



Food Preferences and Obesity

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Obesity is a multifactorial disease with several potential causes that remain incompletely understood. Recent changes in the environment, which has become increasingly obesogenic, have been found to interact with individual factors. Evidence of the role of taste responsiveness and food preference in obesity has been reported, pointing to a lower taste sensitivity and a higher preference and intake of fat and, to a lesser extent, sweet foods in obese people. Studies in the last decades have also suggested that individual differences in the neurophysiology of food reward may lead to overeating, contributing to obesity. However, further studies are needed to confirm these findings. In fact, only a limited number of studies has been conducted on large samples, and several studies were conducted only on women. Larger balanced studies in terms of sex/gender and age are required in order to control the confounding effect of these variables. As many factors are intertwined in obesity, a multidisciplinary approach is needed. This will allow a better understanding of taste alteration and food behaviours in obese people in order to design more effective strategies to promote healthier eating and to prevent obesity and the related chronic disease risks.

Keywords: Obesity; Food preferences; Taste; Body mass index; Propylthiouracil; Reward

INTRODUCTION

Obesity has nearly tripled worldwide since 1975 [1]. Since then, the availability of food has increased tremendously, particularly processed foods that are high in sweet, fat, and salt. Obesity is a multifactorial disease with several potential causes, but the impact of recent environmental changes, including an overabundance of palatable food and little opportunity to work off the extra energy, appears to be undeniable [2], even if these changes are not sufficient to explain the pandemic [3]. Obesity, which is defined as abnormal or excessive fat accumulation that may impair health [1], is a major risk factor for noncommunicable diseases such as cardiovascular diseases, diabetes, musculoskeletal disorders and some cancers. Furthermore, childhood obesity is associated with a higher risk of obesity, premature death, and

disability in adulthood. According to the World Health Organization, children in low- and middle-income countries are more vulnerable to inadequate pre-natal, infant, and young child nutrition. These children are exposed to high-fat, high-sugar, high-salt, energy-dense, and micronutrient-poor foods, which tend to be cheaper but also lower in nutrient quality. These dietary patterns, in conjunction with lower levels of physical activity, have resulted in sharp increases in childhood obesity even as undernutrition issues have remained unsolved [4].

In addition to economic and environmental factors, many other factors are well known to influence food choices and preferences, such as physiological and neurophysiological factors, sensory acuity, psychological traits, and cultural and social aspects [5,6]. Since not everyone who lives in the current obesogenic environment develops obesity, individual-level risk fac-

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tors should be identified in order to develop effective strategies to prevent and treat obesity more effectively.

This paper will review the main sensory, psychological, and physiological factors that influence food choices, contribute to shape food preferences, and have been found to be associated with obesity. Although the literature on the topic is quite wide, many studies have been conducted on a small sample. Table 1 presents studies conducted among more than 40 obese individuals, while studies with smaller samples are also commented upon in this manuscript.

OBESITY AND FOOD PREFERENCES

In simple terms, obesity is a consequence of an energy imbalance, when energy intake exceeds energy expenditure over a considerable period [1]. High-fat and energy-dense diets have been found to be strongly associated with the increased prevalence of obesity worldwide [7]. A higher liking or preference for fats in obese people was reported in several studies [8-18]. This preference for fatty foods seems to be more of a cause of obesity than an effect, as it was also found that children from obese/overweight families had a higher preference for fatty foods than children of normal-weight parents, even if they were not obese [19]. Fatty foods are innately liked, which may be due to multiple reasons, including their orosensory properties and post-ingestive and metabolic effects [12,17,20,21]. Fat is a concentrated source of energy with rewarding post-ingestive effects [20]. Sweet and salty high-fat foods have been proven to be particularly palatable, and gender differences have been reported, with obese women tending to prefer sweet-fat foods [22,23] and obese men tending to prefer savoury-fat foods [22].

