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Article

Correlates of Sugar Consumption Among High School Students and Faculty

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SUMMARY

The majority of Americans are overweight or obese, putting them at increased risk for high blood pressure, stroke, heart disease, type 2 diabetes, cancer, and other adverse outcomes. Multiple factors contribute to this trend, including the increased availability and portion size of Highly Palatable Food (HPF), which is defined by the combination of sugar, fat, and/or salt. Food addiction theory describes a cycle of ingesting sugary food, followed by insulin and dopamine responses that lead to increased cravings for HPF. With repeated exposure to HPF, some individuals become chronic over-consumers with a strong drive for this type of reward-based eating. This study sought to characterize the relationships between Reward-based Eating Drive (RED), consumption of HPF, cravings for sugary beverages, and knowledge of sugar's effects on the brain and body in male and female high school students and faculty. Survey questions were uploaded to Surveymonkey and a link to the survey was sent to the listservs for all individuals with an email account at the high school. 176 anonymous responses were received. The results showed that reward-based eating drive was related to consumption and to cravings. For females, knowledge of sugar's effects was significantly and inversely associated with consumption of sugary food. This finding suggests that public health interventions to increase knowledge of sugar's adverse effects may be an avenue to decreasing consumption of HPF, ultimately decreasing the proportion of overweight and obese individuals, especially in young women.

INTRODUCTION

The number of overweight (Body Mass Index, BMI ≥ 25) and obese (BMI ≥ 30) individuals in the United States is approaching epidemic proportions (1). Since 1960, the rate of obesity has more than doubled in adults (from 14.3% to 38%) and more than tripled in children and adolescents (from 5% to 16.9%) (2, 3). A majority of adults (70.7%) are now overweight. Obesity increases risk for many adverse health conditions, including high blood pressure, stroke, heart disease, type 2 diabetes, cancer, and early death (4). A number of factors are believed to have played a role in this upwards trend. Experts point to reductions in physical activity and labor, increases in portion sizes, and increases in added sugar and salt in processed foods (5). Increased access to food and snacks may have led to habitual and mindless overeating (6). Rather than eating three meals a day, approximately 20-35% of Americans consume food hourly or every hour and a half (7).

"Calories in, calories out" (CICO) has been a leading theory of weight balance. According to CICO, the effects of food on weight gain can be entirely explained by calorie count. In other words, what matters is the quantity, and not quality, of the calories consumed (5). However, recent studies have shown that foods vary in their effects on hormones, metabolism, neural activity, calorie absorption, and psychological states (8, 9). Sugary beverages and processed foods are known as Highly Palatable Food (HPF), which is characterized by combinations of fat, salt, and simple carbohydrates. Overconsumption of HPF causes changes in brain pathways involved with rewards and reactions to stress (8). Consuming energy in liquid form may elicit incomplete energy compensation, displacement of more satiating foods, and passive (mindless) caloric overconsumption, thereby promoting weight gain and obesity (10). Consumption of sugar-sweetened beverages (SSB) is associated with weight gain in both children and adults (10).

HPF, especially the combination of sugar and fat, has been shown to create addictive behavior. In behavioral experiments, lab animals chose sweetened water over cocaine (11, 12). HPF also interacts with affective behavior. Humans placed on a high-fat diet for one month report increased anger and hostility when switched to a low-fat diet (13). Normal-weight individuals decrease their food intake when experiencing anxiety and depression, whereas overweight individuals often increase their food intake (9). This suggests that some people consume food to self-medicate negative emotions. The effects of HPF are dynamic and can lead to changes in cravings and learned behavior, resulting in a food addiction (**Figure 1**) (14).

The focus of this paper is hedonic or reward-based food addiction, characterized by a lack of control overeating, a preoccupation with food, and a lack of satiety. The mechanism underlying reward-based addiction to HPF involves both hormones and neurotransmitters (8). One model proposes that sugar intake triggers a glucose spike and leads to the release of dopamine, a neurotransmitter that conveys feelings of pleasure, into the nucleus accumbens of the brain (9). This glucose spike also leads to an insulin reaction, lowering blood-sugar levels by turning glucose into fat. Low levels of glucose are accompanied by fatigue, low energy, poor concentration, and hunger. Repeated exposure

Figure 1. Sugar Addiction Cycle. This is a simplified model of one component of sugar addiction, based on the reward aspects of sugar consumption and the pancreatic response of insulin release, which results in lower blood glucose and greater hunger. Adapted with permission from King, 2013.

to sugar or HPF downregulates dopamine receptors in the nucleus accumbens. With fewer dopamine receptors, more food is required to produce the same level of satisfaction (10). Over time, external cues such as the sight, smell, or description of HPF start to signal the opportunity for reward. Strong reward-based temptation can be difficult to resist and can cause cognitive distortions that justify consumption or overeating (13).

