechtl CG, Spector AC, le Roux CW. Effects of preoperative exposure to a high-fat versus a low-fat diet on ingestive behavior after gastric bypass surgery in rats. *Surg Endosc.* 2013 Nov;27(11):4192–201.
14. Shin AC, Zheng H, Townsend RL, Patterson LM, Holmes GM, Berthoud H-R. Longitudinal assessment of food intake, fecal energy loss, and energy expenditure after Roux-en-Y gastric bypass surgery in high-fat-fed obese rats. *Obes Surg.* 2013 Apr;23(4):531–40.

15. Thanos PK, Subrize M, Delis F, Cooney RN, Culnan D, Sun M, et al. Gastric bypass increases ethanol and water consumption in diet-induced obese rats. *Obes Surg*. 2012 Dec;22(12):1884–92.
16. Tichansky DS, Glatt AR, Madan AK, Harper J, Tokita K, Boughter JD. Decrease in sweet taste in rats after gastric bypass surgery. *Surg Endosc*. 2011 Apr;25(4):1176–81.
17. Wilson-Perez HE, Chambers AP, Sandoval DA, Stefater MA, Woods SC, Benoit SC, et al. The effect of vertical sleeve gastrectomy on food choice in rats. *Int J Obes (Lond)*. 2013 Feb;37(2):288–95.
18. Zheng H, Shin AC, Lenard NR, Townsend RL, Patterson LM, Sigalet DL, et al. Meal patterns, satiety, and food choice in a rat model of Roux-en-Y gastric bypass surgery. *Am J Physiol Regul Integr Comp Physiol*. 2009 Nov;297(5):R1273-82.

Appendix 3.A. Summary table of the outcomes assessed with the online questionnaire.

Section	Outcomes
1 Bariatric surgery and weight history	<ul style="list-style-type: none"> • Type of surgery • Date of surgery • Weight before the surgery • Current weight • Minimum weight after the surgery • Weight change trajectory • Height
2 Food exclusions	<ul style="list-style-type: none"> • Food exclusions • Details of excluded foods
3 Food preferences	<ul style="list-style-type: none"> • Hunger level • Desire to eat • Satiety level • Food preferences for 24 food items (<i>red meat, white meat, fish, sea foods, eggs, delicatessen, green vegetables, colored vegetables, legumes, starchy foods, milk, plain dairy products, sweet dairy products, cheese, fruits, dried foods, dessert and sweets, fried foods, added fat, bread, still water, hot drinks, sweet drinks, alcohol</i>) • Perceived change in food preference for 24 food items • Changes immediately after surgery, which have not persisted over time
4 Taste alterations	<ul style="list-style-type: none"> • Perceived alterations of taste • Type of taste alterations perceived • Type of foods / non-food items concerned by the taste alterations • Changes immediately after surgery, which have not persisted over time • Non-food taste alterations.
5 Smell alterations	<ul style="list-style-type: none"> • Perceived alterations of smell • Type of smell alterations perceived • Type of foods / non food items concerned by the smell alterations • Changes immediately after surgery, which have not persisted over time • Non-food smell alterations
6 Food rejections	<ul style="list-style-type: none"> • Foods considered as not appetizing • Foods considered as disgusting • Foods considered as unbearable
7 Socio-economic background	<ul style="list-style-type: none"> • Age • Gender • Household • Education level • Employment status • Physical activity • Physical inactivity • Smoking status

Appendix 3.B. Translated online questionnaire used in the study.

Hello and welcome!

Please read the information sheet for your attention by following the link below:

<http://bit.ly/noteinformation>

The following questions are asked as part of a research project.

Please respond to them individually and as spontaneously as possible.

Your answers will remain anonymous.

I. Data on bariatric surgery

Have you had obesity surgery? Yes No

What type of surgery is this? Gastric band Sleeve gastrectomy Roux-en-Y gastric bypass (classic) Omega gastric bypass (Mini-Bypass) Other

If other, specify the type of surgery: _____

When did you have your operation? |_|_| day |_|_| month |_|_|_|_| year

II. Weight history

What was your pre-operative weight? |_|_|_|, |_| kg

What is the minimum weight you reached after your surgery? |_|_|_|, |_| kg

What is your current weight? |_|_|_|, |_| kg

Currently you are: Losing weight In stable weight Gaining weight

What is your height? |_|_|_| cm

III. Food exclusions

Are you currently excluding certain foods from your diet for medical, religious or personal reasons?

(e.g., renal failure, allergies, intolerances, vegetarian diet, ...) Yes No

If so, what foods do you exclude? _____

IV. Food preferences.

When filling out this questionnaire, how hungry are you? Not at all Not really A little Extremely

When filling out this questionnaire, how strong is your desire to eat? Not at all Not really A little Extremely

When completing this questionnaire, how full do you feel? Not at all Not really A little Extremely

Please indicate how much you like each of the food items in the list below and if you have observed any changes in liking for these food items since your bariatric surgery. Do not take into account how much you actually eat these food items, or your possible eating difficulties. What interests us is how much you like the foods below. For any food or drink that you do not know or do not eat, please select "Not applicable".

Red meat (e.g., beef, lamb, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

White meat (e.g., chicken, turkey, ...)

- Currently, I like A lot Slightly Not really Not at all

- Compared to before my surgery, I like Less than before As before More than before Not applicable

Fish (e.g., hake, salmon, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Shellfish, crustaceans, seafood

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Eggs

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Delicatessen (e.g., rosette, bacon, ham, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Green vegetables (e.g., green beans, zucchini, salad, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Colorful vegetables (e.g., tomato, pumpkin, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Legumes (e.g., lentils, chickpeas, beans, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Starches (e.g., pasta, rice, potatoes, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Milk

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Plain dairy products (e.g., cottage cheese, spread cheese, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Sweet dairy products (e.g., flavored yogurt, dessert cream, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Cheese

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Fruits

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Dried fruits (e.g., walnuts, almonds, pistachios, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Desserts and sweets (e.g., chocolate cake, crème brûlée, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Fried foods (e.g., fries, donuts, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Added fats (e.g., oil, butter, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Bread

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Still water

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Hot drinks (e.g., tea, coffee, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Sweet drinks (e.g., soda, syrups, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Alcohol (e.g., wine, beer, ...)