Based on a hypothesis of a sweet tooth in obese people, preferences for sweet foods in this group are expected and have been widely investigated. However, the results are mixed. Several studies showed that liking of foods did not substantially differ between obese and non-obese individuals, and reported that obese individuals liked sweetness to the same extent, or even less strongly, than non-obese individuals [24-28]. However, more recent studies have found evidence that obese people like sweet foods more than lean individuals [11,29]. Furthermore, it is well known that even if liking for sweetness is innate, individuals differ in their liking for sweetness. Individuals have different optima of sweetness, and there are individuals for whom an increase in sweetness is associated with an increase in preference. On the contrary, for other individuals, preference decreases as sweetness increases, or it increases up to a certain intensity

and then decreases [30,31]. A few studies examined the relationship between the sweet-liking phenotype and body mass index (BMI), with mixed results. While Garneau et al. [32] did not find any association in a sample of children and young adults, Iatrudi et al. [33] reported that sweet likers had a higher BMI and fat-free mass but only in the older groups. Based on these findings, the authors suggest that exposure to an obesogenic environment contributes to an increase in sweet-liking.

Sensory-specific satiety, namely the decline of the pleasantness/desire to eat a particular food after eating that food compared to the decline in pleasantness of uneaten foods [34], has been hypothesized to be related to obesity, both positively and negatively [35]. There is some evidence that obese people have lower levels of sensory-specific satiety, which may explain their attitude towards overeating [36,37], but results are inconclusive [38]. However research on sensory-specific satiety has suggested that a reduction in dietary variety of highly palatable, energy-dense foods may be useful in the treatment and prevention of obesity, as it reduces food intake [35].

OBESITY AND TASTE ACUITY

Individuals differ in their taste acuity, which may influence food acceptability and eating behaviours [39,40]. It is well known that individuals differ greatly in their responsiveness to 6-n-propylthiouracil (PROP), and that a heightened response to this compound is associated to a heightened response to bitterness as well as to other sensory properties, such as sweetness, pungency, and even fat [41-43]. This may explain the relationship that has been found between responsiveness to PROP and food preferences, intake, and BMI, even if the results are mixed [39,44]. An inverse relationship between PROP responsiveness and BMI was found in several studies both in the general population [45-47] and in obese individuals [48], but other studies reported no relationship [49,50]. These mixed results may be explained by the many variables that influence the relationship between PROP taste sensitivity and BMI, such as genetic factors, ethnicity, oestrogenic phase, variations in the endocannabinoid system, age, sex, and cognitive factors [44].

Individuals differ greatly also in the density of fungiform papillae in the tongue, which host the taste receptors. A lower density has been associated with heightened sensitivity, but studies on larger samples did not confirm this association [51,52] and rather suggested that other factors play a role apart from the number of papillae, such as taste pore density [53,54]. Recently, some studies reported that obese children [55] and adults [56]

Table 1. Studies on Food Preferences, Taste Responsiveness, and Personality Traits Affecting Eating Behaviours in Obesity (Only Studies with >40 Obese Subjects Are Reported). References, Study Design, Number of Subjects, Gender, Age, BMI, Main Outcomes and the Presence of Sensory Tests (Which Included a Tasting of Solutions, Foods or Beverages) Are Reported for Each Study