HPF, including SSB, are ubiquitous. In 2006, 86% of US high schools had vending machines that sold SSBs (15). An accounting of beverage sales at San Francisco University High School, with a student body of approximately 400, found that the average daily cafeteria sales were 20-30 bottles of water, 70 bottles of soda, and 53 bottles of juice (conducted by the author). This count is likely an underestimate, as it excludes caffeinated beverages with added sugar such as coffee and tea. Two possible inferences from the higher rate of SSB (compared to water) are that students may be unaware of the negative effects of SSB or that they have become dependent on SSB.

High school can be a place where lifelong habits develop; yet, little is known about the factors that relate to sugar consumption in high school students and whether gender plays a role. No prior research has addressed the role of gender, and thus this study hypothesizes on a purely exploratory basis that males and females will differ in their rates of reward-based eating, sugar craving, consumption of sugar, and knowledge of the adverse effects of sugar. Such differences may occur due to differences in hormones and social messaging, and due to the cultural emphasis on slimness in females. This study further hypothesizes that possessing knowledge of the adverse effects of sugar consumption will be negatively associated with actual consumption of sugar.

RESULTS

This study used survey methodology to evaluate the relationships among Reward-based Eating Drive (RED), Cravings for Sugary Drinks (craving), Sugary Foods Eaten (consumption), and Knowledge of Sugar's Effects on Brain and Body. Correlation and multiple regression were used to describe relationships among the variables, and t-test was used to identify gender differences. The analyses identified gender differences in RED, but not in craving, consumption, or knowledge of sugar's effects. In females, knowledge was inversely associated with consumption.

The correlation coefficients between measures (Pearson's *r*) were modest, but are generally in the expected directions (**Table 1**). Reward-Based Eating Drive was positively correlated with both cravings and consumption of sugar, and these were positively correlated with each other. Knowledge of sugar's adverse effects was negatively correlated with consumption. Next, the joint association of Reward-Based Eating Drive and Craving for Sugary Beverages with sugar consumption (SFEQ) was evaluated using multiple regression. Although both RED and craving were associated with consumption individually (**Table 1**), when evaluated together, only craving was significantly associated with consumption in the regression model ($p<0.001$) (**Table 2**). This means that the association of RED with consumption is mostly accounted for by the association of craving with consumption.

Effects of Gender

On an exploratory basis, analyses were conducted using sex as a variable. Males and females did not strongly differ on the SFEQ (both genders reported consuming sugary

Pearson Correlation Coefficients/Probability				
	RED-13	SFEQ	CSBQ	KSEBBQ
RED-13	1	r=0.163 p=0.032	r=0.257 p=0.001	r=-0.098 p=0.200
SFEQ		1	r=0.382 p<0.001	r=-0.224 p=0.003
CSBQ			1	r=-0.066 p=0.393
KSEBBQ				1

Table 1. Correlations between sugary food consumption, craving, and reward based eating.

	b	*SE*	*Beta*	*t value*	*p*
Reward-based Eating (RED-13)	0.118	0.109	0.071	1.09	*0.2375*
Craving (CSBQ)	0.3701	0.072	0.366	5.12	*<0.0001*

Table 2. Predictors of sugary food consumption

foods, on average, between 1–3 times per month and once a week, $p>0.55$). Males and females did not differ on the CSBQ (mean ratings indicated "Slight or mild craving, $p>0.36$) or on the KSEBBQ (mean ratings indicated "a little knowledge", p>0.36). However, significant gender differences were found on the RED scale (t=-3.22, $p<0.002$). The means were 1.35 for males (SD=0.65) and 1.73 for females (SD=0.77) (**Figure 2**).

We then conducted analyses within sex, even though there were no interactions found between sex and the associations among other variables (data not shown). Craving was significantly and positively correlated with sugary food consumption for both females and males ($r>0.036$, $p<0.001$). Reward-based eating was positively associated with sugary food consumption for females ($r=0.24$, $p<0.02$), but not males ($p>0.1$). When craving and reward-based eating were put in the statistical models together and ran separately for females and males, only craving remained a significant predictor of sugary food consumption ($p<0.001$).

Males and females also differed in whether their knowledge of sugar's effects on the brain and body was related to their sugary food consumption. For males, knowledge was insignificantly correlated with consumption (r=-0.17, $p>0.1$). For females, knowledge of sugar's effects was significantly inversely correlated with consumption of sugary food (r=-0.3, $p<0.002$).

DISCUSSION

Not surprisingly, craving was significantly correlated with consumption in the full sample and for both males and females. This finding could be interpreted to mean that craving has a causal effect on consumption, or that consumption exacerbates cravings. This dynamic would be consistent with the theoretical model of sugar addiction, which states that repeated consumption of sugar creates craving by altering dopamine and insulin.

