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Effects of addictive-like eating behaviors on weight loss with behavioral obesity treatment

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Abstract To examine the relationship between food cravings and food addiction as defined by the Yale Food Addiction Scale (YFAS) and to assess the effects of these variables on weight loss during a 14-week group lifestyle modification program. Data were from 178 participants who were prescribed a 1000–1200 kcal/day portion-controlled diet and provided with weekly group lifestyle modification sessions. Participants completed the Food Craving Inventory and YFAS pre- and post-treatment. Weight was measured weekly. Participants with YFAS-defined food addiction (6.7%) reported more frequent overall food cravings relative to those without food addiction. More frequent food cravings at baseline were associated with less weight loss over the 14 weeks. Analyzed categorically, participants in the highest tertile of baseline food cravings lost $7.6 \pm 0.5\%$ of initial weight, which was significantly less compared to those in the lowest tertile who lost $9.1 \pm 0.5\%$. Percent weight loss did not differ significantly between participants with YFAS-defined food addiction ($6.5 \pm 1.2\%$) and those who did not meet criteria ($8.6 \pm 0.3\%$). Addictive-like eating behaviors significantly declined from pre- to post-treatment. Participants with frequent food cravings lost less weight than their peers. Targeted interventions for food cravings could improve weight loss in these individuals. Few participants met YFAS-defined criteria for food addiction. Addictive-like eating behaviors tended to decline during behavioral weight loss, but neither baseline nor change in YFAS scores predicted weight loss.

Keywords Obesity · Cravings · Weight loss · Food addiction · Treatment

Introduction

Addictive-like eating is commonly described by patients as a contributor to their obesity and barrier to weight loss (Hammarström et al., 2014; Ruddock & Hardman, 2017). "Food addiction" is most frequently measured with the Yale Food Addiction Scale (YFAS) which conceptualizes addictive-like eating as eating patterns that share behavioral similarities with substance use disorders (Gearhardt et al., 2009a, b). The YFAS was developed by applying the seven criteria for substance dependence from the Diagnostic and Statistical Manual of Mental Disorders (DSM) IV-TR to food and eating behaviors (Gearhardt et al., 2009b). The YFAS defines addictive-like eating using the following criteria: giving up or reducing important social, occupational, or recreational activities due to issues with certain foods or eating; taking the substance in larger amounts and for a longer period than intended; persistent desire or repeated unsuccessful attempts to quit; much time/activity to obtain, use, recover; withdrawal symptoms when cutting down on certain foods; use despite knowledge

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of adverse consequences; and tolerance. On the YFAS, a diagnosis of food addiction is made if individuals endorse at least three dependence symptoms and have clinically significant impairment or distress. In 2013, the American Psychiatric Association updated the criteria for substance use disorders to include cravings, a strong desire or urge to use a substance (American Psychiatric Association, 2013). While craving is a core feature of substance use disorders, the empirical basis for adding this criterion to the food addiction diagnosis has not been well investigated.

A food craving is defined as an intense desire to consume a particular food or food type that is difficult to resist (White et al., 2002). Food cravings are commonly reported among individuals with obesity and are associated with more frequent consumption of craved foods and with increased body mass index (BMI) and weight gain (Boswell & Kober, 2016; Chao et al., 2014). In studies of community- and internet-based samples, more frequent food cravings were related to symptoms of and a diagnosis of food addiction on the YFAS (Joyner et al., 2015; Meule & Kübler, 2012). It is not clear whether individuals with obesity who meet YFAS criteria for food addiction have more frequent food cravings relative to those with a similar BMI who do not meet criteria. More studies are needed to assess the relevance of cravings to the food addiction construct.

In addition, research is needed on the effects of both food cravings and addictive-like eating behaviors on weight loss. While food cravings tend to decrease with weight loss (Kahathuduwa et al., 2017), findings are inconsistent concerning whether food cravings are associated with attrition and weight loss during obesity treatment (Batra et al., 2013; Buscemi et al., 2017; Gilhooly et al., 2007; Martin et al., 2006; Moldovan et al., 2016; Smithson & Hill, 2016). In addition, higher addictive-like eating (as measured by the YFAS) has been linked with poor weight loss during obesity treatment in some (Burmeister et al., 2013; Tompkins et al., 2017), but not all studies (Lent et al., 2014; Sawamoto et al., 2017).