Study	Study design	No. of subjects	Age, yr	Gender	BMI, kg/m ²	Outcome: food preferences and/or intake	Outcome: taste responsiveness	Outcome: personality traits and eating behaviours	Including sensory tests
Mendoza et al. (2007) [7]	General population	1,454 Obese 8,233 Non-obese	>20	825 Women (16.9% of women) 629 Men (13.1% of men)	≥30	Dietary energy density was associated with a higher BMI in women and trended toward a significant association in men.	-	-	-
Dressler et al. (2013) [8]		54 Overweight/obese 29 Lean/normal		83 Women (100%)	>25 <25	Liking for spreadable fats, several types of breads, and other products was higher in overweight/obese individuals.	-	-	-
Lampure et al. (2014) [9]	General population	37,181 (<i>n</i> obese not reported)	44.4 Mean age 51.9 Mean age men	28,504 Women (<i>n</i> obese not reported)	-	Obese women and men were found to have a strong liking for the fat-and-sweet sensations.	-	-	-
Lampure et al. (2016) [10]	General population	664 Obese 24,112 Non-obese	-	Women (75.8%) Women (75.1%)	-	Liking for fat and for salt was higher in obese than in non-obese individuals.	-	-	-
Bartoshuk et al. (2006) [11]	Attendees at lectures	305 Obese 144 Underweight	-	-	30 (mean) <18.5 (mean)	Sweet foods and fat food liking increased with BMI and was higher in obese than underweight individuals.	-	-	Yes
	Attendees at lectures	3,740 (<i>n</i> obese not reported)	-	-	<50	The higher the BMI, the lower the perceived sweetness.	-	-	Yes
Proserpio et al. (2017) [18]	Obese vs. control group	46 Obese 45 Non-obese	47.86 (mean) 41.64 (mean)	26 Women (56.5%) 21 Women (46.6%)	37.53 (mean) 22.03 (mean)	Liking of samples with the strongest butter aroma was higher in obese individuals.	Sweetness and vanilla flavour of the samples with the strongest butter aroma were perceived as more intense by obese (particularly women).	-	Yes
Drewnowski et al. (1992) [22]	Obese patients	475 Obese	-	386 Women (81.2%) 89 Men	32.9 36.4	Obese men listed mainly protein/fat sources among their favourite foods, while obese women listed mainly carbohydrate/fat sources.	-	-	-

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Table 1. Continued

Study	Study design	No. of subjects	Age, yr	Gender	BMI, kg/m ²	Outcome: food preferences and/or intake	Outcome: taste responsiveness	Outcome: personality traits and eating behaviours	Including sensory tests
Drewnowski et al. (1991) [28]	Community-based sample	61 Obese 21 Lean	20–45	29 Women (47.5%) 16 Women (76.2%)	-	Obese subjects characterized by large weight fluctuations showed elevated preferences for sugar and fat mixtures compared with the stable subgroup, while early age at onset of obesity (<10 years) had no significant effects on taste preferences. No differences in preferences for sugar solutions were reported.	No differences in perceptions for sugar solutions were reported.	-	Yes
Spinelli et al. (2021) [50]	General population	166 Obese 2,141 Non-obese	43.88 37.21	86 Women (51.8%) 1,270 Women (59.3%)	33.55 23.05	No association between PROP and BMI in obese and non-obese individuals.	-	Sensitivity to disgust predicted BMI only indirectly (mediated by restrained eating) in non-obese individuals. No association in obese individuals was reported.	Yes
Proserpio et al. (2016) [56]	Obese vs. control group	51 Obese 52 Non-obese	42.00 (mean) 38.38 (mean)	28 Women (54.9%) 27 Women (51.9%)	34.08 21.57	Liking for high-energy dense products was higher in obese than in normal-weight subjects.	Obese subjects showed higher threshold values (= reduced sensitivity) for basic tastes and fat and a reduced number of fungiform papillae compared with non-obese individuals.	No difference in neophobia was reported between obese and non-obese individuals.	Yes
Davis et al. (2004) [72]	Obese vs. control group	40 Obese 108 Non-obese	33.3	148 Women (100%)	>30 <30	-	-	Overweight women were significantly more sensitive to reward than those of normal weight, but more anhedonic than the overweight women.	Yes
Proserpio et al. (2018) [92]	Obese vs. control group	45 Obese 40 Non-obese	43.46 Mean age for women 52.4 Mean age for men	25 Women (55.5%) 21 Women (52.5%)	37.57 (mean) 22.67 (mean)	-	PROP responsiveness and fungiform papillae number were lower in obese men (vs. obese women and non-obese).	Obese individuals were more neophobic than non-obese individuals.	Yes

