No evidence for an association between obesity and food liking

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Abstract

Background: Prevailing models of obesity posit that hedonic signals override homeostatic mechanisms to promote overeating in today's food environment. What researchers mean by "hedonic" varies considerably, but most frequently refers to an aggregate of appetitive events including incentive salience, motivation, reinforcement, and perceived pleasantness. Here we define hedonic as orosensory pleasure experienced during eating and set out to test whether there is a relationship between adiposity and the perceived pleasure of a palatable and very energy dense milkshake.

Methods: The perceived liking, wanting and intensity of two palatable and energy-dense milkshakes were assessed using the labeled hedonic scale (1), visual analogue scale, and Generalized Labeled Magnitude Scale (2) in 110 individuals ranging in body mass index (BMI) from 19.3 to 52.1 kg/m². Waist circumference, waist-hip ratio, and percent body fat were also measured. Importantly, unlike the majority of prior studies, we attempted to standardize internal state by instructing participants to arrive to the laboratory neither hungry nor full and at least one-hour fasted. Hunger ratings were also examined prior to hedonic measurement and included as covariates in our analyses.

Results: Data were analyzed with general linear and linear mixed effects models (GLMs). We identified a significant association between ratings of hunger and milkshake liking and wanting. By contrast, we found no evidence for a relationship between any measure of adiposity and ratings of milkshake liking, wanting, or intensity.

Conclusions: We conclude that adiposity is not associated with the pleasure experienced during consumption of our energy-dense and palatable milkshakes. Our results provide evidence against the hypothesis that heightened hedonic signals drive weight gain.

1. Introduction

The obesity epidemic is often blamed on the ubiquity of hyperpalatable energy-dense foods (3–5). Implicit in this view is that the pleasure derived from eating these foods systematically varies as a function of adiposity, because those who experience greater pleasure overeat and gain weight. However, the literature examining the association between adiposity and pleasure derived from eating is highly inconsistent.

Resolving this inconsistency depends first upon how pleasure is defined. Ingestive behavior is multifaceted and encompasses a number of distinct motivational processes. Theoretical frameworks of motivation range from drive reduction, to incentive motivation, “wanting” and “liking”, reinforcement learning, and effort appraisal; all relevant to ingestive behavior and associated with distinct neurobiological underpinnings (6–8). Moreover, the terms ‘liking’ and ‘preference’ -- often used interchangeably in the literature -- are tested through unique behavioral paradigms. Liking is typically assessed by self-report with participants rating how much they like (or dislike) a stimulus according to a standard scale (e.g. visual analog, Likert scale, ‘Labeled Hedonic Scale’ (LHS)) (1). In contrast, preference is determined by a decision or selection when two or more alternatives are presented, usually within a forced-choice tracking procedure when the food or beverage is sampled (9), but also applies to preference questionnaires where lists of foods are ranked or rated for preference. However, preference does not map directly onto liking or perceived pleasure. For example, imagine a series of lemonade beverages of increasing sweetness. One participant, John, prefers the sweetest beverage while another participant, Heather, prefers the second sweetest beverage. This does not mean that John finds sweetness more pleasurable than Heather, because Heather may well rate both lemonades as more liked than John (10). Systematic biases toward sensations with higher energy densities are meaningful and important observations, but they do not mean that such biases reflect enhanced hedonic responses.

Here we focus on understanding whether a relationship exists between measures of adiposity and conscious liking, or “sensory pleasure,” which depends on self-report, and may be uniquely human (11). However, even this narrowed definition includes multiple distinct domains. Visual, aromatic, and contextual food cues can be rated for how liked or disliked they are, but are still distal to the pleasure experienced during eating. They can and do, however, promote craving and food intake (12), which are related to pleasure but are nevertheless distinct psychological