- Currently, I like A lot Slightly Not really Not at all
- Compared to before my surgery, I like Less than before As before More than before Not applicable

Following your bariatric surgery, do you think that your changes in food preferences have contributed to your weight loss? Yes No I don't know

Did you notice that your food preferences changed after surgery and then returned to the same as before surgery? Yes No I don't know

V. Taste alterations

Since my surgery, food / drink tastes have changed ... Strongly agree Agree Disagree Strongly disagree

If I strongly agree or disagree, since my surgery I find the tastes of food / drink are ... Less intense More intense Different I don't feel anything anymore

Specify which foods / drinks are affected by these changes in taste:

Did you notice that the tastes of the food / drink changed after the surgery and then returned to the same as before the surgery? Yes No

Have you noticed any other changes in taste? (e.g., metallic taste in the mouth) Yes No

If yes, specify: _____

VI. Smell alterations

Since my surgery, the smells of food / drink have changed ... Strongly agree Agree Disagree Strongly disagree

If I strongly agree or agree, since my surgery I find that food / drink smells are ... Less intense More intense Different I don't feel anything anymore

Specify which foods / drinks are affected by these odor changes:

Did you notice that food / drink smells changed after surgery and then returned to the same as before surgery? Yes No

Have you noticed any other changes in the smells? (e.g., laundry odors, body odors, floral odors, etc.) Yes No

If yes, specify: _____

VII. Food rejections

At the moment, these foods / drinks are not appetizing ... (e.g., It doesn't please me, I don't want to, ...):

At the moment, these foods / drinks disgust me... (e.g., I find them repulsive, I am disgusted, ...):

At the moment, I cannot stand these foods / drinks (e.g., I have pain, nausea, blockage, ...):

VIII. Socioeconomic background

How old are you? |_|_| years

Are you? A man A woman

Currently you live: Alone Alone with child(ren) With a spouse without a child With a spouse with child(ren) Other

If other, specify: _____

What is your grade level? I have never been to school Primary school Middle school High school Higher level education Other

If other, specify: _____

What is your profession? Farmer-operator Craftsman, trader, business manager Higher intellectual profession Intermediate profession Employee Worker Retired Unemployed Student

During the day, how long do you practice a physical or sports activity? (e.g., running, walking, gardening, cycling, scooter, cleaning ...) Less than 30 min More than 30 minutes

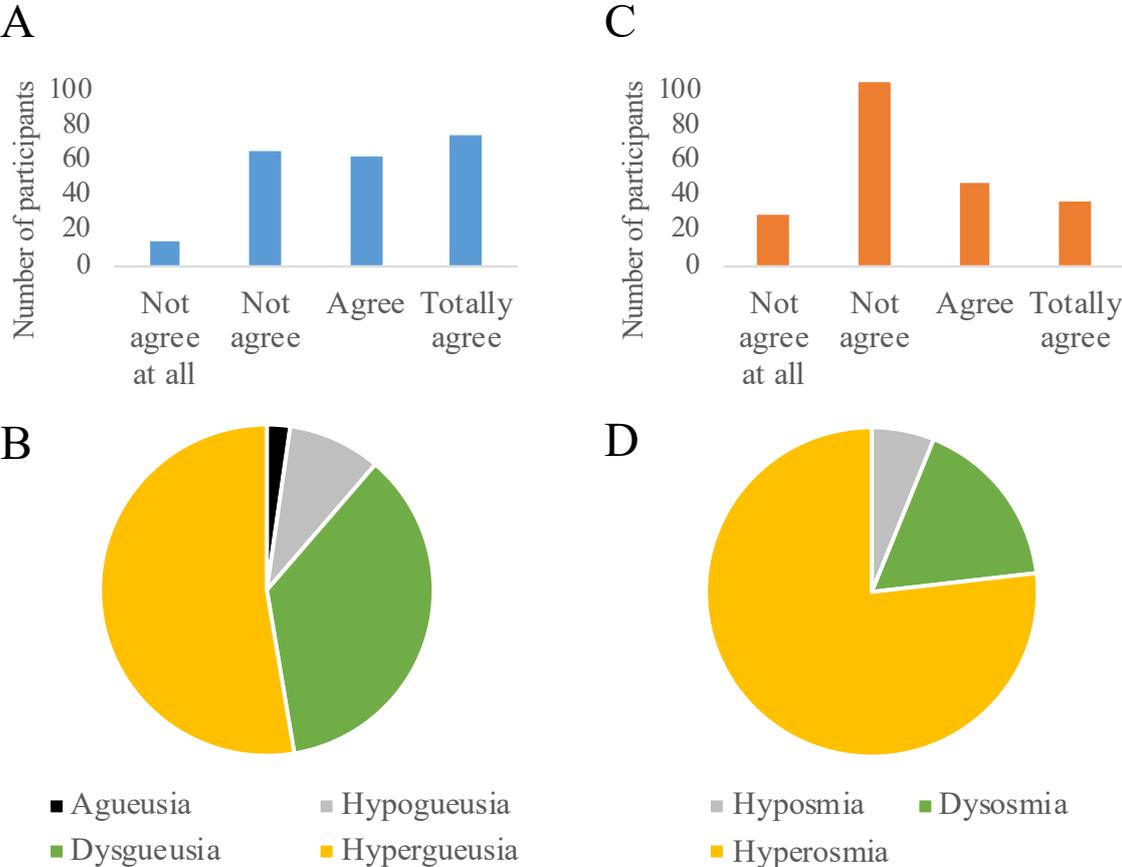
How long do you sit during the day? (e.g., at work, in public transport, by car ...) Less than 7 hours per day More than 7 hours per day

Were you a smoker before the surgery? Yes No

Currently, are you? Non-smoker Smoker Former smoker

We thank you for your participation!

Appendix 3.C. Perceived taste and smell alterations after bariatric surgery among 220 participants.



Perceived taste and smell alterations after bariatric surgery among 220 participants
 Panel A. Perceived taste alteration after bariatric surgery. Panel B. Type of alterations among the participants that agree or totally agree to have taste alterations. Panel C. Perceived smell alterations after bariatric surgery. Panel D. Type of smell alterations among the participants that agree or totally agree to have smell alterations.

Appendix 4.A. Food items used in the LFPQ.