One source of variability in study findings may be the type of dietary prescription used. Prior studies that examined the relationship of YFAS-defined food addiction and weight loss focused primarily on behavioral weight loss treatments, which combine diet, exercise, and behavior modification (Burmeister et al., 2013; Sawamoto et al., 2017; Tompkins et al., 2017). Lent et al. (2014) examined the effect of YFAS-defined food addiction on weight loss in two outpatient treatment programs. The first program included meal replacements and lifestyle intervention, and the second included an enhanced behavioral treatment that included emotion regulation and mindfulness. Lent et al. (2014) found that YFAS status and symptoms were not statistically associated with weight loss. The study analyses included a statistical control for type of treatment, but results were not presented separated by treatment.

The present study extends the literature by examining the relationships of food cravings and YFAS-defined food addiction to weight loss achieved with a structured dietary plan that incorporated meal replacements with behavioral obesity treatment. Meal replacements help address several challenges related to weight loss and can help improve outcomes relative to isocaloric diets of conventional foods (Heymsfield et al., 2003; Keogh & Clifton, 2005).They typically provide 1000–1200 kcal/day in the form of liquid shakes, meal bars, and prepared entrees (Heymsfield et al., 2003). The food is portion-controlled, so people know precisely how many calories they are consuming and can avoid the calorie underestimation commonly seen with conventional foods (Lichtman et al., 1992). Meal replacements may help to reduce foods cues by decreasing the number of food choices and the possibility of higher calorie food selections. Since the shakes and pre-prepared entrees require little preparation and effort, their use may provide more time to focus on social, occupational, or recreational activities that promote positive weight management practices. The rigid structure and restricted nature of meal replacements, however, may be challenging for individuals with frequent food cravings and those who meet criteria for food addiction, as suggested by research on dietary restraint (Polivy & Herman, 1985; Ruderman, 1986). Disruption of dietary restraint may result in overeating or binge eating. Similarly, in the case of substance use disorders, cravings appear to play a central role in drug relapse (Niaura, 2000).

This study had three aims. The first which was to examine whether individuals with YFAS-defined food addiction had increased levels of total food cravings and cravings for specific food types (e.g., sweets, high fats). We hypothesized that participants who met YFAS criteria for food addiction would have more frequent food cravings relative to individuals who did not meet criteria. The second aim was to assess the effects of baseline food cravings and YFAS-defined food addiction on attrition and weight loss during a 14-week group lifestyle modification program that included a 1000–1200 kcal/day meal-replacement diet. We predicted that individuals with more frequent baseline food cravings would have greater attrition and lose less weight at 14 weeks than those with less frequent cravings. We assessed the same hypothesis for food addiction. The third aim explored whether changes in food craving frequency or food addiction symptoms were associated with weight loss. We anticipated that greater reductions in food cravings and YFAS-defined food addiction would be associated with more weight loss.

Methods

Study design

Details of the parent study have been described previously (Chao et al., 2017; Tronieri et al., 2017, 2018). The present investigation used data from a prospective, single-arm study of a 14-week group behavioral weight loss program with a structured meal replacement diet (Health Management Resources; HMR800). The program was designed to induce a ≥ 5% loss of initial body weight (Wadden et al., 2004, 2011).

Participants

Major inclusion criteria were: being ≥ 21 and ≤ 65 years of age; having a body mass index (BMI) ≥ 33 and ≤ 55 kg/m^2 or (BMI ≥ 30 kg/m^2 with an obesity-related comorbidity); and receiving routine medical care from a primary care provider. The primary exclusion criteria were: clinically significant medical or psychiatric conditions that would contraindicate weight loss; diabetes; pregnant or nursing; current major depressive episode, active suicidal ideation, or history of suicide attempts; antidepressant or antipsychotic use in the past 14 days; ≥ 10 lb weight loss within the past 3 months; history or plans for bariatric surgery; or inability to walk 5 blocks.

Procedures

Participants were recruited via local advertisements. Eligibility was assessed using a telephone prescreen and in-person screening visit. At the screening visit, informed consent was obtained, and participants completed a behavioral evaluation with a clinical psychologist. Participants then met with a study nurse practitioner or physician to complete a medical history and physical exam. Applicants were enrolled if they met eligibility criteria and confirmed their desire to participate in the study. The study was approved by the University of Pennsylvania Institutional Review Board.