and neurobiological phenomena (13). Lists of food items can be assessed for liking or preference. Orosensory systems can also be evaluated discretely (e.g. sweet taste) or as flavor ("taste" of a food item or beverage). Regardless of the domain or stimulus evaluated, a review of this literature (Table 1) reveals significant inconsistency with adiposity (typically quantified using body mass index (BMI)). Figure 1 summarizes these reports, grouped by domain and stimulus. Among these reports, approximately 33% find a positive relationship, 11% a negative relationship, and 56% no relationship with BMI (Figure 1A), clearly demonstrating a lack of consensus (14–51). Moreover, very few of these studies assess the influence of adiposity measures on liking ratings produced during the sampling of actual foods or beverages. Yet, it is this experience that defines the pleasure of food. Of the seven studies identified, four reported no relationship and three a positive relationship with BMI across a range of stimuli including candy, lemonade, soda, fruits and vegetables, chips and other snacks, spreadable fats, and more. These studies tended to have a small sample size or include data collected in uncontrolled environments and protocols (e.g. lecture halls) without considering factors like time since last meal or hunger and with only BMI to index adiposity. We therefore endeavored to perform a larger-scale analysis by combining perceptual ratings across a series of studies in our laboratory all using similar methods (e.g. controlling for time since last meal and hunger ratings), identical rating scales and stimuli (chocolate and strawberry milkshake), and multiple measures of adiposity.

2. Methods

2.1 Participants

In total, we included data from 110 participants (69 women, 41 men, mean age: 28.92 ± 6.68 years, mean BMI: 28.62 ± 6.89 kg/m², range 19.3 - 52.1 kg/m²) acquired from three separate study cohorts (52–54). Participants were recruited through flyers and advertisements around Yale University and the city of New Haven. All study procedures were approved by the Yale University School of Medicine Human Investigation Committee (HIC) and informed consent was obtained from everyone. Participants reported having no known taste, smell, neurological, psychiatric or other pathological disorder. Because these cohorts were part of functional neuroimaging studies, potential participants were excluded for MRI contraindications.

2.2 Measures

Anthropometric measures were obtained from participants and included body weight ($n = 110$), height ($n = 110$), BMI ($n = 110$), waist circumference ($n = 66$), hip circumference ($n = 66$), and body fat percentage ($n = 72$). Participants were asked to wear light clothing and to take off their shoes before height and weight were measured. Body fat percentage (BF%) was calculated using air displacement plethysmography (BodPod). Waist and hip circumference were assessed with a measuring tape. Waist-hip ratio (cm waist/cm hip) and BMI (weight (kg) / [height (m)]²) were calculated based on their component measures.

2.3 Procedure

2.3.1 Stimuli

Two flavored milkshakes (chocolate and strawberry) were made in the laboratory. Chocolate milkshakes were made with 12 fl oz of whole milk and equal parts Garelick Farms Chug Chocolate and Garelick Farms Chug Cookies & Cream milkshakes. Strawberry milkshakes were made with 32 fl oz of whole milk and 6 fl oz of Hershey's strawberry syrup (50).

2.3.2 Stimulus Delivery

Chocolate and strawberry milkshakes were delivered to participants in the MR scanner environment. In brief, 0.5 mL of milkshake was delivered over the course of 2s using an MRI compatible gustometer. The gustometer consisted of programmable BS-8000 syringe pumps (Braintree Scientific, Braintree, Massachusetts) that were loaded with 60 mL syringes containing milkshake. Syringes were connected to 25 ft of Tygon tubing (Saint Gobain Performance Plastics, Akron, Ohio) that were fed through the wall of the scanner control room and were further connected to a Teflon gustatory manifold attached to the MR head coil. The manifold consisted of several arteries that converged onto a single point, allowing for liquid solutions to drip passively through the mouthpiece onto the tongue (55).

