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Salivary habituation to food stimuli in successful weight loss maintainers, obese and normal-weight adults

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Abstract

Objective—Research shows that slower habituation of salivary responses to food stimuli is related to greater energy intake and that obese (Ob) individuals habituate slower than those of normal weight (NW). No study has examined habituation rates in weight loss maintainers (WLMs) who have reduced from obese to normal weight, relative to those who are Ob or NW.

Design—Salivation to two baseline water trials and 10 lemon-flavored lollipop trials were studied in 14 WLMs, 15 Ob and 18 NW individuals comparable in age, gender and ethnicity. Linear mixed models were used to compare WLMs with Ob and NW groups.

Results—Salivation in the WLM and NW groups decreased significantly (for both $P < 0.005$) across trials, indicative of habituation. Salivary responses in the Ob group did not habituate ($P = 0.46$). When compared with Ob group, WLMs showed a quicker reduction in salivation ($P < 0.05$). WLM and NW groups did not differ in habituation rate ($P = 0.49$).

Conclusions—WLMs have habituation rates that are comparable to NW individuals without previous history of obesity, and show quicker habituation than those who are currently obese. These results suggest that physiological responses to food may ‘normalize’ with successful weight loss maintenance.

Keywords

weight loss maintenance; habituation; salivation; eating behavior

Introduction

Successful control of body weight depends on effectively regulating eating, which is influenced by how quickly satiation within a meal occurs.^{1–3} One factor that may influence satiation is the rate of habituation of physiological responses, such as salivation, to repeated

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presentations of a food.^{4,5} Habituation is defined as a decrease in the rate of responding to repeated presentations of the same stimulus, followed by an increase in responding to a new stimulus. Recovery of responding indicates that habituation, rather than other factors such as neural fatigue, is responsible for decreased responding.⁵ Individuals who show quicker rates of salivary habituation consume fewer calories than those who show slower rates,⁶ suggesting that habituation is a mechanism for cessation of eating.

Previous research shows that obese individuals (Ob) show slower rates of salivary habituation than normal-weight individuals (NW).^{10,11} However, no study has examined salivary habituation in weight loss maintainers (WLMs) who have reduced from obese to normal weight. An important question is whether these individuals continue to habituate slowly as observed in Ob individuals, and thus may be predisposed to overeating and weight regain, or alternatively whether after weight reduction their habituation patterns become more similar to those of NW individuals. Recent studies comparing weight control behaviors performed by WLMs and NW individuals indicate that the former have to work harder to maintain their body weight,^{12,13} suggesting potential compensation for remaining physiological vulnerability to obesity. The purpose of this study was to examine salivary responses to repeated presentations of a food stimulus in WLMs, relative to those in Ob and always NW individuals.

Methods

Participants

Male and female participants between 25 and 65 years of age were categorized into groups based on reported lifetime weight history. WLMs ($n=17$) lost and maintained 30 lb from maximum weight for 3 years and reduced from lifetime maximum body mass index (BMI) of 30 to current BMI of >18.5 and <24.9 . Ob individuals ($n=16$) had a BMI of ≥ 30 . NW individuals ($n=19$) had lifetime maximum BMI of >18.5 and <24.9 . All participants reported being weight stable for 2 years. NW individuals and WLMs maintained their weight within ± 10 lb and Ob individuals stayed within ± 15 lb.

Procedure

Participants were recruited as part of a larger study examining brain responses to food stimuli using functional magnetic resonance imaging. Exclusionary criteria included taking medications that could influence weight loss or salivation (for example, antidepressants) and binge eating. Eligible individuals through phone screening were scheduled for testing at the laboratory. Participants refrained from food 4h before testing, reporting an average pre-experimental food deprivation of 7.9 ± 4.0 h, with no difference between groups ($P=0.25$). Upon arrival, current weight status was confirmed through height and weight measurement. Testing was conducted in a quiet environment with participants positioned supine on an exam table to simulate experimental conditions used in the subsequent functional magnetic resonance imaging study. However, no functional magnetic resonance imaging measures were conducted during these experimental procedures. The protocol was approved by the Miriam Hospital Institutional Review Board, Providence, RI, USA.