Behavioral weight loss intervention

Participants were provided 14 weekly, 90-min, in-person group lifestyle modification sessions, as described previously (Wadden et al., 2004). Groups consisted of 10–15 participants and were led by registered dietitians or psychologists. At week 1, participants were instructed to record their dietary intake and make modifications to prepare their home for the meal replacement program. From weeks 2 to 12, they were instructed to consume a

1000–1200 kcal/day diet that consisted of four servings daily of chocolate or vanilla liquid shakes (HMR; 160–170 kcal per shake), a prepackaged (or frozen) food entrée (250–300 kcal), 1–2 servings of fruit, and a side salad (Wadden et al., 2004, 2011). This diet was selected because it increases weight loss by approximately 3 kg as compared to a 1200 kcal/day diet comprised of conventional foods (Heymsfield et al., 2003). Participants were provided with the liquid shakes and frozen food entrees free of charge. From weeks 12–14, participants were prescribed a refeeding diet that gradually replaced the consumption of shakes with conventional foods, so that the use of meal replacements was terminated by week 14. Beginning at week 6, participants were encouraged to gradually increase their physical activity to reach 175 min/week by week 14. Group sessions were conducted at the University of Pennsylvania's Center for Weight and Eating Disorders, following a protocol adapted from prior studies (Wadden et al., 2004, 2011).

Measures

At each clinic visit, weight was measured on an electronic scale (Detecto, model 6800A) with applicants dressed in light clothing, without shoes. Height was assessed with a wall-mounted stadiometer (Veeder-Root, Elizabethtown, NC). Each measure was performed twice, and the averages were used to calculate each participant's BMI. Approximately 1–2 weeks before starting the weight loss program, participants completed a set of questionnaires. Questionnaires were repeated at an assessment visit at week 14. Demographic data on age, gender, and race/ethnicity were collected using a form designed for this study.

Food cravings were measured with the Food Craving Inventory (FCI) (White et al., 2002), a validated and reliable measure that asked about cravings for specific foods over the past 28 days. Craving frequency was assessed on a scale of 1 (never) to 5 (always/almost every day). The FCI generates a total score and subscale scores for high fats, sweets, complex carbohydrate/starches, and fast-food fat cravings. The Cronbach's alpha for the total score was 0.92. The Cronbach's alpha for the subscale scores were: high fats = 0.80; sweets = 0.86; complex carbohydrates/starches = 0.81; and fast-food fats = 0.67.

Food addiction was assessed using the original version of the Yale Food Addiction Scale (YFAS). This is a 25-item instrument that applies the DSM-IV-TR criteria for substance use to food and eating behaviors, and does not include questions on food cravings (Gearhardt et al., 2009b). The measure was scored using a symptom count ranging from 0 to 7, with higher scores indicating more symptoms of dependence (i.e., consumed more than planned; continued use despite physical or psychologic prob-

lems; desire or repeated failed attempts to reduce or stop consumption; great deal of time spent in activities necessary to obtain, use, or recover; giving up other important activities; tolerance; withdrawal). On the YFAS, a diagnosis of food addiction was given to persons who endorsed three or more symptoms of dependence and reported impairment or distress due to these behaviors. In this sample, the Kuder–Richardson's alpha was 0.71. Participants were also asked to select all foods that they have problems with from a list of 26 items (e.g., pizza, cookies, cakes).

Statistical analysis

Analyses were performed using SPSS version 24.0 (Armonk, NY). Correlations, Fisher's exact tests, independent t-tests, and Mann–Whitney U tests were used to examine the relationship among food cravings, YFAS-defined food addiction status/symptom count, and attrition. Analyses for food cravings were also repeated using two-sample bootstrapped resampling based on 1000 replicates and bias corrected and accelerated (BCa) 95% confidence intervals. Participants were classified into an attrition group if they did not attend any visits after week 10.

To assess the effects of baseline food cravings and YFAS-defined food addiction on percent weight loss over the 14 weeks, we used intention-to-treat linear mixed models with an unstructured variance covariance form. Separate models were used to examine the variables of interest (i.e., food cravings and food addiction). Analyses were conducted with and without adjustments for demographic and clinical variables that may influence weight loss (i.e., race, gender, age, and baseline BMI). Supplementary analyses were also conducted using a continuous YFAS symptom count and tertile scores of baseline food craving frequencies to predict percent weight loss.

Paired t-tests were used to examine changes in food cravings and YFAS symptoms over time. To examine whether pre- to post-treatment changes in food cravings and YFAS symptoms were associated with weight loss, we conducted a completers analysis with food cravings and food addiction entered as time-varying variables. Ad hoc analyses were also conducted to examine change in food craving and YFAS scores based on tertile scores of baseline food cravings. Statistical significance was defined as a $p < 0.05$.

