Cigarette smoking and obesity are associated with decreased fat perception in women

Marta Yanina Pepino, PhD[1] and **Julie A. Mennella, PhD**[2]

[1]Center for Human Nutrition and Atkins Center of Excellence in Obesity Medicine, Washington University School of Medicine, St. Louis, MO 63110

[2]Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104-3308

Abstract

Objective—Smoking and obesity are independently associated with high consumption of high-fat foods in women. We tested whether the co-occurrence of smoking and obesity associates with reduced oral fat perception.

Design and Methods—Four groups of women (14 obese smokers, 11 obese never-smokers, 10 normal-weight smokers, 12 normal-weight never-smokers) rated vanilla puddings that varied in fat content for perceived intensity of creaminess and sweetness, using the general Labeled Magnitude Scale (gLMS), and degree of pleasantness, using the hedonic gLMS. To determine the role of retronasal smell, subjects rated puddings with and without noseclips.

Results—For all groups, creaminess grew with increasing fat concentrations; puddings with any amount of fat were perceived as sweeter than fat-free pudding, and sweetness was enhanced when tasted without noseclips. Overall, obese smokers perceived less creaminess, sweetness, and pleasure while tasting the puddings than did the other three groups (all P-values<0.02).

Conclusion—The ability to perceive fat and sweetness in and derive pleasure from foods is particularly compromised in obese women who smoke, which could contribute to excess calorie intake in this population already at high risk for cardiovascular and metabolic disease. Retronasal olfaction appears not to contribute to blunted flavor perception observed in obese smokers.

Keywords

Smoking; Obesity; Taste; Fat Intake; Dietary; Women

Introduction

Women smoke for different reasons than men.[1] Women are less likely to quit smoking than men, and when they do, they are more likely to relapse, because of concerns about post-cessation weight gain [1] and beliefs that smoking aids in weight loss. [2] However, there is

Corresponding author: M. Yanina Pepino. Center for Human Nutrition, Washington University School of Medicine, 660 South Euclid Avenue St. Louis, MO 63110, Telephone: 314 362 8113, Fax: 314 362 8230, ypepino@dom.wustl.edu.

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little evidence to suggest that, in the long term, smoking is an efficient method to control body weight. On the contrary, smokers do not gain less body weight over time than do nonsmokers, [3] and cigarette smoking is associated with increased central obesity; [4,5] a better predictor of morbidity and mortality than body mass index. [6]

In addition, data from several epidemiological studies show that people who smoke have unhealthier dietary habits than do people who do not smoke.[7, 8] Smokers living in many different cultures eat more fatty foods than do nonsmokers, even after controlling for important socio-demographic factors and despite the extreme variability in food availability and cultural food habits throughout the world. [7,8] Complementing this finding, we found that women who smoke crave fatty food more often than do women who don't smoke [9,10] and that cravings for cigarettes and cravings for food are related such that the more women are craving cigarettes, the more they are craving carbohydrates and high-fat foods. [9]

Like smokers, obese individuals crave high-fat foods more frequently, [10, 11] prefer foods with higher fat content, [12, 13] and consume more fat than do lean individuals. [14] Recent data from both animal and human studies reveal that the consumption of a high-fat diet is associated with a decreased oral sensitivity to detect fatty acids. [15, 16] This finding explains, at least in part, the observation that obese subjects have reduced oral fat perception compared with lean subjects, [17–19] a gustatory adaptation that could further contribute to excess fat intake among obese individuals. Interestingly, the few studies that have examined whether smoking status affects oral fat perception found no differences between smokers and nonsmokers. [19, 20]

The current experimental study builds upon these findings and was designed to test the hypotheses that the perception of fat in food is further reduced by the co-occurrence of obesity and smoking. Accordingly, we evaluated sensory and hedonic components of fat perception in a food matrix (pudding) in four groups of women: obese smokers, obese never-smokers, lean smokers, and lean never-smokers. Because smokers often exhibit deficits in odor sensitivity, [21] we explored whether differences, if any, in the perception and preferences of fatty foods between groups were explained, in part, by olfactory cues perceived retronasally.