Measurement

The Strongin-Hinsie-Peck technique¹⁴ was used for measuring salivation. This method involves absorption of saliva by three rolls of cotton; one roll is placed horizontally under the tongue and the other rolls are positioned on each side of the mouth between the lower gum and cheek. Salivation is determined by weighing the rolls before and after the collection period.

After inserting the cotton rolls, participants were either given a syringe containing water that they deposited on the middle of their tongue, or a lollipop that they held stationary in their mouth during 1-min periods of saliva collection. The salivation measure consisted of two baseline trials of a 0.05-ml water stimulus, 10 trials of a lemon lollipop (habituating stimulus) and two trials of a green apple lollipop (novel stimulus). A 1-min interval separated each trial. Following each trial, participants removed the rolls, placed them in the bag and gave the bag to the experimenter. The bags were weighed to 0.01 g (Ohaus Dialogram balance, Florham PK, NJ) immediately after the experiment. Trial blocks were computed by averaging values across blocks of two trials. Changes in salivation across the lemon lollipop (trial blocks 1–5) and green apple lollipop (trial block 6) trial blocks were computed by subtracting values from baseline.

Analytic plan

Data were analyzed using the Statistical Package for the Social Sciences 14.0 (SPSS, Inc., Chicago, IL, USA). One-way analysis of variance and chi-square tests were used to compare the groups on demographics and weight. Given that sensitization or increased salivation to the habituating stimulus is necessary for habituation to occur, 5 (1 Ob, 1 NW and 3 WLMs) out of 52 participants who showed no change or decrease in salivation to the habituating stimulus were excluded from analyses, resulting in a final sample of 47 individuals (18 NW, 15 Ob and 14 WLMs). The proportion of participants excluded from each group did not differ ($P = 0.39$). Salivary changes within groups and comparisons of WLMs with Ob and NW groups were analyzed using linear mixed models with the auto regressive (1) covariance structure. Salivation data are presented as mean $\pm$ s.e.m. (g).

Results

Participant characteristics are presented in Table 1. The groups did not differ by age, gender and ethnicity. By design, the groups differed in current and lifetime maximum BMI.

Average baseline salivation for the three groups (Table 2) was not significantly different ($P = 0.15$). Group differences in salivation across blocked trials of the lemon lollipop stimulus are presented in Figure 1. Looking first at a total change in salivation in each group separately (Table 2), WLM and NW groups showed a significant decrease in salivation across blocked trials (for both, $P < 0.005$), whereas reduction in salivation among Ob group was not significant ($P > 0.40$).

Subsequent analyses showed a greater reduction in salivary responses for WLM when compared with the Ob group (group $\times$ trial block interaction; $P = 0.03$). WLMs did not differ from the NW group (group $\times$ trial block interaction; $P = 0.49$).

All three groups, as shown in Table 2, showed a significant increase in salivation to the novel green apple lollipop stimulus (for all, $P < 0.001$). Magnitude of salivation increase among WLMs was not different from the NW ($P > 0.70$) or Ob ($P > 0.90$) groups.

Discussion

This study is the first to examine salivary habituation to repeated presentations of food stimuli in WLMs. WLMs who reduced from obese to normal weight showed rates of habituation that were similar to NW individuals with no previous history of obesity and more rapid than Ob individuals. These findings have implications for broadening our understanding of successful weight loss and maintenance.

Although previous research suggests that efforts to maintain reduced body weight are opposed by physiological adaptations that favor increased food seeking and weight regain,^{15–17} our findings suggest that slower habituation of physiological responses to food observed in Ob individuals may be ‘normalized’ through weight loss. A faster rate of habituation is related to quicker satiation, which should promote lower energy intake,^{4–6} assisting efforts of WLMs to remain at normal body weight. If habituation patterns can be ‘normalized’ through weight loss, research is needed to determine whether weight loss magnitude, duration of weight loss maintenance and/or absolute BMI is the most important factor. Alternatively, it is possible that, before losing weight, the WLMs may have habituated to food cues similar to NW individuals, and that a more rapid pattern of habituation in an obese individual may be a marker for ability to achieve successful weight loss maintenance.