Results

Participant characteristics

Recruitment yielded 1034 program applicants who were screened via phone for eligibility. From this sample, 324 were scheduled for an in-person assessment, resulting in enrollment of 178 participants. The most common reasons participants were excluded after the phone screen were being not interested in the study or unavailable (n = 200), medical/behavioral exclusion (n = 183), or BMI out of range (n = 179). Medical/behavioral exclusions (n = 45) or lost to follow-up (n = 72) were the most common reasons participants were excluded from enrollment. Participants had a mean age of 44.2 ± 11.2 yr and baseline BMI of 40.9 ± 5.9 kg/m² (Table 1). Most of the sample was female (87.6%), and 71.3% of participants were black, 21.9% white, and 6.8% were categorized as other race/ethnicity. The most common co-morbidities were hypertension (53.9%) and dyslipidemia (46.1%).

The mean ± standard deviation (SD) for the FCI total score was 2.3 ± 0.7. The averages for the FCI subscales are presented in Table 2. Of the total sample, 83.7% reported having cravings for all four types of food, 8.4% reported cravings for 3 of the food types, 1.1% for 2 food types, and 2.2% for only 1 type of food. Only 1.1% of participants reported never having any cravings for any of the foods in the past 28 days. Participants had the highest cravings for fast food fats. The most frequently craved

Table 1 Participant characteristics (N = 178)

Sex (female)	156 (87.6)
Race	
Black	127 (71.3)
White	39 (21.9)
Other	12 (6.8)
Age (years)	44.22 ± 11.19
Baseline weight (kg)	114.63 ± 20.99
Baseline BMI (kg/m²)	40.94 ± 5.92
Hypertension[a]	96 (53.9)
Dyslipidemia[a]	82 (46.1)
Arthritis	35 (19.7)
Asthma	30 (16.9)
Gastroesophogeal reflux disease	30 (16.9)
Obstructive sleep apnea	26 (14.6)
Hypothyroidism	10 (5.6)
Gallbladder disease	10 (5.6)

Mean ± SD or N (%)

[a]Includes individuals taking medication for the disorder, self-reported history of the disorder, and people who had lab values that would meet criteria for the disorder

Table 2 Food craving, Yale Food Addiction Scale (YFAS) symptoms, and weight at baseline and changes from pre- to post-treatment

	Baseline[a]		Pre-treatment[b]		Post-treatment[b]		p value[c]
	M	SD	M	SD	M	SD	
Cravings[d]							
Total	2.25	0.65	2.24	0.66	1.87	0.55	< 0.001
Sweets	2.35	0.83	2.32	0.84	1.86	0.69	< 0.001
High fats	2.09	0.72	2.08	0.73	1.81	0.63	< 0.001
Complex carbs/starches	2.11	0.77	2.11	0.78	1.70	0.63	< 0.001
Fast-food fats	2.67	0.81	2.66	0.82	2.32	0.75	< 0.001
YFAS symptoms[e]	2.28	1.55	2.24	1.58	1.93	1.24	0.02
Weight (kg)	114.40	20.95	114.62	22.53	104.12	20.84	< 0.001

[a]Includes entire baseline sample (N = 178)

[b]Includes individuals who completed the post-treatment assessment (n = 138)

[c]The p value value is from paired-tests for individuals who completed both the pre-treatment and post-treatment assessment (n = 138)

[d]Scores range from 1 (never) to 5 (always/almost every day)

[e]Scores range from 0 to 7 with higher scores indicating more dependence symptoms

foods were chips, pizza, fried chicken, French fries, and chocolate.

We have reported the prevalence of YFAS-defined food addiction for this sample previously (Chao et al., 2017). Twelve of the 178 (6.7%) participants met YFAS criteria for food addiction. The average number of food addiction symptoms in the total sample was 2.3 ± 1.6 out of a potential 7 symptoms (Table 2). On the YFAS, participants endorsed having the most problems with controlling their intake of chips (52.2% of the total sample), cookies (43.3%), French fries (42.1%), ice cream (40.4%), and cake (37.1%). Participants selected an average of 6.2 ± 4.0 of the 26 foods listed on the YFAS as contributing to problematic eating. Demographic characteristics (i.e., age, sex, race) and BMI were not significantly different between individuals who did and did not meet criteria for food addiction on the YFAS (ps > 0.05).