Methods and Procedures

Subjects

The study population consisted of four groups of women (N=47), all between 21 and 41 years of age. Subjects were recruited from advertisements and flyers in local newspapers. Exclusion criteria included diabetes, pregnancy, lactation, history of chronic rhinitis or food allergies, being a former smoker, and the use of any medication except birth control pills. During initial screening, women were asked about their smoking status and were categorized as either current smokers (N=24) or never-smokers (N=23). The never-smoker group of women reported that they either never smoked a cigarette (N=20) or smoked fewer than 4 cigarettes (N=3) in their lifetime. They were also asked to estimate their height and weight and were categorized by their BMI (kg/m^2); only those with BMI between 18.5 kg/m^2 and 24.9 kg/m^2 (normal-weight group; *N*=22) or >29.9 kg/m^2 (obese group; *N*=25) were asked

to participate. To corroborate self-reports, women were weighed (Detecto Model 439, Physician Scale; Webb City; MO) and measured for height at Monell Chemical Senses Center and their BMI was computed. Four women who reported they were obese (based on reported weight and height their BMI's would be >29.9 kg/m^2) had a BMI less than 29.9 kg/m^2 but greater than 28.5 and were kept in the obese group. All procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania, and each woman gave informed written consent before study entry.

General Procedures

To standardize testing procedures and the level of hunger/satiation at the time of testing, subjects were asked to abstain from smoking (if smokers) and from eating for 12 hours before testing. To assess compliance, glucose was tested in a capillary blood sample, taken by finger prick (OneTouch, LifeScan Inc., Milpitas, CA), to ensure that they had fasted, and carbon monoxide levels were measured using a Vitalograph-Breath CO monitor (Vitalograph Inc., Lenexa, KS) to ensure that smokers had abstained from smoking. Upon arrival at Monell (8–10 a.m.), participants were provided and consumed a standard breakfast, consisting of a protein bar (180 calories) and 14 ounces of orange juice (190 calories). As described below, immediately after breakfast, anthropometric measurements were taken, and participants were asked to complete a series of questionnaires. Psychophysical tests started approximately 30 min after eating.

Taste perception (Intensity and Pleasantness)

Before testing, each subject was trained in the use of the general Labeled Magnitude Scale (gLMS), [22] with the top of the scale described as the "strongest imaginable" sensation of any kind. [23] The gLMS is a computerized psychophysical tool that requires subjects to rate the perceived intensity along a vertical axis lined with adjectives that are spaced semilogarithmically, based upon experimentally determined intervals to yield ratio-quality data.[22] To determine the role of retronasal volatiles in overall flavor perception, subjects were evaluated both without and with noseclips (which eliminated retronasal perceived volatiles). For each noseclip condition, stimuli were presented in two blocks; each block consisted of randomized presentations of the four puddings differing in fat concentrations. After tasting each sample for five seconds and without swallowing, subjects used the gLMS to rate the intensity of creaminess, oiliness, sweetness, and saltiness [22, 23] and the hedonic gLMS to rate intensity of pleasantness. [24] One minute separated the presentation of each stimulus, and two minutes separated each of the two blocks. The mean of the intensity at each concentration (for each quality) during the two-block series provided the estimate of subject's taste/texture/pleasantness intensity perception.

To ensure that group differences in perception of taste were indeed specific to taste/texture sensations and not differences in how the scales were used, each subject also judged intensities of weights using the same gLMS scales used to judge taste intensities, [25] by rating the heaviness of six opaque, sand-filled jars (225, 380, 558, 713, 870, 999 g). Because there were no differences between the groups in the perception of heaviness of jars with different sand content (all P-values>0.76), ratings in the gLMS did not required standardization across subjects.