2.3.3 Ratings

Subjects provided multiple ratings of the chocolate and strawberry milkshakes on different days. To be consistent with previous literature, we used the ratings from the first exposure in our initial analyses. We later re-ran analyses with the average rating across exposures and these analyses produced similar results (data not shown). Perceptual ratings of the milkshakes were made inside the scanner with participants indicating magnitude by moving a cursor along a line with a rotating trackball. The Labeled Hedonic Scale (LHS) was used to assess liking (1). In contrast to the often employed 9- point scale, the LHS is an empirically-derived scale designed to produce normally distributed ratio-level data, and is relatively resistant to ceiling effects and other similar confounds (1). In addition, it includes empirically-derived and placed semantic labels ranging from “most disliked sensation imaginable” to “most liked sensation imaginable.” Intensity ratings were assessed with the generalized Labeled Magnitude Scale (gLMS) (2). Like the LHS, the gLMS is empirically-derived, includes semantic labels, and produces ratio-level data resistant to ceiling effects. On the gLMS the anchors range from “no sensation” to “strongest imaginable sensation.” Milkshake wanting was assessed using a 200mm visual analog scale (VAS), which was bounded by “I would never want to consume this” and “I would want to consume this more than anything.” Finally, the Dietary Fat and free Sugar (DFS) (56) and Three Factor Eating Questionnaire (TFEQ) (57) were administered to collect information on food intake and eating behaviors. The DFS is a series of twenty-six questions evaluating intake of fat and free sugar, yielding three scores: sugar, saturated fat, and total (Cronbach’s $\alpha = 0.76$ in Francis and Stevenson (2013)(56)). The TFEQ is a series of fifty one-pointed questions to determine cognitive food restraint, disinhibition, and hunger levels (Cronbach’s $\alpha = 0.93, 0.91$ and 0.85 for these subscales, respectively, in Stunkard and Messick (1985)(57)).

2.4 Statistical Analysis

All statistical analyses were performed in R (3.5.1, 2018-07-02). Datasets that included repeated measures were analyzed with linear mixed models (LMMs) using package Lme4 (v1.1-21). P-values and type 3 ANOVAs for these models were calculated using the Satterthwaite approximation of degrees of freedom (package LmerTest, v3.0-1). Datasets that did not include repeated measures were analyzed with type 3 ANOVAs using the ‘Anova’ function from package ‘car’ (v3.0-2).

To investigate the influence of hunger on perceptual ratings, we constructed separate models with milkshake liking, wanting, and intensity ratings as dependent variables and hunger ratings

as the independent variable. A similar procedure was performed to test for associations between hunger and adiposity measures. Sex, research study ID, and BMI were used as covariates for perceptual rating models whereas research study ID, and sex were used as covariates for adiposity models. To investigate the relationship between perceptual ratings and adiposity, separate models were constructed with milkshake liking, wanting, and intensity as dependent variables and BMI, waist-hip ratio, waist circumference, and body fat percentage as independent variables. Sex, research study ID, age, and hunger served as covariates. Age was used as a covariate when measures of adiposity were used as independent variables to account for the influence of age on adiposity. Additionally, separate models were created to test average milkshake liking, wanting and intensity across all exposures to the milkshake. Research study ID, sex, age, and hunger were used as covariates. To investigate the relationship between food intake and perceptual ratings, separate models were constructed with milkshake liking, wanting, and intensity as dependent variables and DFS free sugar score, DFS saturated fat score and DFS total score as independent variables. Similarly, the relationships between food intake and adiposity measures were investigated through separate models with BMI, waist-hip ratio, waist circumference, and body fat percentage as dependent variables and DFS free sugar score, DFS saturated fat score, and DFS total score as independent variables. To investigate the relationship between the TFEQ measures of eating behavior and perceptual ratings, separate models were constructed with milkshake liking, wanting, and intensity as dependent variables, and TFEQ cognitive food restraint score, TFEQ disinhibition score, and TFEQ hunger score as the independent variables. Additionally, the relationships between the TFEQ measures of eating behavior and adiposity measures were investigated through separate models with BMI, waist-hip ratio, waist circumference, and body fat percentage as dependent variables and TFEQ cognitive food restraint score, TFEQ disinhibition score, and TFEQ hunger score as the independent variables. Correction for multiple comparisons were performed by adjusting the α according to the Bonferroni method. For LMMs, subject ID was entered as a random variable. We identified one outlier (0.9% of the dataset), defined as more than 2.5 standard deviations from the mean. The removal of the outliers did not change the analyses so the data were retained.