Relationships between food cravings and food addiction

Compared to participants who did not meet YFAS criteria for food addiction, individuals who met criteria had significantly higher total food cravings (p = 0.01), as well as cravings for sweets (p = 0.001), complex carbohydrates/starches (p = 0.01), and fast-food fats (p = 0.01). Cravings for high-fat foods did not differ between groups (p = 0.28; Fig. 1). The BCa confidence intervals for the mean difference in food cravings between participants who did and did not meet criteria for YFAS-defined criteria for food addiction were as follows: total (0.17, 0.89); sweets (0.36, 1.21); complex carbohydrates/starches (0.05, 1.09); fast-food fats (0.11, 0.83); and high fats (− 0.22, 0.73). YFAS symptoms were positively correlated with total food crav-
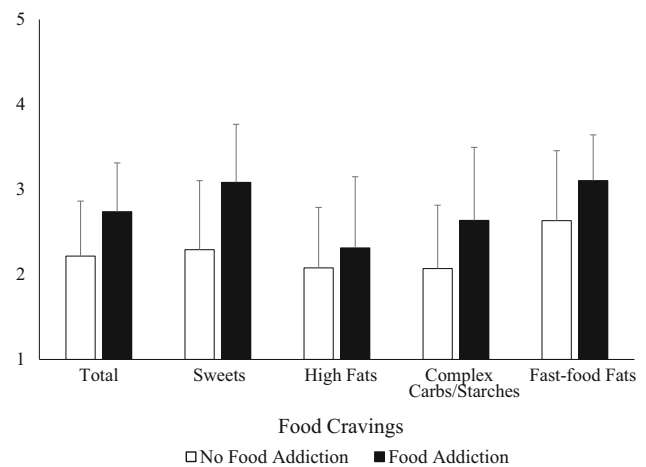

Fig. 1 Mean ± SD values for total food cravings and cravings for specific food types between individuals who did (n = 12) and did not meet criteria (n = 166) for food addiction as defined by the Yale Food Addiction Scale. Scores range from 1 (never) to 5 (always/almost every day)

ings (r = 0.21, p = 0.007), sweet cravings (r = 0.25, p = 0.001), and complex carbohydrate/starch cravings (r = 0.19, p = 0.01). YFAS symptoms were not significantly correlated with high fat cravings (r = 0.08, p = 0.28) or fast-food fat cravings (r = 0.15, p = 0.05). Selecting more foods as problematic on the YFAS was correlated with reporting higher total food cravings (r = 0.51, p < 0.001).

Effects on attrition of food cravings and addiction

Of the 178 participants who began treatment, 150 participants completed the 14-week behavioral weight loss pro-
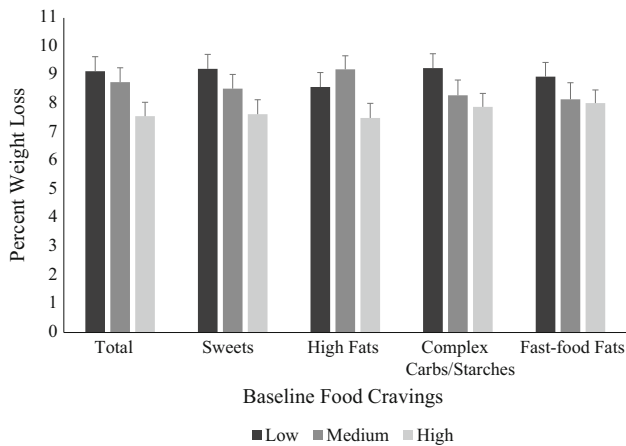
Fig. 2 Percent weight loss estimates (mean ± SE) at week 14 based on tertile scores from baseline food cravings (N = 178). Results are from linear mixed models and adjusted for race, gender, age, and baseline BMI

gram (84.3%). Total food cravings at baseline did not differ between individuals who did and did not complete the program ($p = 0.63$). Specific cravings for high fats, sweets, complex carbohydrates/starches, and fast-food fats did not differ between those who completed and did not complete the program ($p = 0.86, 0.80, 0.63$, and 0.33, respectively). Baseline YFAS-defined food addiction status was not significantly associated with attrition ($p = 0.10$); four (33.3%) participants who did and 24 (14.5%) who did not meet criteria for food addiction did not complete treatment. Baseline YFAS symptom count did not differ significantly between individuals who did ($2.3 ± 1.6$) and did not complete the program ($2.4 ± 1.5$; $p = 0.78$).