Stimuli

Four vanilla puddings (Jell-O Pudding, General Foods, White Plains, NY) were prepared with graded amounts of fat (0%, 3.1%, 6.9%, and 15.6% fat wt/wt). Preparation procedures followed from the methods of Mattes (1993)[26]: samples were made by mixing 5.3 g vanilla pudding powder with 24.7 g milk with different fat content. Skim milk (0% fat) and heavy cream (33% fat) were mixed to prepare milks with fat contents (wt/wt) of 3.8% (84.6 g skim milk + 11.4 g heavy cream), 8.4% (74.4 g skim milk + 25.6 g heavy cream), or 19% (42.5 g skim milk + 57.6 g heavy cream). One drop of yellow food coloring (McCormick & Co., Inc., Hunt Valley, MD, USA) was added to the 15.6% fat pudding sample to mask color differences. Pudding samples were refrigerated at 4°C until 5 minutes before the test. To further mask visual differences among samples with different fat contents, all sensory tests were conducted under red light.

Anthropometry, Food Cravings, Preferences, and Restrictive Eating Behavior

Weight, height, and hip and waist circumference were measured, and body composition (total body water, fat-free mass, and fat) was estimated by bioelectrical impedance analysis, which measures resistance and reactance at 50 kHz between the right hand and the right food, using the Quantum X instrument (RJL Systems, MI). Data on hip and waist circumference were not obtained in 5 subjects (4 smokers and 1 never-smoker). Subjects also completed standardized questionnaires relative to their food preferences (Fat Preference Questionnaire (FPQ;[13]), food cravings inventory (FCI; [11]), and restrictive eating behavior (Factor I from Stunkard and Messick's Three Factor Eating Questionnaire (TFEQ); [27]). The FCI is a validated measure of the frequency of overall food cravings, as well as cravings for specific types of foods (high fats, sweets, carbohydrates/starches, and fast-food fats) during the past month. [11] For FCI, subjects score their answers by using a 5-point Likert scale (1=never, 5=very often/always). The FPQ is a validated instrument that assesses the preference for dietary fat by measuring the percentage of food sets in which high-fat choice was selected over lower-fat choices of the same food to "taste better" (TASTE score) and to be "eaten more often" (FREQ score). [13] Factor I from the TFEQ is a validated measure of cognitive dietary restraint, with higher scores denoting higher level of restrained eating. [27]

Data Analyses

We determined whether smoking and body weight status affected women's perception of creaminess and sweetness of puddings that varied in added amounts of fat, and whether differences in taste/texture perception were explained, in part, by signals from the sense of smell (via retronasal stimulation). We conducted separate four-way ANOVAs for creaminess, sweetness, and pleasantness, with smoking status (smokers vs. never-smokers) and body weight category (obese vs. normal-weight) as between-subjects factors and noseclip condition (with vs. without noseclips) and the four fat concentrations (0%, 3.1%, 6.9%, and 15.6% fat wt/wt) as within-subject factors. Ratings for oiliness and saltiness were not analyzed because values scored on these scales were almost nil.

Perceived creaminess, sweetness, and pleasure intensities were positively skewed and required square root transformations to approximate a normal distribution. When ANOVAs revealed significant effects, post -hoc Fisher least significant difference analyses were

conducted. In addition, separate ANOVAs were used to detect differences in demographic and anthropometric characteristics, craving scores, restrictive eating behavior, and fat preferences between groups that differed in body weight category and smoking status. Data in the tables and figures are presented as means ± SD unless otherwise indicated. All analyses were performed with STATISTICA 8.0 (StatSoft, Tulsa OK), and criterion for statistical significance was p<0.05.

Results

Subject characteristics

The four groups of women did not significantly differ in age, race, income level, or fasting glucose levels. However, smokers had a lower level of formal education than did never-smokers (p=0.01; Table 1). Current smokers reported smoking for 10±6 (range, 2–25) years and averaged 11±7 (range, 1–33) cigarettes/day. They first experimented with cigarettes when they were 16±4 (range, 10–30) years of age but did not begin smoking regularly until they were 18±4 (range, 11–30) years of age. Smokers reported that, when smoking was at peak levels, they smoked 19±13 (range, 3–60) cigarettes/day. There was a non-significant trend that obese smokers started smoking regularly at a younger age than did normal-weight smokers (17±3 years vs. 20±4; P=0.09). All other smoking habits were similar between obese and normal-weight smokers (P-values>0.20).