3. Results

3.1 Hunger is related to liking and wanting but not intensity or adiposity

GLMs indicated a significant positive relationship between hunger and liking ($F(1,110) = 5.47, p = .02$), as well as hunger and wanting ($F(1,110) = 15.97, p < .001$), but not between hunger and perceived intensity ($F(1,110) = 3.16, p = .08$). Once p-values were corrected for multiple comparisons, only the relationship between hunger and wanting remained significant. There was no association between hunger and any of the measures of adiposity (BMI $F(1,105) = .81, p = .37$; waist-hip ratio $F(1,62) = 1.14, p = .29$; waist circumference $F(1,62) = 2.87, p = .10$; body fat percentage $F(1,68) = 2.63, p = .11$) (Figure 2). These analyses indicate that hunger but not adiposity is associated with milkshake wanting.

3.2 Perceptual ratings are not significantly related to adiposity

GLMMs showed no significant relationships between adiposity and perceptual ratings (Table 2). This was true even when not correcting for multiple comparisons. Furthermore, hunger had no influence on these findings (Figure 3). Similar findings were obtained when average ratings from all milkshake exposures were analyzed (data not shown).

3.3 Self report fat and sugar intake and eating behavior are not associated with adiposity or perceptual ratings

GLMs showed a significant relationship between DFS free sugar score and BMI ($F(1,69) = 6.08, p = .016$); however this relationship did not survive correction for multiple comparisons. A trend was observed between DFS free sugar score and waist circumference ($F(1,61) = 3.05, p = .08$), but not between DFS free sugar score and waist hip-ratio or body fat percentage ($F(1,61) = 1.35, p = .25$; $F(1,67) = 1.13, p = .29$, respectively). Likewise, no significant relationships were found between DFS free sugar score and perceptual ratings (liking $F(1,73) = .00, p = 1.00$; wanting $F(1,73) = .24, p = .63$; intensity $F(1,73) = .05, p = .83$). A trend was identified between intensity ratings and both DFS saturated fat and DFS total scores ($F(1,73) = 3.68, p = .06$ and $F(1,73) = 3.39, p = .07$, respectively). No other relationships were found between DFS saturated fat score and adiposity measures (BMI $F(1,69) = .11, p = .74$; waist-hip ratio $F(1,61) = .35, p = .56$; waist circumference $F(1,61) = .09, p = .77$; body fat percentage $F(1,67) = .00, p = .99$) or perceptual ratings (liking $F(1,73) = .18, p = .67$; wanting $F(1,73) = .43, p = .51$). Moreover, we found no association between DFS total score and adiposity measures (BMI $F(1,69) = .99, p = .32$; waist-hip ratio $F(1,61) = .22, p = .64$; waist circumference $F(1,61) = .001, p = .98$; body fat

percentage $F(1,67) = .08, p = .77$) or perceptual ratings (liking $F(1,73) = .82, p = .37$; wanting $F(1,73) = .30, p = .59$).

GLMs between adiposity measures and perceptual ratings with cognitive food restraint, disinhibition, and hunger scores from the TFEQ showed no significant relationships (Table 3).

4. Discussion

There is significant controversy around the nature and existence of an association between adiposity and the pleasure derived from eating (Figure 1, Table 1). This is an important gap in knowledge because it is often assumed that increased hedonic experience from eating promotes overeating and obesity. Here we combined data from multiple studies in our lab in which participants rated the perceptual attributes of two palatable and energy-dense milkshakes and regressed these ratings against multiple measures of adiposity. We found no evidence for a relationship between any of the adiposity measures (BMI, percent body fat, waist hip ratio, waist circumference) and the perceived liking, wanting or intensity of the milkshakes. This null finding is consistent with the majority of prior reports evaluating the relationship between BMI and the rated perception of foods and beverages, tastes, and aromas (Figure 1, Table 1).