Effects on weight loss of food cravings and addiction

Overall, participants lost an average of $9.0 ± 0.3\%$ of initial weight over the 14 weeks. Higher frequencies of baseline total food cravings were associated with significantly lower weekly weight losses ($B = 0.07$; $SE = 0.03$; $p = 0.03$; Fig. 2). Exploratory, post hoc analyses were conducted with the FCI subscale scores. Individuals with higher cravings for sweets had significantly smaller weekly weight losses ($B = 0.67$, $SE = 0.03$, $p = 0.04$). Cravings for high fats were significantly associated with smaller weekly weight losses ($B = 0.07$, $SE = 0.03$, $p = 0.03$). More frequent baseline cravings for complex carbohydrates/starches and fast-food fats were not significantly associated with weekly weight losses ($p = 0.12$, 0.30, respectively).

Analyzed categorically, participants in the highest tertile of baseline food cravings lost $7.6 ± 0.5\%$, which was significantly less than the $9.1 ± 0.5\%$ lost by those in the lowest tertile ($p = 0.03$). Participants in the middle food

cravings tertile lost $8.8 ± 0.5\%$ of initial weight, which was not significantly different from those in lowest ($p = 0.59$) or highest tertile ($p = 0.09$). Participants in the highest tertile of sweet food cravings lost $7.6 ± 0.5\%$ of initial weight, which was significantly less than the $9.2 ± 0.5\%$ lost by those in the lowest tertile ($p = 0.03$; Fig. 2). Those in the highest tertile of high-fat cravings lost $7.5 ± 0.5\%$ of initial weight, which was significantly less than the $9.2 ± 0.5\%$ for participants in the middle tertile ($p = 0.02$). For high-fat cravings, those in the highest tertile did not differ in percent weight loss from those in the lowest tertile ($8.6 ± 0.5\%$; $p = 0.14$).

Participants who met YFAS criteria for food addiction lost $6.5 ± 1.2\%$ of initial body weight. This value did not differ significantly from the $8.6 ± 0.3\%$ lost by those who did not meet YFAS criteria for food addiction ($p = 0.09$). The continuous YFAS symptom score was not significantly associated with percent weight loss ($p = 0.13$). Results are from linear mixed models and adjusted for race, gender, age, and baseline BMI.

Changes in food cravings, food addiction, and weight loss

Among the 138 participants who completed the pre- and post-treatment assessment visit, total food cravings and cravings for high fats, sweets, complex carbohydrates/starches, and fast-food fats declined significantly from pre- to post-treatment ($ps < 0.001$; Table 2). Participants in the middle and highest tertiles of food cravings experienced significant pre- to post-treatment reductions in total food cravings ($ps < 0.001$), as well as cravings for high fats ($p = 0.01$, < 0.001, respectively), sweets ($ps < 0.001$), complex carbohydrates/starches ($ps < 0.001$), and fast-food fats ($p = 0.003$, < 0.001, respectively; Table 3). Those who were in the lowest tertile of cravings did not experience significant changes in cravings from pre- to post-treatment ($ps > 0.05$). YFAS symptoms also declined significantly from before ($2.2 ± 1.6$) to after treatment ($1.9 ± 1.2$; $p = 0.02$). Two people met criteria for food addiction post-treatment. Changes in total food cravings and YFAS symptoms were not associated with weight loss ($ps = 0.10$ and 0.80, respectively).

Discussion

Relative to other clinical samples, few participants (6.7%) in this sample of persons who sought weight loss treatment met YFAS criteria for food addiction (Pursey et al., 2014). Consistent with an addiction framework, those who met criteria for food addiction had significantly higher total food cravings than those who did not meet criteria. Par-

Table 3 Pre- to post-treatment changes in food cravings based on baseline tertile of the respective type of food craving

	Lowest tertile	Middle tertile	Highest tertile
Total	− 0.08 ± 0.31	− 0.29 ± 0.46	− 0.76 ± 0.66
p value	0.11	< 0.001	< 0.001
Sweets	− 0.03 ± 0.38	− 0.51 ± 0.46	− 0.87 ± 0.91
p value	0.62	< 0.001	< 0.001
High fat	+ 0.06 ± 0.40	− 0.21 ± 0.53	− 0.70 ± 0.71
p value	0.37	0.006	< 0.001
Complex carbs/starches	− 0.02 ± 0.30	− 0.37 ± 0.52	− 0.83 ± 0.75
p value	0.69	< 0.001	< 0.001
Fast-food Fats	+ 0.07 ± 0.52	− 0.40 ± 0.69	− 0.70 ± 0.79
p value	0.36	0.003	< 0.001