Food categories	Food items
HC-SO	Chocolate Gingerbread Crepe Fries
HC-FL	Dessert cream Sweet drink yoghurt Orange juice Blackcurrant juice
LC-SO	Salmon Cheese dice Sausages Mimosa eggs Gazpacho
LC-FL	Vegetables soup Milk Coffee
DA-CO	Decorated cream cake Colored ice creams Two-taste dessert cream Red cheesecake Cheese
DA-NC	Milk Vanilla ice cream Vanilla custard cream
ND-CO	Normal and paprika chips M & M's Decorated donuts Candies Croissant
ND-NC	Sausages Almond pastry Chips
HF-SA	Peanuts Chips Gruyere Fried egg Apple pie with whipped cream
HF-SW	Chocolate donut Chocolate Cream puffs Red wine
LF-SA	Cucumber Savory sticks Vegetables broth Gingerbread
LF-SW	White grapes Banana Marshmallow

		Rice with tomato sauce
	FI-SC	Milk with cereals high in fiber
		Cantonese rice with meat sauce
		White cheese with fruits
		High fiber cereals
	FI-NS	Peanuts
		Various fruits
		Dried fruits
		Ice cream with fruit coulis
	NF-SC	Mimosa eggs
		Potatoes in sauce
		Pasta with sauce
		Salmon
	NF-NS	Ice cream
		Hard boiled egg
		Pasta
		Salmon
	ME-HF	Sausage
		Roasted chicken leg
		Pork chop
		White fish fillet
	ME-LF	Chicken breast
		Roast pork
		Rump
		Peanuts
	NM-HF	Fried egg
		Pizza
		Cheese
		Spinach
	NM-LF	Crepe
		Savory sticks
		Cucumbers
		Various cheese slices
	HP-VA	Various sliced sausages
		Various fish fillets
		Various sliced deli meats
		Chicken breast
	HP-NV	Roast pork
		Fish fillet
		Cheese dice
		Roasted, mashed and dauphine potatoes
	LP-VA	Various fruits in slices
		Various green vegetables
		Various aperitif biscuits
		Gingerbread
	LP-NV	Roasted potatoes
		Sliced apples
		Green beans

Abbreviations: CO, color; DA, dairy; FI, fiber; FL, fluid; HC, high carbohydrate; HF, high fat; HP, high protein; LC, low carbohydrate; LF, low fat; LFPQ, Leeds Food Preference Questionnaire; LP, low protein; ME, meat; NC, no color; ND, nondairy; NF, no fiber; NM, no meat; NS, no sauce; NV, no variation; SA, savory; SC, sauce; SO, solid; SW, sweet; VA, variation.

Appendix 4.B. Liking scores according to the operative status of the 86 included patients (2018-2019).

	All (N=86)	OB (N=30)	SG (N=30)	RYGB (N=26)	p-value*	p-value [§] for pairwise comparison		
						OB vs. SG	RYGB vs. SG	RYGB vs. OB
Unadjusted explicit liking scores								
HC-SO	34.0 (2.7)	48.5 (4.2)	27.4 (4.2)	24.9 (4.6)	0.0003	0.0021	0.0009	0.92
HC-FL	31.0 (2.4)	41.7 (3.9)	28.2 (3.9)	21.9 (4.2)	0.0026	0.423	0.024	0.52
LC-SO	40.1 (3.1)	57.8 (4.6)	34.5 (4.6)	26.0 (5.0)	<.0001	0.0018	<.0001	0.43
LC-FL	29.2 (2.6)	38.2 (4.3)	22.9 (4.3)	26.2 (4.6)	0.035	0.035	0.14	0.85
DA-CO	31.1 (2.8)	46.3 (4.4)	23.9 (4.4)	21.8 (4.8)	0.0002	0.0015	0.0007	0.92
DA-NC	33.7 (2.6)	44.0 (4.2)	29.8 (4.2)	26.0 (4.6)	0.011	0.051	0.014	0.82
ND-CO	26.7 (2.5)	36.9 (3.9)	26.5 (3.9)	14.8 (4.3)	0.0012	0.15	0.0007	0.11
ND-NC	32.1 (2.6)	47.4 (3.8)	28.3 (3.8)	18.5 (4.1)	<.0001	0.0017	<.0001	0.20
HF-SA	34.5 (2.9)	48.5 (4.5)	31.6 (4.5)	21.6 (4.8)	0.0004	0.025	0.0003	0.28
HF-SW	36.1 (3.2)	57.1 (4.7)	26.4 (4.7)	23.2 (5.0)	<.0001	<.0001	<.0001	0.89
LF-SA	22.1 (2.0)	27.9 (3.3)	21.3 (3.3)	16.4 (3.5)	0.064	NA	NA	NA
LF-SW	34.6 (2.5)	46.2 (4.0)	31.7 (4.0)	24.5 (4.3)	0.0014	0.034	0.0012	0.45
FI-SC	34.8 (2.6)	45.2 (4.2)	32.5 (4.2)	25.3 (4.5)	0.0056	0.084	0.0047	0.48
FI-NS	29.5 (2.4)	36.4 (4.1)	27.1 (4.1)	24.5 (4.4)	0.11	NA	NA	NA
NF-SC	37.3 (2.9)	54.8 (4.4)	29.8 (4.4)	25.9 (4.7)	<.0001	0.0004	<.0001	0.82
NF-NS	39.5 (2.8)	54.4 (4.4)	32.9 (4.4)	29.7 (4.7)	0.0003	0.0024	0.0007	0.87
ME-HF	38.2 (3.3)	55.6 (5.1)	30.7 (5.1)	26.8 (5.4)	0.0002	0.0023	0.0006	0.86
ME-LF	38.5 (3.3)	51.9 (5.4)	31.1 (5.4)	31.5 (5.8)	0.012	0.022	0.032	1.00
NM-HF	35.5 (3.0)	49.7 (4.7)	30.4 (4.7)	25.1 (5.1)	0.0012	0.013	0.0017	0.72
NM-LF	29.4 (2.4)	40.2 (3.8)	24.8 (3.8)	22.2 (4.1)	0.0030	0.016	0.054	0.88
HP-VA	36.2 (2.9)	48.5 (4.7)	32.8 (4.7)	25.9 (5.0)	0.0040	0.049	0.0039	0.57
HP-NV	39.3 (3.2)	51.3 (5.2)	34.7 (5.2)	30.6 (5.5)	0.016	0.065	0.021	0.85
LP-VA	34.8 (2.3)	43.7 (3.8)	32.4 (3.8)	27.3 (4.1)	0.012	0.093	0.011	0.64
LP-NV	36.4 (2.4)	46.2 (3.9)	31.0 (3.9)	31.4 (4.2)	0.011	0.020	0.031	1.00
Adjusted explicit liking scores								
HC-SO	34.0 (7.8)	48.5 (4.6)	27.1 (6.9)	13.2 (11.4)	0.0032	0.012	0.0052	0.30
HC-FL	31.0 (7.5)	41.0 (4.4)	29.7 (6.7)	13.5 (11.0)	0.050	0.17	0.023	0.21
LC-SO	40.1 (7.2)	55.4 (4.2)	30.7 (6.5)	31.2 (10.6)	0.0031	0.0020	0.037	0.97
LC-FL	29.2 (8.2)	37.8 (4.8)	19.1 (7.3)	36.1 (12.0)	0.11	NA	NA	NA