In contrast, we did identify a significant, albeit weak, positive association between ratings of hunger and milkshake liking. This observation is potentially important in explaining the inconsistent reports in the literature. First, among prior publications reviewed, only three explicitly controlled for the participants' self-reported hunger in the analyses that were performed (17,25,28). Second, although the majority of studies required a minimum fasting period prior to assessment (i.e., at least 1-4 hours), they routinely did not account for potential variance in the time since the last meal. It is therefore possible that participants with higher adiposity were hungrier. If so, then hunger rather than adiposity might be driving positive associations with liking. Relatedly, other studies have shown that fullness is inversely related to food palatability and intake (58).

Another factor that could contribute to variable results is the use of food lists rather than the sampling of food. Humans perform poorly at predicting how pleasant they will find the taste of a food (58). Of the seven food and beverage liking studies we identified using real food/flavor stimuli (Table 1A), three reported a positive association (21,29,30) and five no association (17,28,32,59,60) with BMI. Notably, the studies finding a positive association did not evaluate and/or control for hunger. Also of relevance, two of the studies using real food also assessed other aspects of food motivation. Saelens and Epstein (1996) (17) asked female participants to choose to eat food or perform a sedentary activity, such as playing a video game or reading magazines. Women with overweight and obesity were more likely to choose food consumption over the sedentary alternative compared to women with normal weight. Likewise, Giesen et al.

(2010) (28) found that individuals with overweight/obesity were willing to work more for high-calorie snacks versus low-calorie fruits and vegetables, which they interpreted as an increase in the 'relative-reinforcing value' of food. These studies support a positive association between adiposity and motivation to consume unhealthy food in the context of normal hedonic responses, which is in line with the conclusion of a review paper on adiposity and food reward (61) and with the incentive sensitization theory (62).

A final issue worth considering relates to the instruments used to collect ratings. Many studies used a 9-point scale (31,33), which is prone to biases such as centering and end effects, or the tendencies to avoid using the extreme ends of the scale or to distribute ratings across the range that is presented (reviewed in Lim 2011 (63)). In addition, categorical scales only yield ordinal level data because there is no zero point, nor evidence that the distance between categories is equal (64). Thus, the resulting data violates many of the assumptions for ordinary linear regression models (e.g., normality) (65,66). This raises questions over the validity of applying ordinary linear regression models to evaluate data from such scales. Finally, scales anchored with reference to food -- for example, least-liked food on the left and extremely-liked food on the right -- assume that the value ascribed to extremely-liked food is similar across all users (21). Here we used the LHS, which is a category-ratio scale that was derived using magnitude estimation that produces ratio-level data and is bound by cross-modal semantic labels that allows subjects to draw across all of their hedonic experiences (1). It therefore overcomes many of the shortcomings of the 9-point scale.

Importantly, a lack of a relationship between adiposity and food hedonics does not imply that there is no association between obesity and food reward. Many prior studies report heightened food-cue reactivity and food reinforcement - or motivation to obtain food - among individuals with overweight or obesity (e.g.16,27,63). Similarly, a meta-analysis of 45 publications ($n > 3000$) suggests that increased food cravings can promote overeating and predict subsequent weight gain (68), while a survey of individuals with increased food cravings were more likely to have overweight and obesity as well as engage in sedentary behaviors that promote weight gain, such as spending more hours watching television (69). Finally, many functional brain imaging studies report strong associations between brain response to beverage and food related stimuli and adiposity or risk for weight gain (70–76).

4.1 Strengths, Limitations, and Future Directions

Our study has several strengths that lend confidence in our findings. Multiple measures of adiposity were obtained and we used the gold standard instrument for measuring hedonics in a large sample of individuals who sampled a palatable and energy dense food. We also accounted for a comprehensive set of potential confounds including subjective hunger, participant sex, and age. We also note several limitations. First, it is possible that ratings of milkshake beverages do not generalize to solid foods or other stimuli. Second, ratings were obtained while participants were engaged in an fMRI study, raising the possibility that this unique environment systematically biased ratings. Due to the diameter of the scanner bore, this environment also necessitated exclusion of individuals with morbid obesity.