Intensity of creaminess, sweetness, and pleasantness

In all groups, ratings of creaminess significantly increased with increases in fat content; although sugar content remained the same, puddings that contained some amount of fat were perceived as sweeter than fat-free pudding ($F(3,129)=41.8$, $F(3,129)=5.97$, respectively; both P<0.001; Figure 1). Relative to the other three groups, obese smokers rated all puddings as less creamy and less sweet ($F(1,43)=5.20$, $F(1,43)=6.47$, respectively; both P<0.03; Figure 2A & B). For all groups, puddings were rated as sweeter when women were not wearing noseclips (i.e., could use the sense of smell) than when they were wearing noseclips (3.6±2.2 vs. 3.3±2.0; $F(1,43)=7.24$; P=0.01).

Puddings with fat were perceived as more pleasant than the fat-free pudding (3.0±1.5 vs. 3.5±1.5; $F(3,129)=11.08$; P<0.00001), and wearing noseclips lowered overall pleasantness ratings of the puddings in smokers compared with never-smokers ($F(1,43)=5.60$; P=0.02; Figure 3). Obese smokers reported perceiving less pleasure from tasting vanilla pudding than did the other three groups ($F(1,43)=11.01$; P<0.002; Figure 2C).

Anthropometry, Food Cravings, Preferences, and Restrictive Eating Behavior

Although women who smoked and women who never smoked had similar BMI and percent body fat, smokers had higher waist-to-hip ratios than never-smokers ($F(1,40)=6.91$; P=0.01; Table 1). Smokers identified a higher percentage of high-fat food items as the foods that "taste better" (78±3% vs. 64±3%; $F(1,42)=11.63$; P=0.001; Table 2), craved specifically high-fat foods (but not carbohydrates or sweets) more often ($F(1,43)=3.10$; P=0.03; Table 2), and ate high-fat foods more often than did never-smokers (64±4% vs. 48±4%; $F(1,43)=7.90$; P=0.007; Table 2). In addition, smokers were less restrictive eaters than were

never-smokers (F(1,42)=4.67; P<0.04; Table 2). Obesity status did not affect food cravings or preferences for fat (all P-values>0.12.), but obese women were more restrictive eaters than normal-weight women (F(1,42)=9.48; P<0.004). Frequency of eating high-fat foods (by FPQ) was positively correlated with frequency of cravings for fatty foods (r=0.34; P=0.02) and negatively correlated with restrictive eating behavior (r=−0.44; P=0.002).

Discussion

In the present study, we evaluated whether women perceive fat in food differently if they are smokers and obese. Accordingly, we studied obese and normal-weight women who were current smokers, and obese and normal-weight women who never smoked in their lifetime. In addition, because smokers often exhibit deficits in odor sensitivity, [21] we determined whether differences in the perception of creaminess between groups were explained, in part, by olfactory cues perceived retronasally (i.e., olfactory cues sensed through the mouth). Our results indicate that the co-occurrence of smoking and obesity is significantly associated with reduced perception and hedonic value of dessert-type sugar/fat mixtures. Obese women who smoke, relative to the other groups, perceived less creaminess, sweetness, and pleasure when tasting puddings that varied only in fat content. Tasting foods without input of olfactory cues (i.e., when subjects wore noseclips, depriving them of retronasal olfactory cues) diminished ratings of sweetness, but not creaminess, among all participants, which suggests that retronasal olfaction does not play a role in the blunted perception of flavor observed among obese smokers.

Why is the co-occurrence of smoking and obesity associated with a blunted perception of creaminess and sweetness of food? The first and simplest explanation for this finding is that differences in sensory perception observed between groups were due to a scaling artifact. However, when using identical sensory scales to judge non-taste-related stimuli (heaviness of different weights), obese smokers judged these stimuli similar to the other groups. Second, the combination of obesity and smoking may act synergistically to decrease flavor perception as a consequence of independent but additive effects in taste functionality. For example, both smoking and obesity have been independently associated with lower levels of serotonin, [28–30] a neurotransmitter that modulates cellular responses of taste receptors within the taste bud,[31] and thus taste sensitivity,[32] and appetite and mood within the brain. [30] Third, the blunted perception of creaminess and sweetness may relate to difficulty in separating hedonic responses from objective sensations of flavor intensity. However, wearing noseclips reduced sweetness intensity ratings in all groups but reduced hedonic ratings in smokers only, which suggests that the women in the present study could indeed separate hedonic ratings from intensity ratings.