DA-CO	30.9 (8.4)	48.5 (4.9)	22.6 (7.4)	8.7 (12.3)	0.0013	0.0048	0.0036	0.34
DA-NC	33.5 (7.8)	43.4 (4.6)	33.1 (7.0)	24.5 (11.5)	0.21	NA	NA	NA
ND-CO	26.5 (7.4)	38.6 (4.3)	21.8 (6.5)	8.7 (10.8)	0.013	0.035	0.012	0.30
ND-NC	31.9 (6.3)	49.5 (3.7)	22.9 (5.6)	6.0 (9.2)	0.012	0.0002	<.0001	0.12
HF-SA	34.5 (6.8)	49.8 (4.0)	25.1 (6.1)	8.1 (10.0)	<.0001	0.0012	0.0002	0.15
HF-SW	36.1 (8.7)	58.9 (5.1)	30.1 (7.8)	8.6 (12.7)	<.0001	0.0027	0.0005	0.15
LF-SA	22.1 (5.5)	28.7 (3.2)	14.1 (4.9)	11.8 (8.1)	0.019	0.015	0.055	0.81
LF-SW	34.6 (6.9)	48.3 (4.0)	41.7 (6.1)	8.9 (10.1)	0.0024	0.37	0.0005	0.0071
FI-SC	34.8 (6.6)	46.3 (3.9)	28.4 (5.9)	28.6 (9.7)	0.023	0.013	0.094	0.99
FI-NS	29.5 (6.9)	37.6 (4.0)	31.8 (6.1)	13.4 (10.1)	0.084	0.43	0.028	0.12
NF-SC	37.3 (7.0)	57.0 (4.1)	29.3 (6.3)	18.2 (10.3)	<.0001	0.0004	0.0008	0.36
NF-NS	39.5 (7.1)	56.1 (4.2)	37.4 (6.3)	32.0 (10.4)	0.015	0.016	0.036	0.66
ME-HF	38.2 (8.2)	56.5 (4.8)	24.1 (7.3)	37.0 (12.1)	0.0015	0.0004	0.14	0.36
ME-LF	38.5 (8.8)	53.5 (5.2)	24.2 (7.9)	36.2 (13.0)	0.0093	0.0028	0.22	0.43
NM-HF	35.5 (7.6)	50.9 (4.5)	27.4 (6.8)	28.0 (11.1)	0.0086	0.0050	0.061	0.96
NM-LF	29.4 (6.6)	42.1 (3.8)	19.3 (5.8)	27.6 (9.6)	0.0056	0.0017	0.17	0.46
HP-VA	36.2 (7.6)	46.8 (4.5)	28.8 (6.8)	15.6 (11.2)	0.011	0.031	0.012	0.32
HP-NV	39.3 (8.7)	51.7 (5.1)	26.8 (7.7)	36.4 (12.7)	0.027	0.0089	0.27	0.52
LP-VA	34.8 (6.2)	44.8 (3.6)	25.0 (5.5)	23.5 (9.1)	0.0048	0.0038	0.033	0.89
LP-NV	36.4 (6.6)	47.5 (3.9)	32.1 (5.9)	26.9 (9.6)	0.031	0.031	0.051	0.65
Unadjusted explicit wanting scores								
HC-SO	32.8 (2.7)	48.5 (3.9)	25.4 (4.2)	23.2 (4.6)	<.0001	0.0005	0.0002	0.93
HC-FL	30.0 (2.5)	43.9 (4.2)	25.5 (3.5)	19.2 (4.0)	<.0001	0.0031	0.0001	0.51
LC-SO	38.0 (3.1)	56.2 (4.2)	32.3 (5.2)	23.6 (4.6)	<.0001	0.0012	<.0001	0.40
LC-FL	28.0 (2.6)	36.8 (3.7)	22.6 (4.2)	24.1 (5.1)	0.039	0.050	0.11	0.97
DA-CO	29.3 (2.8)	44.1 (4.7)	21.9 (3.7)	20.4 (5.1)	0.0003	0.0015	0.0012	0.97
DA-NC	32.5 (2.6)	42.7 (3.8)	28.6 (4.0)	25.1 (5.1)	0.011	0.047	0.015	0.84
ND-CO	25.7 (2.5)	36.5 (4.0)	23.2 (4.3)	15.7 (3.8)	0.0022	0.051	0.0018	0.41
ND-NC	30.9 (2.6)	46.3 (3.6)	26.7 (4.5)	17.5 (3.3)	<.0001	0.0013	<.0001	0.24
HF-SA	33.1 (2.9)	47.4 (4.1)	29.8 (5.3)	20.4 (4.1)	0.0003	0.019	0.0003	0.33
HF-SW	34.1 (3.2)	56.8 (5.0)	23.5 (4.5)	20.4 (4.6)	<.0001	<.0001	<.0001	0.89
LF-SA	21.2 (2.0)	27.2 (2.7)	19.4 (3.8)	16.5 (3.4)	0.067	NA	NA	NA
LF-SW	33.7 (2.5)	44.7 (3.2)	30.6 (4.5)	24.5 (4.5)	0.0026	0.038	0.0026	0.56
FI-SC	35.0 (2.7)	45.8 (3.9)	32.4 (5.0)	25.6 (4.4)	0.0071	0.081	0.0063	0.55
FI-NS	28.9 (2.5)	37.8 (4.0)	25.9 (4.5)	22.0 (3.8)	0.024	0.10	0.026	0.80