Females demonstrated a higher reward-based eating drive than males. This may put females at higher risk for sugar addiction. However, craving was a stronger predictor of sugary food consumption than reward-based eating. This finding suggests that potential interventions should focus on strategies to manage cravings for sweets, including warning consumers that stopping consumption of HPF can result in short-term negative emotions and irritability. Females who reported greater knowledge of sugar's effects on the brain and body also reported consuming less sugary food. This is a clear indication it is important to educate people on sugar's effects on the brain and body in order to reduce sugar consumption.

In this study there were too few older subjects to meaningfully address age differences. Future research might be directed toward discovering if there are differences between younger and older populations. In addition, this study looked at data collected at only a single time point. Significant correlations that were found cannot be interpreted as causation. Thus, our interpretations must consider that causation may have occurred from either direction, or may have occurred from the effects of a third variable.

The results here are preliminary but promising in suggesting links between cravings, reward-based eating, sex, and sugar consumption. More research should also be conducted to determine if the gender differences reported here will be found in different populations and in longitudinal designs. If these findings are replicated, they could be used to support targeted educational efforts, such as heavier delivery of internet materials to females. Better dissemination of the known effects of sugar and other HPFs may help to reduce consumption and thus lead to a decrease in the size of overweight and obese populations.

METHODS

Study Participants

Our study enrolled 176 participants, including 144 UHS students (approximately 36% of the student body) and 32 faculty/staff (out of 61 faculty and unknown number of staff). 64 participants identified as male, 108 as female, and 4 as other.

Data Collection

The study collected anonymous data and thus was not subject to human subjects protection. Surveys are a feasible means of gathering large amounts of data anonymously, and are a commonly used method of gathering data on the variables of interest via self-report. For the first three

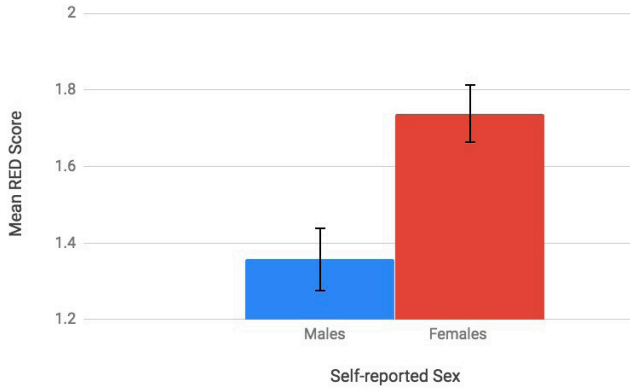

Figure 2. Differences in reward-based eating drive between males and females. On average, females had a higher RED score than males ($p<0.05$, t-test), implying that females experience greater reward-based eating drive than males.

instruments described below, we adapted a paper self-report form for use with an online administration. A questionnaire that included all study measures was entered into Surveymonkey. A link was sent to all UHS students and faculty/staff, inviting recipients to voluntarily respond to the questionnaire.

The Reward Based Eating Drive (RED-13) Scale (16).

This 13-item, 5-point scale, self-report measures reward-related eating including food preoccupation, uncontrolled eating, and binge-eating. Response options include: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. It is positively correlated with BMI, Type 2 diabetes, and cravings for sweet/savory foods (17).

Sugary Foods Eaten Questionnaire (SFEQ, 18).

This questionnaire assesses how many sugary foods are being consumed. It is a 3-item self-report with a 7-point scale. Response options to how many times the participant consumes sugary foods include: never, once or twice, 1-3 times per month, once a week, 2-4 times a week, about once a day, and twice a day or more.

Cravings for Sugary Beverages Questionnaire (CSBQ, 19)

This questionnaire measures how much the respondent is thinking about sugary drinks. It is a 4-item self-report with a ranging 5–7-point scale. Response options range from: almost never to almost all the time (measuring availability of SSB and frequency of craving) and from: no urge to strong urge (measuring intensity of craving).

Knowledge of Sugar's Effects on Brain and Body Question (KSEBBQ).

This is a single item self-rating with a 4-point scale, developed by the authors, of amount of knowledge of food's effects on the brain and body. Response options include: not knowledgeable at all, a little knowledgeable, fairly knowledgeable, and very knowledgeable.

Statistics

All data analyses were conducted by a statistical consultant (LJP), using SAS 9.4 (20). First-order relationships among survey measures were evaluated using Pearson correlations (PROC CORR). Concurrent prediction of sugary food consumption was evaluated using multiple regression (PROC REG). Sex differences were evaluated using t-tests. T-test was conducted using PROC GLM (generalized linear model) to allow for unequal variances and n. Analyses were required to use only cases without missing data, and only two cases had data missing from any analysis.

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