Sweetness was enhanced by stimulation of the retronasal olfactory system, a well-known phenomenon of volatile-enhanced taste perception. [33] Thus, we hypothesize that smokers like puddings more when they can use retronasal smell because smokers like more intense sweetness than do no smokers. [19] Data from brain imaging studies suggest that both obesity and smoking are associated with neuroadaptations that can reduce the hedonic value of primary rewards, such as palatable food. [34–36] Additional studies are needed to fully

elucidate the mechanisms responsible for the alterations in taste intensity perception and the decrease in hedonic value of palatable foods observed in obese women who smoke.

Consistent with previous findings, we also found that smokers, regardless of BMI, had higher waist-to-hip ratios [4, 5] and craved and selected high-fat foods more frequently than did women who never smoked in their lifetimes. [7–10] However, smoking had no effect on oral perception of fat (see also [19, 20]). Taken together, these findings support the conclusion that smokers prefer a diet rich in fat and that this preference was not due to reduced sensitivity to flavor cues of fat.

The results of our study should be considered along some limitations, all of which should be addressed in future research. First, although we found that retronasal olfaction does not play a role in the blunted perception of fat observed in obese smokers, we did not measure functionality of the sense of smell. Noteworthy, smokers often exhibit deficits in odor sensitivity when smells are perceived orthonasally (through the nose), [21] but, to the best of our knowledge, none of the published studies have directly measured functionality of the retronasal olfactory pathway (through the back of the mouth) in smokers. Because retronasal and orthonasal olfaction activates different brain regions, with retronasal activation more likely to be interpreted by the brain as a food stimulus, [37] future studies that examine retronasal odorant perception in smokers are needed. Second, the finding that smoking and obesity are associated with decreased fat perception in sweet-tasting puddings may not generalize to other fatty foods (see [38]). Third, although the FPQ has been shown to be a valid instrument to assess preference for dietary fat [13] and that the more frequent the cravings for specific foods, the more likely the person would "give in" to those cravings and consume that type of food, [11, 39] patterns of nutrient intake were not assessed through dietary records.

In conclusion, the ability to perceive fat and sweetness and to derive pleasure from foods is particularly compromised in obese women who smoke, which could contribute to excess fat intake in this population already at high risk for cardiovascular and metabolic disease. Although retronasal olfaction affects perception of sweetness in smokers, it appears not to contribute to blunted flavor perception observed in obese smokers. Smoking, regardless of BMI, is associated with increased reported cravings and frequency of consumption of high-fat foods and with higher waist-to hip ratios, both of which are independent health risk factors and predictors of mortality. [40] These findings contribute to the growing body of evidence that challenges the perception that smoking can help a person to maintain a "healthy" weight, because alterations in body fat distribution and eating a high-fat diet may actually increase risk of disease.

Acknowledgments

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What is already known about this subject

- Obesity and smoking are independently associated with cravings for and high consumption of high-fat foods.

- Obese subjects have reduced oral fat perception compared with lean subjects, which could further contribute to excess fat intake among obese individuals.

- Smokers often exhibit deficits in sensitivity to odors perceived orthonasally and to sweet and bitter taste.

What this study adds

- Obese women who smoke perceive less pleasure from sweet, creamy puddings compared with normal-weight smokers and obese and normal-weight never-smokers.

- The ability to perceive changing concentrations of fat in foods is particularly compromised in obese smokers, which could contribute to excess fat intake in this population already at high risk for cardiovascular and metabolic disease.