NF-SC	36.4 (2.9)	54.1 (4.4)	28.1 (4.5)	25.5 (4.5)	<.0001	0.0002	<.0001	0.92
NF-NS	38.7 (2.8)	53.1 (3.9)	32.3 (4.6)	29.6 (5.2)	0.0006	0.0040	0.0016	0.91
ME-HF	37.2 (3.3)	56.3 (5.1)	27.6 (5.2)	26.4 (4.9)	<.0001	0.0003	0.0003	0.98
ME-LF	37.0 (3.4)	49.7 (5.5)	29.1 (5.4)	31.6 (6.3)	0.022	0.028	0.074	0.95
NM-HF	34.6 (2.9)	49.4 (4.8)	30.0 (5.0)	22.6 (4.0)	0.0004	0.010	0.0004	0.52
NM-LF	27.9 (2.4)	39.2 (3.8)	23.2 (4.0)	20.4 (3.7)	0.0017	0.010	0.0032	0.87
HP-VA	35.7 (3.0)	47.6 (4.6)	31.6 (5.2)	26.8 (5.2)	0.012	0.060	0.014	0.79
HP-NV	38.9 (3.3)	51.5 (4.8)	33.5 (5.6)	30.5 (6.1)	0.016	0.049	0.024	0.93
LP-VA	32.8 (2.3)	40.4 (2.9)	32.3 (4.7)	24.5 (3.9)	0.021	0.30	0.016	0.35
LP-NV	32.8 (2.7)	46.4 (3.2)	33.0 (4.6)	29.1 (5.1)	0.014	0.068	0.017	0.80
Adjusted explicit wanting scores								
HC-SO	32.8 (7.8)	49.4 (4.5)	22.9 (6.9)	16.2 (11.3)	0.0011	0.0019	0.0079	0.62
HC-FL	30.0 (7.6)	43.2 (4.4)	24.0 (6.8)	11.3 (11.1)	0.0070	0.020	0.0094	0.33
LC-SO	38.0 (7.4)	54.4 (4.3)	27.9 (6.6)	29.6 (10.8)	0.0021	0.0013	0.037	0.90
LC-FL	28.0 (8.1)	37.1 (4.7)	18.7 (7.2)	36.1 (11.9)	0.11	NA	NA	NA
DA-CO	29.1 (8.5)	43.6 (5.0)	22.2 (7.5)	7.4 (12.4)	0.0065	0.020	0.0084	0.31
DA-NC	32.3 (7.6)	42.1 (4.4)	31.3 (6.7)	16.7 (11.1)	0.075	NA	NA	NA
ND-CO	25.5 (7.5)	37.5 (4.4)	17.4 (6.7)	9.2 (11.0)	0.0092	0.014	0.019	0.52
ND-NC	30.6 (6.4)	45.8 (3.8)	19.5 (5.7)	5.6 (9.4)	<.0001	0.0003	0.0002	0.21
HF-SA	33.1 (6.7)	49.9 (3.9)	21.2 (6.0)	8.2 (9.8)	<.0001	0.0001	0.0002	0.26
HF-SW	34.1 (8.7)	58.8 (5.1)	23.8 (7.8)	9.4 (12.7)	<.0001	0.0003	0.0006	0.34
LF-SA	21.2 (5.4)	27.7 (3.2)	13.1 (4.8)	11.9 (7.9)	0.019	0.13	0.067	0.90
LF-SW	33.7 (6.8)	47.3 (4.0)	37.4 (6.1)	9.5 (10.0)	0.0026	0.18	0.0007	0.019
FI-SC	35.0 (6.8)	45.6 (4.0)	26.3 (6.1)	26.1 (9.9)	0.016	0.0098	0.073	0.98
FI-NS	28.9 (7.2)	38.8 (4.2)	28.9 (6.4)	18.9 (10.5)	0.15	NA	NA	NA
NF-SC	36.4 (7.0)	56.1 (4.1)	25.7 (6.2)	27.1 (10.2)	0.0001	0.0001	0.011	0.90
NF-NS	38.7 (7.1)	55.6 (4.2)	38.3 (6.4)	32.2 (10.4)	0.024	0.026	0.041	0.62
ME-HF	37.2 (7.6)	57.4 (4.5)	20.2 (6.8)	33.2 (11.2)	<.0001	<.0001	0.048	0.33
ME-LF	37.0 (9.0)	50.8 (5.3)	23.9 (8.1)	44.6 (13.2)	0.025	0.0068	0.67	0.19
NM-HF	34.6 (7.4)	50.8 (4.3)	28.9 (6.6)	24.0 (10.8)	0.0064	0.0071	0.024	0.70
NM-LF	27.9 (6.3)	41.3 (3.7)	20.2 (5.6)	25.6 (9.2)	0.0067	<.0001	0.0006	0.0070
HP-VA	35.7 (8.1)	44.9 (4.8)	25.8 (7.3)	19.4 (11.9)	0.031	0.031	0.051	0.65
HP-NV	38.9 (9.2)	50.6 (5.4)	25.1 (8.2)	29.0 (13.5)	0.027	0.0012	0.14	0.81
LP-VA	32.8 (6.1)	40.2 (3.6)	22.3 (5.4)	17.3 (8.9)	0.0061	0.0076	0.020	0.63
LP-NV	36.5 (7.0)	46.7 (4.1)	30.7 (6.3)	26.3 (10.3)	0.042	0.036	0.070	0.72