4.2 Conclusion

Our study failed to identify a relationship between adiposity and milkshake liking, despite controlling for hunger, employing a large sample size and using the gold standard instrument to assess hedonic experience. This result is consistent with the conclusion made in a previous review (61) and strongly suggests that the experience of enhanced pleasure during the consumption of palatable and energy dense foods does not contribute to overeating. Our findings also underscore the importance of controlling for participant hunger when assessing the hedonic properties of food.

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Tables and Figures

Table 1

Study and Type	Correlation with BMI			Subjective Hunger Controlled
	Positive	Negative	None	
A. FOOD AND BEVERAGE LIKING				
Witherly & Pangborn 1980 (1)	X	X	✓	X
Witherly & Pangborn 1980 (2)	X	✓	X	X
Drewnowski et al. 1982*	X	X	✓	X
Pangborn et al. 1985	X	X	✓	X
Saelens and Epstein 1996*	X	X	✓	✓
Diehl 1999	X	✓	X	X
Nakamura et al. 2001	✓	X	X	X
Salbe et al. 2004	X	X	✓	X
Bartoshuk et al. 2006 (3)*	✓	X	X	X
Bartoshuk et al. 2006 (4)	✓	X	X	X
Davis et al. 2007	✓	X	X	X
Czyzewska & Graham 2008	X	X	✓	X
Keskitalo et al. 2008	X	X	✓	X
Temple et al. 2008	X	X	✓	✓
Duffy et al. 2009	✓	X	X	X
Hill et al. 2009	X	X	✓	X
Giesen et al. 2010*	X	X	✓	✓
Ettinger et al. 2012*	✓	X	X	X
Dressler & Smith 2013*	✓	X	X	X
Deglaire et al. 2015	✓	X	X	X
Laureati et al. 2015*	X	X	✓	X
Lampure et al. 2016 (5)	X	✓	X	X
Lampure et al. 2016 (6)	✓	X	X	X
Lampure et al. 2016 (7)	X	X	✓	X
Proserpio et al. 2016	✓	X	X	X
Polk et al. 2017	✓	X	X	X
Total # Reports: 26	11	3	12	3
B. PURE TASTE LIKING				
Appetitive: Sweet or Fat				
Rodin et al. 1976	✓	X	X	X
Thompson et al. 1977+	X	X	✓	X
Malcom et al. 1980	X	X	✓	X
Frijters & Rasmussen-Conrad 1982+	X	X	✓	X
Pasquet et al. 2007	X	X	✓	X
Hardikar et al. 2017	✓	X	X	X
Total # Reports: 6	2	0	4	0
Non-Appetitive: Bitter or Sour or Salt				

Malcom et al. 1980	X	X	✓	X
Pasquet et al. 2007	X	✓	X	X
Total # Reports: 2	0	1	1	0
C. ODOR LIKING				
Thompson et al. 1977	X	X	✓	X
Brondel et al. 2006	X	X	✓	X
Trellakis et al. 2011	X	✓	X	X
Soussignan et al. 2012 (8)	✓	X	X	X
Soussignan et al. 2012 (9)	X	X	✓	X
Bragulat et al. 2012	X	X	✓	X
Havermans et al. 2012	X	X	✓	X
Eiler et al. 2014	X	X	✓	X
Stafford & Whittle 2015	✓	X	X	X
Jiang et al. 2015	X	X	✓	X
Sun et al. 2016	X	X	✓	X
Yeomans et al. 2016	X	X	✓	X
Total # Reports: 12	2	1	9	0

*Indicates food being consumed in the paradigm

+Pleasantness ratings were adjusted to individual's preferred sweetness

- (1) Lemonade liking
- (2) Apricot nectar liking
- (3) Fruit roll-up liking
- (4) Liking based on food questionnaire
- (5) Sweet food liking
- (6) Fatty food liking
- (7) Salty food liking
- (8) For orofacial reactivity to odors as the measure of liking
- (9) Self-reported odor liking