- Ratings of creaminess were not affected if food was tasted while wearing noseclips, suggesting that retronasal olfaction does not play a role in the blunted perception of fat observed in obese smokers.
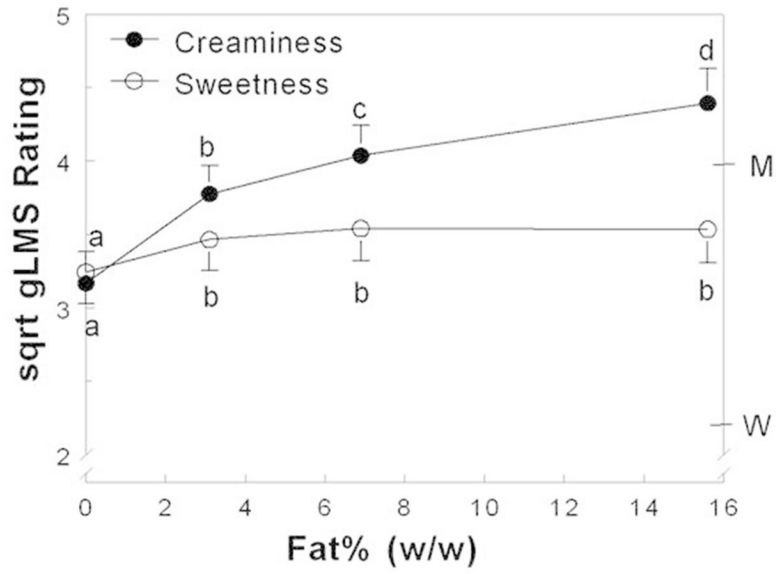
Figure 1.
gLMS ratings of creaminess (close symbols) and sweetness (open symbols) as a function of fat content (0%, 3.1%, 6.9%, and 15.6% fat wt/wt) in vanilla puddings. Different letters signify significant differences at p<0.05 between texture/taste descriptors.
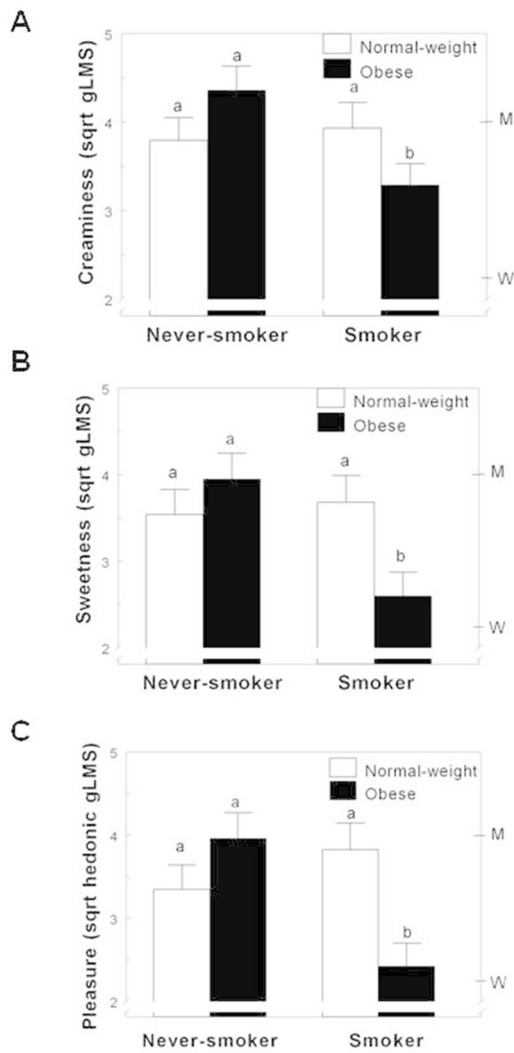
Figure 2.
gLMS ratings of creaminess (A) and sweetness (B) and hedonic gLMS ratings of pleasure
(C) of puddings by smoking and obesity status. Data are mean values ± SEM. Data
collapsed across all puddings. Groups that do not share a subscript differ by *post-hoc* testing.
W, weak; M, moderate.