Unadjusted implicit wanting scores								
HC-SO	1.0 (3.1)	7.4 (5.2)	-0.4 (5.2)	-4.9 (5.6)	0.26	NA	NA	NA
HC-FL	-6.6 (2.2)	-7.5 (3.8)	-4.5 (3.8)	-8.1 (4.1)	0.78	NA	NA	NA
LC-SO	20.9 (2.8)	22.3 (4.7)	24.4 (4.7)	15.3 (5.0)	0.39	NA	NA	NA
LC-FL	-15.3 (3.5)	-22.3 (5.7)	-19.5 (5.7)	-2.3 (6.1)	0.044	0.94	0.051	0.11
DA-CO	-1.8 (2.9)	3.6 (5.1)	-5.1 (5.0)	-4.0 (5.3)	0.42	NA	NA	NA
DA-NC	15.5 (2.9)	-1.2 (4.4)	20.4 (4.4)	28.3 (4.7)	<.0001	0.0024	<.0001	0.44
ND-CO	-18.8 (2.8)	-12.6 (4.7)	-17.0 (4.6)	-27.6 (5.0)	0.087	NA	NA	NA
ND-NC	5.1 (3.0)	10.2 (5.1)	1.6 (5.1)	3.3 (5.4)	0.46	NA	NA	NA
HF-SA	8.4 (2.8)	8.1 (4.7)	10.0 (4.6)	6.8 (5.3)	0.90	NA	NA	NA
HF-SW	3.2 (3.0)	17.1 (4.8)	-3.1 (4.7)	-5.9 (5.2)	0.0022	0.0095	0.0049	0.92
LF-SA	-19.4 (3.2)	-26.5 (5.3)	-18.2 (5.3)	-12.6 (5.7)	0.21	NA	NA	NA
LF-SW	7.3 (2.4)	4.2 (4.1)	11.2 (4.0)	6.0 (4.4)	0.45	NA	NA	NA
FI-SC	2.1 (2.4)	4.7 (4.1)	0.3 (4.1)	1.1 (4.3)	0.72	NA	NA	NA
FI-NS	-15.2 (2.6)	-21.8 (4.4)	-11.6 (4.5)	-11.6 (4.7)	0.19	NA	NA	NA
NF-SC	-0.1 (2.2)	5.9 (3.7)	-1.9 (3.6)	-4.6 (3.9)	0.13	NA	NA	NA
NF-NS	11.7 (2.4)	7.6 (4.1)	12.7 (4.1)	15.1 (4.3)	0.44	NA	NA	NA
ME-HF	10.4 (2.1)	15.6 (3.6)	10.5 (3.6)	4.1 (3.9)	0.099	NA	NA	NA
ME-LF	7.8 (2.1)	7.2 (3.6)	5.8 (3.6)	11.0 (3.9)	0.60	NA	NA	NA
NM-HF	-0.6 (2.5)	-1.4 (4.2)	2.1 (4.2)	-2.9 (4.6)	0.71	NA	NA	NA
NM-LF	-16.4 (3.0)	-21.4 (5.1)	-18.4 (5.1)	-8.1 (5.4)	0.18	NA	NA	NA
HP-VA	-0.7 (2.4)	2.1 (4.2)	-2.9 (4.2)	-1.3 (4.5)	0.69	NA	NA	NA
HP-NV	9.8 (2.4)	6.6 (4.0)	14.6 (4.0)	7.9 (4.3)	0.33	NA	NA	NA
LP-VA	-8.3 (2.1)	-9.9 (3.5)	-9.5 (3.5)	-5.0 (3.8)	0.59	NA	NA	NA
LP-NV	-0.8 (2.3)	1.2 (4.0)	-2.2 (4.0)	-1.6 (4.2)	0.82	NA	NA	NA
Adjusted implicit wanting scores								
HC-SO	1.0 (9.8)	10.3 (5.8)	1.2 (8.8)	-21.7 (14.4)	0.12	NA	NA	NA
HC-FL	-6.6 (7.3)	-11.5 (7.9)	10.9 (11.6)	22.4 (12.6)	0.16	NA	NA	NA
LC-SO	20.9 (9.1)	21.1 (5.3)	22.4 (8.2)	19.3 (13.4)	0.98	NA	NA	NA
LC-FL	-15.3 (10.7)	-23.0 (6.3)	-26.5 (9.6)	21.7 (15.7)	0.025	0.76	0.010	0.011
DA-CO	-1.8 (9.6)	6.8 (5.6)	-3.5 (8.5)	-11.6 (13.9)	0.35	NA	NA	NA
DA-NC	15.3 (8.6)	-2.9 (5.0)	32.8 (7.6)	38.8 (12.5)	0.0001	0.0002	0.0028	0.68
ND-CO	-18.6 (9.3)	-14.3 (5.5)	-20.0 (8.3)	-31.3 (13.6)	0.49	NA	NA	NA
ND-NC	5.1 (9.9)	10.5 (5.8)	-9.3 (8.8)	4.2 (14.4)	0.18	NA	NA	NA
HF-SA	8.1 (8.6)	11.6 (4.9)	3.5 (7.4)	3.5 (12.2)	0.60	NA	NA	NA

HF-SW	3.2 (9.1)	16.9 (5.2)	-3.0 (7.9)	-7.1 (13.0)	0.052	NA	NA	NA
LF-SA	-19.4 (9.9)	-29.0 (5.8)	-24.6 (8.8)	7.5 (14.5)	0.071	NA	NA	NA
LF-SW	7.3 (7.7)	2.4 (4.5)	24.2 (6.8)	-6.3 (11.1)	0.015	0.0092	0.47	0.022
FI-SC	2.4 (7.6)	4.1 (4.7)	-9.2 (6.7)	-2.7 (11.0)	0.27	NA	NA	NA
FI-NS	-15.0 (8.2)	-20.3 (5.0)	-3.5 (7.2)	-20.7 (11.7)	0.15	NA	NA	NA
NF-SC	-0.1 (7.1)	7.5 (4.4)	-8.0 (6.2)	0.9 (10.3)	0.13	NA	NA	NA
NF-NS	11.5 (7.8)	7.6 (4.7)	20.4 (6.8)	22.5 (11.1)	0.21	NA	NA	NA
ME-HF	10.5 (6.9)	15.0 (4.0)	5.9 (6.1)	2.6 (10.0)	0.31	NA	NA	NA
ME-LF	7.8 (7.3)	7.0 (4.3)	4.2 (6.5)	6.8 (10.6)	0.94	NA	NA	NA
NM-HF	-0.6 (8.3)	0.2 (4.9)	7.1 (7.4)	-7.2 (12.2)	0.57	NA	NA	NA
NM-LF	-16.4 (10.0)	-22.1 (5.8)	-17.2 (8.9)	0.3 (14.6)	0.36	NA	NA	NA
HP-VA	-0.7 (7.5)	0.2 (4.4)	0.7 (6.7)	-7.2 (11.0)	0.80	NA	NA	NA
HP-NV	9.8 (8.0)	6.3 (4.7)	7.0 (7.2)	2.6 (11.8)	0.95	NA	NA	NA
LP-VA	-8.3 (6.8)	-7.4 (4.0)	-11.1 (6.1)	1.6 (10.0)	0.55	NA	NA	NA
LP-NV	-0.8 (7.6)	0.8 (4.4)	3.4 (6.8)	3.1 (11.1)	0.94	NA	NA	NA

Abbreviations: CO, color; DA, dairy; FI, fiber; FL, fluid; HC, high carbohydrate; HF, high fat; HP, high protein; LC, low carbohydrate; LF, low fat; LP, low protein; ME, meat; NC, no color; ND, nondairy; NF, no fiber; NM, no meat; NS, no sauce; NV, no variation; OB: non-operative patients with obesity; SA, savory; SC, sauce; SG: group of patients with a sleeve gastrectomy; RYGB: group of patients with a Roux-en-Y gastric bypass; SO, solid; SW, sweet; VA, variation. Data are presented as mean (SEM) or least squares mean (SEM). *p values are for the differences between patients with OB, SG and RYGB on the basis of ANOVA's unadjusted or adjusted for hunger, fullness, time since the last meal, interaction between group of patients and hunger, interaction between group of patients and fullness, and interaction between group of patients and time since the last meal. §p values are for pairwise comparison using Tukey's post-hoc test.