Table 2

	LIKING	WANTING	INTENSITY
BMI	$F(1,110) = .13$ $p = .72$ $F(1,110) = .04$ $p = .85$	$F(1,110) = .64$ $p = .43$ $F(1,110) = 1.01$ $p = .32$	$F(1,110) = .04$ $p = .84$ $F(1,110) = .01$ $p = .94$
Waist-Hip Ratio	$F(1,66) = .09$ $p = .76$ $F(1,66) = .05$ $p = .82$	$F(1,66) = .12$ $p = .73$ $F(1,66) = .37$ $p = .55$	$F(1,66) = .05$ $p = .81$ $F(1,66) = .14$ $p = .70$
Waist Circumference	$F(1,66) = .26$ $p = .61$ $F(1,66) = .17$ $p = .68$	$F(1,66) = .79$ $p = .38$ $F(1,66) = 1.48$ $p = .23$	$F(1,66) = .05$ $p = .82$ $F(1,66) = .00$ $p = .99$
Body Fat Percentage	$F(1,72) = .00$ $p = .99$ $F(1,67) = .00$ $p = 1.00$	$F(1,67) = .68$ $p = .41$ $F(1,72) = 1.20$ $p = .28$	$F(1,72) = 2.24$ $p = .14$ $F(1,72) = 1.89$ $p = .17$

Statistics reported in black use hunger as a covariate in analyses with general linear mixed effects models. Statistics reported in blue do not include hunger as a covariate in these analyses.

Table 3

		Cognitive Food Restraint	Disinhibition	Hunger
PERCEPTUAL RATINGS OF MILKSHAKE	Liking	$F(1,82) = .28$ $p = .60$	$F(1,82) = 1.48$ $p = .23$	$F(1,82) = 1.29$ $p = .26$
	Wanting	$F(1,82) = .74$ $p = .39$	$F(1,82) = 3.71$ $p = .06$	$F(1,82) = 2.16$ $p = .15$
	Intensity	$F(1,82) = .06$ $p = .81$	$F(1,82) = .74$ $p = .39$	$F(1,82) = 1.78$ $p = .19$
ADIPOSIY MEASURES	BMI	$F(1,77) = .06$ $p = .81$	$F(1,77) = .32$ $p = .57$	$F(1,77) = .07$ $p = .79$
	Waist-Hip Ratio	$F(1,41) = .10$ $p = .75$	$F(1,41) = 2.42$ $p = .13$	$F(1,41) = .98$ $p = .33$
	Waist Circumference	$F(1,41) = 1.52$ $p = .22$	$F(1,41) = .24$ $p = .63$	$F(1,41) = .00$ $p = .98$
	Body Fat Percentage	$F(1,46) = 1.12$ $p = .29$	$F(1,46) = .07$ $p = .79$	$F(1,46) = .11$ $p = .74$

B. Food and Beverage Liking

C. Pure taste liking

D. Odor liking

Figure 1. Pie charts indicating percentage of reports finding a positive association, negative association, or no association with BMI. Summary chart (A) is for all literature described in Table 1. This literature is also depicted in separate charts by correlate type: food and flavor liking (B), pure taste liking (C), and odor liking (D), corresponding to Tables A, B and C respectively. Percentages are rounded to the nearest tenth. Total summary percentage sums to 99.99% due to rounding. *Italicized total* refers to total number of reports reviewed by correlate type or in summary.

A. Adiposity Measures

B. Perceptual Ratings

Figure 2

Figure 2. Hunger is related to liking and wanting but not intensity or adiposity. A) Scatter plots of hunger as a function of body mass index, waist hip ratio, circumference, and body fat percentage, adjusted for sex and study. B) Scatter plots of hunger as a function of milkshake liking, milkshake wanting, milkshake intensity, adjusted for sex, study, and BMI. All p values are uncorrected. Hunger as a function of wanting is the only p value that remains significant upon correction and remains with removal of two outliers.

A. Liking **B. Wanting** **C. Intensity**

Figure 3

Figure 3. Perceptual ratings of milkshake as a function of adiposity. Scatter plots representing milkshake A) liking, B) wanting, and C) intensity as a function of body mass index, waist hip ratio, waist circumference and body fat percentage. P values in black were adjusted for sex, study, age and hunger. P values in blue were adjusted for sex, study and age. All p values are uncorrected for multiple comparisons and none are significant.