Figure 3.
Hedonic gLMS ratings of pleasure by smoking status and noseclip condition. Data are mean values ± SEM. Data collapsed across all puddings. Groups that do not share a subscript differ by *post-hoc* testing. W, weak; M, moderate.
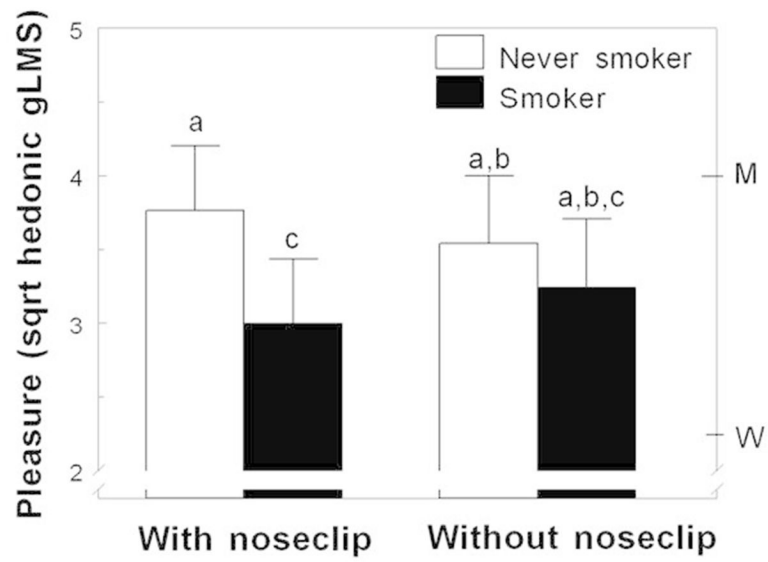
Table 1

Subject characteristics

	Never-Smoker		Smoker		P value Main effect smoking status
	Normal-weight	**Obese**	**Normal-weight**	**Obese**	
Age (years)	27.2 ± 3.8	30.1 ± 7.2	28.8 ± 9.6	27.8 ± 6.1	0.86
Race (% group)					
White	50	36	60	43	0.90
Black	42	55	40	43	
Mixed or other races	8	9	0	14	
Body weight (kg)	61.7 ± 7.1	99.9 ± 21.3	61.2 ± 5.7	99.8 ± 19.5	0.94
BMI (kg/m^2)	22.3 ± 1.8	37.6 ± 6.6^a	22.0 ± 1.7	36.8 ± 6.5^a	0.72
Fat mass (% body weight)	32.9 ± 4.3	50.5 ± 5.5	28.2 ± 4.5	51.1 ± 5.7	0.18
Waist-to-hip ratio	0.73 ± 0.04	0.80 ± 0.08^a	0.76 ± 0.05	0.87 ± 0.06^a	**0.01**
Blood glucose levels (mg/dl)	79.6 ± 6.9	87.5 ± 5.8^a	75.7 ± 9.6	83.4 ± 7.4^a	0.08
Education (years)	16.3 ± 1.6	14.8 ± 1.7	14.4 ± 1.9	13.6 ± 2.6	**0.01**
Income (% group)					
<$15,000	17	9	44	36	0.09
$15,000 to $35,000	33	27	56	14	
>$35,000	50	63	0	50	

Values are means ± SD.

[a] P<0.05 vs. normal-weight, but no significant smoking by weight status interaction was observed.

Table 2

Surveyed food behaviors

	Never-Smoker		Smoker		P value Main effect smoking status
	Normal-weight	Obese	Normal-weight	Obese	
Food cravings					
High fats	1.86 ± 0.83	2.36 ± 0.79	2.96 ± 1.0	2.55 ± 0.94	**0.02**
Starches	2.11 ± 0.76	2.60 ± 0.97	2.36 ± 0.80	2.30 ± 0.18	0.85
Sweets	2.47 ± 0.65	2.54 ± 1.14	2.58 ± 0.60	2.43 ± 0.93	0.99
Fast-food fats	2.48 ± 0.68	2.80 ± 0.88	3.03 ± 0.58	2.70 ± 0.81	0.28
Fat preferences (%)					
Taste better	67 ±14	60 ± 17	78 ± 10	78± 14	**0.001**
Eaten more often	51 ± 20	44 ± 13	69 ± 17	59 ± 26	**0.007**
Restrictive eating behavior (Stunkard factor I)	8.4 ± 4.2	13.1 ± 4.0[a]	6.1 ± 4.0	9.6 ± 5.3[a]	**0.04**

Values are means ± SD.

[a]P<0.05 vs. normal-weight; no significant smoking status by weight category interaction was observed.