Appendix 5.A. Nutritional values of the ad-libitum buffet meal.

	Nutritional intakes per 100 g				Energy density	Normal quantity/portion (g)	Nutritional intake per portion				Quantity x3 (g)	Nutritional intake per portion x 3			
	P (g)	F (g)	C (g)	Energy (kcal)			P (g)	L (g)	G (g)	Energy (kcal)		P x3 (g)	L x3 (g)	G x3 (g)	E* x3 (g)
Chocolate cake	5.9	24.0	48.0	431.6	4.3	90.0	5.3	21.6	43.2	388.4	270	15.9	64.8	129.6	1165.3
Dauphine potatoes	3.5	16.0	26.0	262	2.6	150.0	5.3	24.0	39.0	393.0	450	15.8	72.0	117.0	1179.0
Tuna Rice Salad	6.5	16.0	18.2	242.8	2.4	100.0	6.5	16.0	18.2	242.8	300	19.5	48.0	54.6	728.4
Breaded Chicken Fries	12.0	15.0	17.0	251	2.5	100.0	12.0	15.0	17.0	251.0	300	36.0	45.0	51.0	753.0
Comté	26.0	34.0	0.5	412	4.1	30.0	7.8	10.2	0.2	123.6	90	23.4	30.6	0.5	370.8
Country style terrine	15.9	22.3	4.7	283.1	2.8	40.0	6.4	8.9	1.9	113.2	120	19.1	26.8	5.6	339.7
Ground beef	18.5	15.0	0.0	209	2.1	100.0	18.5	15.0	0.0	209.0	300	55.5	45.0	0.0	627.0
Mayonnaise	1.4	80.0	1.2	730.4	7.3	15.0	0.2	12.0	0.2	109.6	45	0.6	36.0	0.5	328.7
Apple compote	0.2	0.2	24.4	100.41	1.0	100.0	0.2	0.2	24.4	100.4	300	0.7	0.6	73.2	301.2
Ketchup	1.2	0.5	23.0	101.3	1.0	200.0	2.4	1.0	46.0	202.6	600	7.2	3.0	138.0	607.8
Bread	9.5	2.0	50.0	255.82	2.6	50.0	4.8	1.0	25.0	127.9	150	14.3	3.0	75.0	383.7
Pasta	4.2	4.5	24.0	153.3	1.5	200.0	8.4	9.0	48.0	306.6	600	25.2	27.0	144.0	919.8
Fromage blanc	7.2	4.5	4.6	87.78	0.9	100.0	7.2	4.5	4.6	87.8	300	21.5	13.5	13.9	263.3
Basil Tomatoes	1.0	3.5	2.2	44.3	0.4	100.0	1.0	3.5	2.2	44.3	300	3.0	10.5	6.6	132.9
Parsley Green Beans	2.1	1.1	3.0	30.3	0.3	150.0	3.2	1.7	4.5	45.5	450	9.5	5.0	13.5	136.4
Colin with Sorrel sauce	13.8	3.3	0.5	86.9	0.9	100.0	13.8	3.3	0.5	86.9	300	41.4	9.9	1.5	260.7
TOTAL							102.8	146.9	274.9	2832.6	TOTAL	308.5	440.6	824.6	8497.8

Abbreviation: P: protein; F: fat; C: carbohydrate. Red boxes indicate fat or carbohydrate content > 15%; green boxes indicate fat or carbohydrate content <5%; the boxes in yellow indicate a protein content above the median of the foods offered at the buffet. Energy density was considered very low when <0.6; low when comprise between 0.6 and 1.5; medium when comprise 1.5 and 4 and high when above 4.

Appendix 5.B. Receipts used for the ad-libitum buffet meal.

Rice salad with tuna (HF-HC)	
Ingredients	Receipt
70g raw basmati rice 50g tuna in oil 25g of egg 20g black olives in oil 40g mayonnaise 0.3g of fine salt (one pinch)	Cook 70g raw rice in 2L of water: - boil water to power 9 - pour the rice, reduce the power to 8 - mix and cook 12 min - pour into a colander and rinse with cold water
Material	Cook 1 hard boiled egg: - Take the egg at refrigerator temperature - boil water to power 9 - put the egg in the water and lower the power to 7 for 10 min - place egg in a bowl of cold water
1 balance 2 pans 1 knife 1 tablespoon 1 white salad bowl or stainless steel pothole stretchable plastic film	In parallel, weigh and mix tuna and mayonnaise. Weigh and cut the black olives in 4. Add them to the mixture. Cut the egg in half and then in 8 pieces. Weigh 25g and add to mixture. Weigh 170g of well-drained cooked rice, adding directly to the mixture. Place the white bowl on the scale to make the tare. Pour the entire mixture into the white bowl and weigh. Cover it with film and set aside in the fridge.

Breaded chicken fries (HF-HC)	
Ingredients	Receipt
12 frozen breaded chicken fries - Carrefour	Preheat the rotary heat oven to 210°C.
Material	Cover the baking sheet with baking paper.
1 oven 1 balance 1 baking sheet 1 white plate baking paper 1 timer aluminum foil 1 gastro bin 1 spatula	Put the chicken fries on the plate. Disperse them homogeneously. Bake 10min in the middle of the oven. Take them out of the oven just before the volunteer arrives for the buffet. Put the gastro tray on the scale to do the tare. Put them in the gastro tray and weigh. Cover with aluminum foil until the volunteer arrives.