Scores are mean ± SD

ticipants with the lowest frequencies of food cravings lost 1.6% more of initial body weight than those with the highest frequencies of food cravings. YFAS-defined food addiction was not significantly related to weight loss during this lifestyle intervention that incorporated meal replacements, though the limited number of participants who met criteria for food addiction limited power to detect differences. Overall, participants who completed the follow-up assessment reported significant declines in food cravings and YFAS symptoms from pre- to post-treatment.

A growing body of literature has demonstrated behavioral and physiologic similarities (as well as differences) between substance use disorders and problematic consumption of highly palatable foods (Avena et al., 2008b; Davis et al., 2011; Long et al., 2015; Rogers, 2017; Volkow et al., 2011), and concerning how substance use disorder criteria may or may not apply to the food addiction construct (Albayrak et al., 2012; Gearhardt et al., 2009a; Garber & Lustig, 2011). In line with models of addiction (Tiffany & Wray, 2012), as well as previous studies (Joyner et al., 2015; Meule & Kübler, 2012), we found that cravings may be a component of addictive-like eating. However, the majority of this sample endorsed some level of craving, and food cravings are commonly reported in the general population (Chao et al., 2014). Conversely, cravings for substances (e.g., nicotine, alcohol) are generally thought to be uniquely associated with substance use disorders. People without substance use disorders generally do not report that they have experienced cravings for specific types of drugs (Agrawal et al., 2011). Thus, a primary differentiating factor between cravings for foods versus cravings for substances and their relation to addiction is the commonality of food cravings. Food cravings may occur outside of food addiction due to factors such as chronic stress, menstrual cycle hormonal changes, or round-the-clock advertisement of highly palatable foods (Chao et al., 2015; Krishnan et al., 2016), whereas cravings for sub-

stances are not common among those without a substance use disorder.

Further research is needed to assess the potential role of food cravings in addictive-like eating. The YFAS has been recently modified to reflect the new DSM-5 criteria for substance use disorders, including the addition of food cravings (Gearhardt et al., 2016). Additional study is warranted to determine thresholds for pathological food cravings, examine the validity of food cravings within the concept of addictive-like eating, and assess how cravings relate to the development and maintenance of addictive-like eating.

All FCI subscales were associated with YFAS-defined food addiction except the high fats foods subscale. One explanation for this is that there are differences in the addictive nature of various foods. In animal models, it has been suggested that sugar and fat may have distinct roles and mechanisms underlying addictive-like eating behaviors (Avena et al., 2009b). For example, rats with addictive-like eating of sugar experience signs of anxiety and distress (e.g., teeth chattering, aggression) if given an opiate antagonist (Avena et al., 2008a). Yet, these opiate-like withdrawal symptoms are not seen among rats maintained on fat-rich diets (Avena et al., 2009). The FCI subscales were not created based on a macronutrient analysis, and items that load onto the high fat food construct include items high in protein (e.g., fried chicken, bacon, steak), as well as those that are high in carbohydrates (i.e., cornbread). No definitive evidence has implicated particular foods or nutrients as addictive in humans.

An alternative explanation for the finding is that the foods on the high-fat food subscale are more meal-type foods compared to the snack and fast-food items listed on other subscales (e.g., cookies, candy, chips). Differences in frequencies may be the result of the availability and ease with which the food can be obtained and consumed. Additional research is needed to assess whether nutrient

composition influences addictive-like eating or whether behavioral factors may promote addictive-like eating behaviors. Since no addictive components in food have yet been conclusively identified, we agree with others about conceptualizing food addiction as a behavioral disorder, rather than a substance-based disorder, and recommend the term addictive-like eating behaviors to characterize this phenotype (Hebebrand et al., 2014; Ruddock et al., 2017). Further examination is also warranted that examines the other criteria for substance use disorder and how these apply to food.