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Table 1. Continued

Study	Study design	No. of subjects	Age, yr	Gender	BMI, kg/m ²	Outcome: food preferences and/or intake	Outcome: taste responsiveness	Outcome: personality traits and eating behaviours	Including sensory tests
Elfhag et al. (2006) [94]	Obese patients	60 Obese	43.5 Mean age 20–65	44 Women (73.3%)	40.1	-	-	Strong sweet taste was associated with a neurotic personality and strong fat preference with lower levels of restrained eating.	
Interventions									
Altun et al. (2016) [61]	Patients undergoing laparoscopic sleeve gastrectomy (LSG)	52 Obese	19–60	30 Women (57.7%)	32.5–63.0 before surgery	-	Significant improvement in taste acuity to sweet, sour, salty, and bitter tastants in morbidly obese patients after LSG during a follow-up period of 3 months.	-	Yes
Holinski et al. (2015) [62]	Patients undergoing laparoscopic Roux-en-Y gastric bypass, sleeve gastrectomy, or adjustable or adjustable gastric banding	44 Obese 23 Lean (control)	47.1 (obese) 39.5 (lean)	29 Women (65.9%) 15 Women (65.2%)	BMI >40 or >35 with relevant co-morbidities	About 22.7% of morbidly obese patients were shown to have limited in gustatory and olfactory function; six months after surgery, olfactory and gustatory function was not different when compared to healthy controls.			Yes
Andriessen et al. (2018) [64]	Intervention (low calorie diet)	123 Overweight and obese	18–65	75 Women (60.9%)	27–45 (range)	Decreased preference for high-carbohydrate, high-fat, and low-energy products after the intervention	-	-	
Van Vuuren et al. (2017) [67]	Patients undergoing laparoscopic sleeve gastrectomy (LSG)	106 Obese	42 (mean)	81% Women	Mean BMI before surgery 44	Decreased enjoyment for sweet and fatty foods and decreased desire for fatty and sweet after bariatric surgery (after 4/6 weeks and after 6/8 months); Increase of intensity of sweet and fatty after the LSG (after 4/6 weeks and after 6/8 months).	-	-	

BMI, body mass index; PROP, 6-n-propylthiouracil.

have a lower number of fungiform papillae than normal-weight individuals. In line with these findings, in a longitudinal study, a decrease in abundance of fungiform papillae with increasing adiposity was observed [57]. Furthermore, other authors [58], while not finding differences in the density of papillae, showed that obesity is associated with altered gene expression in taste buds, reporting a consistent reduction in the expression of taste-related genes (in particular reduced type II taste cell genes) in the obese group compared to the lean group. In addition, some studies pointed out an alteration in taste responsiveness in obese individuals, reporting that obese people experience reduced sweetness [11,29], umami [59], and a reduced taste responsiveness in general [56].

Taken together, these results point towards reduced taste sensitivity in obese individuals; however, this reduced taste sensitivity was found to be reversible with weight loss due to surgery. In fact studies of calorie restriction-induced weight loss and bariatric surgery in humans have suggested that taste alterations and food preferences are reversible and consequently may represent secondary effects of obesity [60-64]. However, the possibility cannot be ruled out that other factors than weight loss *per se*, such as reward value and gut-brain-interactions, drive the observed modifications in taste perception [65]. Furthermore, some studies that considered obese individuals after bariatric surgery also reported a lower intake and liking of high-fat and sweet foods [66]. Post-gastric bypass patients reached satiety much faster than was the case before surgery, and the reason for reduced food intake was a lack of “desire” [67]. This may indicate that obesity surgery—and specifically gastric bypass—not only reduces the amount that people eat, but also changes their perception of food and thus their eating behaviours, suggesting the concept of “behaviour surgery” [68]. However, the effects of obesity surgery on the hedonics of taste remain largely unexplored.

BEHIND EATING BEHAVIOURS: FOOD REWARD

Studies in the last decades have also suggested that individual differences in the neurophysiology of food reward may lead to overeating, thus contributing to obesity [69].