Dauphine potatoes (HF-HC)	
Ingredients	Receipt
600g frozen dauphine potatoes - McCain	Preheat the rotary heat oven to 210°C. Cover the baking sheet with baking paper. Place the potatoes on the baking sheet. Divide them evenly. Bake 15 min in the middle of the oven. Take them out of the oven just before the volunteer arrives for the buffet. Put the gastro tray on the scale to do the tare. Put them in the gastro tray and weigh. Cover with aluminum foil until the volunteer arrives.
Material	
1 oven	
1 balance	
1 baking sheet	
1 white plate	
baking paper	
1 timer	
1 gastro bin	
1 spatula	

Chocolate cake (HF-HC)	
Ingredients	Receipt
90g chocolate cake - Savane	Place a white rectangular plate on the scale to make the tare. Cut 3 parts of 30g Cover with plastic film and leave on the buffet.
Material	
1 knife	
1 balance	
1 white plate	

Country terrine (HF-LC)	
Ingredients	Receipt
120g Country style terrine - Le Porc de nos villages	Place the small white plate on the scale to make the tare. Cut 3 slices of 40g. Cover with plastic film Put it in the fridge
Material	
1 knife 1 cutting board stretchable plastic film 1 balance 1 small white plate	

Minced steak (HF-LC)	
Ingredients	Receipt
3 frozen minced steak 100% pure beef 15% fat - Charal 10 g sunflower oil	Weigh 10g of oil in a pan. Heat 4 min to a power of 8. Put 3 frozen chopped steak on skillet 30 sec per face to a power of 6. Turn and wait 4 minutes. Turn and wait 5 minutes. Salt with a pinch of salt. Put the gastro tray on the scale to do the tare. Put them in the gastro tray and weigh. Put the gastro tray in the chafing dish.
Material	
1 non-stick pan 1 baking sheet 1 spatula 1 white plate 1 gastro tray + chafing dish 1 timer 1 balance	

Comté cheese (HF-LC)	
Ingredients	Receipt
90g Comté cheese - Auchan	Place a small white plate on the scale to make the tare. Remove the skin. Weigh 90g of county. Cut into 3 slices of 30g. Cover with plastic film. Set aside in the fridge.
Material	
1 knife	
1 balance	
1 cutting board	
1 small white plate	
stretchable plastic film	

Mayonnaise (HF-LC)	
Ingredients	Receipt
45g mayonnaise fresh egg - Maille	Place a small white bowl on the scale to make the tare. Weigh 45g into a small white bowl. Cover with plastic film. Put it in the fridge.
Material	
1 spoon	
1 balance	
1 small white bowl	

Pasta (LF-HC)	
Ingredients	Receipt
300g fusilli pasta - Panzani 24g sunflower oil 9g salt	Boil 3L of water with 9g of fine salt to power 9. Weigh 300g of raw pasta. Pour them into the boiling water and lower to power 8.
Material	Let cook 6min30. Stir regularly.
1 saucepan 1 baking sheet 1 colander 1 timer 1 gastro tray + chafing dish 1 white plate 1 balance	Drain and rinse. Return to the pan. Add 24g of oil and stir. Put the gastro tray on the scale to do the tare. Put them in the gastro tray and weigh 600g. Put the gastro tray in the chafing dish.

Compote (LF-HC)	
Ingredients	Receipt
300g apple compote - Andros	
Material	Place a white breakfast bowl on the scale to make the tare.
1 spoon 1 balance stretchable plastic film 1 white breakfast bowl	Weigh 300g of compote. Cover with plastic film. Set aside in the fridge.

Ketchup (LF-HC)	
Ingredients	Receipt
45g Ketchup - Amora	Place a small white bowl on the scale to make the tare. Weigh 45g into a small white bowl. Cover with plastic film. Book in the fridge.
Material	
1 spoon 1 balance 1 small white bowl	

Bread (LF-HC)	
Ingredients	Receipt
3 x 50g small baguette bread - Auchan	Preheat the oven to 210°C with rotating heat. Cover the baking sheet with baking paper. Divide among 3 buns. Bake for 15 minutes. Place a white plate on the scale to make the tare. Present the three buns. Weigh.
Material	
1 oven 1 baking sheet 1 balance 1 knife 1 cutting board	

Tomato basil (LF-LC)	
Ingredients	Receipt
300g tomatoes 2g basil 10g olive oil 0.3g salt (1 pinch)	Wash, cut the tomatoes into 4 and then 8 wedges. Put them in a bowl. Weigh the olive oil and basil directly into the salad bowl. Add a pinch of salt and mix.
Material	Put the white bowl on the scale to make the tare.
1 large white bowl 1 stainless steel salad bowl 1 tablespoon 1 balance stretchable plastic film	Pour the entire mixture into the white bowl and weigh. Cover with plastic film. Set aside in the fridge.

Pollock with sorrel (LF-LC)	
Ingredients	Receipt
2.5 frozen Alaska hake fillets - Auchan 10g sunflower oil 1 lemon 50g sorrel sauce	Weigh 10g of oil in a pan. Heat 4 min to power 8. Put 3 frozen hake fillets on the skillet for 5 min to power 6. Turn and wait 4 minutes. Weigh 50g of oseille sauce and 15g of water in a small saucepan.
Material	Heat the sauce 4 min to power 5 min.
1 non-stick pan 1 baking sheet 1 spatula + 1 knife 1 white plate 1 gastro tray + chafing dish 1 saucepan 1 timer 1 balance	Put the gastro tray on the scale to do the tare. Place the hake and pour the sauce over it. Weigh the whole thing. Put the gastro tray in the chafing dish. Place the lemon cut in 4 on the buffet.

Parsley green beans (LF-LC)	
Ingredients	Receipt
600g extra fine frozen green beans - Bonduelle	Boil 3L of water with 9g of fine salt to power 9.
5g butter	Weigh 600g frozen beans into a bowl.
0.5g salt	Pour them into the boiling water.
5g parsley	Cook for 5 minutes on 9. Stir regularly.
Material	Drain out the beans.
1 saucepan	Weigh 5g of butter, 2g of parsley and a pinch of salt in a skillet.
1 baking sheet	Heat the pan to power 6 until the butter melts.
1 colander	Sauté the beans for 2 min, mixing well.
1 timer	Put the gastro tray on the scale to do the tare.
1 gastro tray + chafing dish	Put them in the gastro tray and weigh 450g.
1 white plate	Put the gastro tray in the chafing dish.
1 balance	

Cottage cheese (LF-LC)	
Ingredients	Receipt
300g cottage cheese 3% fat - Danone	
Material	Place a white breakfast bowl on the scale to make the tare.
1 spoon	Weigh 300g of cottage cheese.
1 balance	Cover with plastic film.
stretchable plastic film	Set aside in the fridge.
1 white breakfast bowl	

Appendix 5.C. Map of the domestic kitchens of Institut Paul Bocuse