Contrary to our hypothesis, the results of this study found that addictive-like eating behaviors were not associated with attrition or impaired weight-loss during a behavioral obesity treatment that included meal replacements. Results should be interpreted cautiously given the small number of participants (6.7%; n = 12) who met YFAS criteria for food addiction in this trial. Our low prevalence may have been attributable to study features that included our sample's demographics or the exclusion of participants if they had major medical conditions such as type 2 diabetes or major depressive disorder. However, the present findings are congruent with those of other studies in which individuals who did and did not meet YFAS criteria for food addiction did not differ in weight loss (Lent et al., 2014; Sawamoto et al., 2017). Our study expands these results by demonstrating that with a more rigid lifestyle program that used meal replacements, food addiction did not negatively affect weight loss. The use of meal replacements may have decreased contact with problem foods and subsequent addictive-like eating of these foods. The meal replacements were provided free of charge which likely decreased the time and effort necessary to obtain food.

More frequent food cravings at baseline were associated with attenuated weight loss. This suggests that individuals with more frequent cravings may have more difficulty decreasing consumption of craved foods during a behavioral weight loss program. Individuals with frequent food cravings may benefit from specific interventions that target cravings, such as stimulus control or acceptance-based behavioral techniques (Forman et al., 2007). Acceptance-based strategies focus on normalizing cravings, accepting thoughts about cravings rather than attempting to change them, redefining and stepping back from cravings, and acting in ways that are in accordance with patient's goals and values (Forman et al., 2007). These strategies may improve weight loss outcomes among patients with high levels of baseline food cravings.

Patients and providers are often concerned that food cravings may increase during weight loss and dieting, especially with dietary monotony. It has been theorized that causes of food cravings include dietary restriction and

energy deficiency (Hill, 2007). However, like other studies, we did not find support for this notion (Harvey et al., 1993; Kahathuduwa et al., 2017; Martin et al., 2006). The current investigation of a lifestyle intervention that incorporated meal replacements showed that on average, participants reported significant declines in general cravings and cravings for specific foods over the 14 weeks. Participants with higher baseline food cravings experienced significant reductions in food cravings after treatment. Those with lower baseline food cravings did not report significant declines post-treatment, likely due to floor effects. Taken together, this supports the view that, for most people, food cravings are likely the result of conditioned stimuli or cognitive processes. Weight loss interventions that disengage the pairing between stimuli and food intake appear to be effective in reducing food cravings, at least in the short-term. Further research is needed to assess the longer-term stability of these results, and to examine which components of the intervention (e.g., behavioral weight loss counseling, meal replacements, or the combination) are most effective for reducing food cravings.

This study had several limitations. The sample was predominantly female and black, few individuals met criteria for food addiction on the YFAS, and all participants were treatment-seeking and met eligibility requirements for this study, which may limit generalizability of results. The findings apply to short-term weight loss, and future studies are necessary to examine the effects of food cravings and food addiction on weight loss maintenance. The fast-food fats craving measure had low reliability in this sample, and results should be interpreted cautiously. Follow-up data on the YFAS and Food Craving Inventory were only collected on individuals at their 14-week assessment; thus, only baseline scores were available for individuals who did not complete the treatment. While baseline food cravings and YFAS symptoms did not differ between individuals who did and did not complete the program, it is possible that participants who had increases on these measures were not as likely to complete the program. This may have contributed to our non-significant findings for the relationship between change in these measures and weight loss.

In conclusion, a lifestyle intervention program that used meal replacements produced significant reductions in food cravings and YFAS symptoms. In this sample, few participants met YFAS-defined criteria for food addiction. Neither baseline nor change in addictive-like eating behaviors predicted weight losses. However, frequent food cravings at baseline appear to be a risk factor for attenuated weight loss during behavioral obesity treatment. Patients with high levels of baseline food cravings who seek weight loss may benefit from targeted interventions focused on cravings including stimuli control and acceptance-based behavioral therapy. This study supports the clinical and

diagnostic utility of considering food cravings in obesity treatment.

Compliance with ethical standards

Conflict of interest Thomas A. Wadden reports receiving personal fees for serving on advisory boards for Novo Nordisk, and Weight Watchers and has received grant support on behalf of the University of Pennsylvania from Eisai Pharmaceutical and Novo Nordisk. Thomas A. Wadden and Ariana M. Chao have received grant support on behalf of the University of Pennsylvania from Shire Pharmaceuticals. Jena Shaw Tronieri discloses serving as a consultant for Novo Nordisk. Rebecca L. Pearl discloses serving as a consultant for Weight Watchers. Naji Alamuddin, Zayna M. Bakizada, Emilie Pinkasavage, Sharon M. Leonard, Nasreen Alfaris, Robert I. Berkowitz declare no conflicts of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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