A prominent view in the last decades to explain obesity has been the reward deficiency hypothesis [70,71]. This theory postulated that obese individuals find foods less rewarding than other individuals, and consequently eat more foods to accumulate rewarding experiences and so make up their reward defi-

ciency. Consistent with this view, obese women were found to be more anhedonic than overweight women—that is, they were characterized by a diminished ability to experience pleasure from natural reinforcers such as food [72]. An alternative view suggested that the attenuated brain responses to energy-dense foods observed in obese reflect weaker learning signals, rather than a reward deficiency and thus anhedonia [73]. However, emerging evidence suggests that some cases of obesity may reflect an incentive-sensitization brain signature of cue hyper-reactivity, causing excessive “wanting” to eat [74]. According to this view, “liking,” which refers to the hedonic impact of a pleasant reward, is distinguished from “wanting,” which is defined as the psychological process of incentive salience generated in the form of cue-triggered motivation [74]. Some authors [75,76], but not all [77], have suggested that obesity may be associated with an increased motivation for food consumption (“wanting”), without necessarily any greater explicit hedonic response or pleasure being derived from the orosensory experience of eating (“liking”). Therefore, overeating in obesity may reflect more responsiveness to non-homeostatic stimuli (i.e., driven by environmental and cognitive factors), rather than a defect or failure of endogenous homeostatic systems involved in energy balance [75]. According to the incentive-sensitization theory, obese individuals may be especially vulnerable to developing neural sensitization of dopamine-related mesocorticolimbic systems of “wanting.” This would lead to excessive “wanting” to eat, typically triggered by palatable food cues, which could become especially exacerbated in moments of stress or emotional arousal that heighten mesolimbic reactivity [74]. Evidence supporting this explanation comes from neuroimaging studies of obese individuals that have reported a sensitization-type brain activation signature to food cues that is remarkably similar to the signature of people who suffer from drug addiction to drug cues [78-80]. In line with these results, some studies found that obese individuals had an increased attentional bias for food stimuli [81]. However, current results on attentional bias for food cues in obese participants are very mixed, as there is empirical evidence for approach, avoidance, and approach-avoidance attention processes in obese versus healthy weight participants when viewing food cues; thus, further studies are required [82].

PERSONALITY TRAITS AND ATTITUDES AND OBESITY

Attitudes [83], and more recently also personality traits [84-86],

have been found to affect food preferences and intake. Individual differences exist in the level to which people experience the emotion of disgust, and higher levels of sensitivity to core disgust have been associated with eating disorders, such as anorexia nervosa, binge eating, and bulimia [87,88]. Furthermore, some studies indicated that defects in experiencing disgust may contribute to overweight and obesity by allowing the overconsumption of food [89-91]. More precisely, Watkins et al. [89] found that lean and obese individuals did not significantly differ in the degree to which they were prone to experiencing disgust (propensity), but obese individuals were less likely to appraise the experience of disgust as negative (sensitivity), which may contribute to their failure to reduce caloric consumption [89]. Furthermore, the authors reported reduced insula activation in obese individuals. These findings raise the possibility that lower disgust sensitivity and reduced insula activation may contribute to the tendency of obese individuals to overeat. In addition, food neophobia, defined as the reluctance to eat novel and unfamiliar foods, was found to be higher in obese individuals and those with a higher BMI [92,93]. Furthermore, a strong sweet taste preference was associated with more neurotic personality traits, in particular lack of assertiveness and embitterment, in obese individuals [94].

CONCLUSIONS

The psychological and physiological mechanisms responsible for obesity are incompletely understood. Evidence of the role of taste responsiveness and food preferences in obesity has been reported, but further studies are needed to confirm previous findings on larger and more balanced (in terms of gender and age) samples. In fact, studies on large samples are limited, and most studies have been characterized by an overrepresentation of women. Balancing for gender and age is extremely important as it is well known that these factors strongly affect taste responsiveness, food preferences, and personality traits, and they may therefore act as confounding factors. Furthermore, sensory tests (both to measure taste responsiveness and liking) have only been used in a limited manner, and when they were used, a variety of different scales and methods were adopted; as a result, it is difficult to directly compare results.

Although there is evidence that obese individuals live in different orosensory worlds than do non-obese individuals, it is unclear how this is associated with food preferences, enjoyment, and reward. As many different factors are intertwined in obesity, a multidisciplinary approach is needed. This will allow

a better understanding of taste alterations and food behaviours in obese individuals in order to design more effective strategies to promote healthier eating and to prevent obesity and the related chronic disease risks.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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