Certain limitations accompany our findings. Salivation may have been affected by participants being positioned supine to simulate conditions in a functional magnetic resonance imaging machine. Weight history and compliance with the food restriction requirement was based on self-report. Participants were predominantly Caucasian and female, limiting generalizability to more diverse samples. Finally, although not significantly different from the other groups, Ob participants showed a smaller sensitization response to the lemon lollipop stimulus. This may relate to differences in taste processing between Ob and NW individuals; for example, Ob individuals perceive sweet tastes less but prefer them more than those who are NW.¹⁸ Additional research using different food cues and measures of palatability is needed to replicate and extend our findings.

In summary, this study suggests that the pattern of physiological responding to food stimuli in WLMs who have reduced from obese to normal weight is more similar to that of NW without previous history of obesity and less similar to Ob. These findings contrast with previous research suggesting that WLMs may have continued biological vulnerability to weight regain and obesity.^{12,13,15–17} Future research in which habituation rates are measured longitudinally is required to better understand the relationship between weight change and physiological responses to eating.

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Figure 1.

Change in salivary response to repeated presentations of a lemon-flavored lollipop stimulus (trial blocks 1–5) in weight loss maintainers (WLM), normal-weight (NW) and obese (Ob) participants across blocks of two trials.

Characteristics of participants in weight loss maintainer (WLM), obese (Ob) and normal-weight (NW) groups (mean±s.d.)

Table 1

	WLM (n=14)	Ob (n=15)	NW (n=18)	Overall P-value ^a	Group comparisons	P-value ^b
Age (years)	49.0 ± 11.4	48.8 ± 7.5	43.6 ± 8.1	0.17		
Sex (%)						
Female	88.2	87.5	89.5			
Male	11.8	12.5	10.5	0.98		
Race (%)						
Caucasian	94.1	81.2	100			
African American	5.9	12.5	0			
Mixed race	0.0	6.3	0	0.29		
BMI (kg m ⁻²)	23.7 ± 1.6	34.5 ± 3.8	21.6 ± 2.0	0.0001	NW, Ob	0.0001
					NW, WLM	0.02
					Ob, WLM	0.0001
Lifetime maximum BMI (kg m ⁻²)	33.1 ± 3.0	35.8 ± 3.8	22.8 ± 2.2	0.0001	NW, Ob	0.0001
					NW, WLM	0.0001
					Ob, WLM	0.053

^a Analyses conducted using chi-square analyses for categorical data and one-way analysis of variance for continuous data.^b *Post hoc* comparisons conducted using Bonferroni's test.

Within-group comparisons in salivary responses to a baseline water stimulus, repeated presentations of a habituating lemon-flavored lollipop stimulus and a novel green apple-flavored lollipop stimulus in weight loss maintainers (WLM), normal-weight (NW) and obese (Ob) participants

Table 2

	WLM (<i>n</i> =14)		Ob (<i>n</i> =15)		NW (<i>n</i> =18)	
	M ± s.e.m.	<i>P</i> -value	M ± s.e.m.	<i>P</i> -value	M ± s.e.m.	<i>P</i> -value
Baseline salivation to water stimulus at block 0	1.3 ± 0.2		1.1 ± 0.2		1.7 ± 0.2	
Change in salivation to habituating stimulus from block 1 to block 5	-1.2 ± 0.3	0.002	-0.3 ± 0.2	0.46	-0.8 ± 0.3	0.001
Change in salivation to novel stimulus from block 5 to block 6	+1.9 ± 0.3	0.001	+1.9 ± 0.4	0.001	+2.1 ± 0.4	0.001

Note that the significance tests were conducted on adjusted within-group change scores from the linear mixed model using Bonferroni's correction.