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The association of addictive-like eating with food intake in children

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ABSTRACT

Objectives: The potential role of an addictive process in problematic eating is a growing area of interest and debate. Children are more vulnerable to the negative effects of addictive substances than adults and may be at increased risk for addictive-like eating behavior. No prior study has evaluated the association of addictive-like eating with objectively measured eating behavior in adults or children. We examined the association between "food addiction" and observed food consumption among children and whether age moderated this association.
Method: Seventy children participated in an observed dinner meal, completed a dietary recall interview, and answered the Yale Food Addiction Scale for Children (YFAS-C), a questionnaire assessing symptoms of "food addiction". Children's total calories ordered, calories consumed at dinner, calories consumed post-dinner, and a total of calories consumed at dinner and post-dinner were calculated along with their BMI percentile. We used generalized estimated equation models to investigate the relationship between the YFAS-C and food consumption.
Results: Elevated "food addiction" symptoms, but not BMI percentile, were positively associated with an increased amount of calories consumed at dinner and post-dinner. Age significantly moderated the relationship between YFAS-C and caloric intake, with only younger children exhibiting this association.
Conclusions: As the first study of objectively measured eating behavior, we found addictive-like eating scores in children were positively associated with the total amount of calories consumed. Among younger children, "food addiction" was more strongly associated with the total calories consumed than BMI percentile, highlighting the importance of assessing behavioral phenotypes when evaluating caloric intake. This association between addictive-like eating and caloric intake among younger, but not older children may be due to differences in inhibitory control and dietary restraint.

1. Introduction

The potential role of an addictive process in problematic eating is an area of growing scientific interest and ongoing debate. Animal studies demonstrate that rats given highly processed foods or intermittent access to sugar demonstrate neurobiological and behavioral indicators of addiction (i.e. tolerance, withdrawal, binging, dopaminergic downgrading) (Avena, Rada, & Hoebel, 2008; Johnson & Kenny, 2010). Neuroimaging studies in adult humans suggest overlapping neurobiological systems are activated by both drugs of abuse and highly palatable food (i.e. foods with added refined carbohydrates and fats) (Volkow, Wang, Tomasi, & Baler, 2013). Individuals with problematic eating-related (e.g. binge eating disorder, obesity) and addictive behaviors exhibit similar patterns of neural reactivity to food or drug cues, respectively (Balodis et al., 2013; Stice, Spoor, Ng, & Zald, 2009; Tang, Fellows, Small, & Dagher, 2012). However, there is not a scientific consensus on whether "food addiction" is a valid concept (Avena, Gearhardt, Gold, Wang, & Potenza, 2012; Ziauddeen, Farooqi, & Fletcher, 2012) and additional research is needed. In particular, little is known about how addictive-like eating may present in children and whether "food addiction" is associated with objectively measured caloric intake.

The Yale Food Addiction Scale (YFAS) is currently the only psychometrically validated assessment tool that to operationalize "food addiction" (Gearhardt, Corbin, & Brownell, 2009). The YFAS

Abbreviations: BMI, Body Mass Index; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders IV; GEE, Generalized Estimating Equation; YFAS, Yale Food Addiction Scale; YFAS-C, Yale Food Addiction Scale for Children.

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applies the diagnostic criteria of substance dependence based upon the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (American Psychiatric Association, 2000) to the consumption of highly palatable foods (Gearhardt et al., 2009) (see Table 1 in the Supplement materials). Elevated scores on the YFAS have been associated with increased impulsivity, higher body mass index (BMI), stronger cravings for high-fat foods in adults, and more frequent self-reported episodes of binge eating (for a review see Meule & Gearhardt) (Meule & Gearhardt, 2014). Additionally, in adults, elevated YFAS scores have been linked to genetic profiles and neural response patterns implicated in addiction (Davis et al., 2011; Gearhardt et al., 2011).

Although research on whether an addictive process may contribute to problematic food consumption in adults is growing, research in children is limited. Based on the addiction literature, children are more vulnerable to the negative effects of addictive substances than adults (Lisdahl, Gilbart, Wright, & Shollenbarger, 2013). Addictive substances are more deleterious to children, in part, by disrupting the normative development of neural and psychological processes (Brown, Tapert, Granholm, & Delis, 2000; Tapert, Caldwell, & Burke, 2004). Thus, if certain foods are addictive, children relative to adults might be at increased risk for addictive-like eating behavior. Consistent with this hypothesis, a qualitative study of messages written by overweight/obese 8-to-21 year olds on an intervention website observed that responders frequently described their relationship with food in a manner that was consistent with the DSM-IV criteria for substance dependence and 66% of participants reported feeling addicted to food (Pretlow, 2011). Merlo and colleagues (Merlo, Klingman, Malasanos, & Silverstein, 2009) reported that 33% of children receiving treatment at a pediatric lipids clinic reported that they were "sometimes" or "often" addicted to food. Further, children with higher scores on the children's version of the YFAS (YFAS-C) have increased BMIs, greater self-reported levels of emotional eating, and lower satiety responsiveness (Gearhardt, Roberto, Seamans, Corbin, & Brownell, 2013). In adolescents with overweight and obesity, YFAS "food addiction" is associated with more self-reported binge eating, elevated food cravings, and higher attentional and motor impulsivity (Meule, Hermann, & Kubler, 2015).

This initial evidence provides preliminary support for the concept of addictive-like eating in children and adolescents. However, no prior study has examined whether "food addiction" is related to objectively measured eating behavior in children or adults. As addiction is associated with an increased desire for and consumption of the addictive substance (Santangelo, Barone, Trojano, & Vitale, 2013), we would predict that elevated "food addiction" in children would be associated with greater caloric intake. To address this gap in the literature, the goal of the current study was to examine the association of the YFAS-C with observed food consumption among children while controlling for BMI percentile, age, sex and race/ethnicity. Further, to investigate potential developmental differences, we conducted an exploratory analysis to test whether age moderated the association between the YFAS-C and observed food consumption.

Table 1
Participant demographics.

	N(%)	*M*	*SD*
Age (years old)		8.24	2.70
Sex			
Male	40 (57.10%)		
Female	30 (42.90%)		
BMI		20.39	6.18
BMI Percentile		71.41	31.8
Weight Category			
Underweight	3(4.84%)		
Normal Weight	27 (43.55%)		
Overweight	9 (14.52%)		
Obese	23 (37.09%)		
Ethnicity			
White	39 (55.70%)		
African American	20 (28.60%)		
Hispanic	4 (5.70%)		
Other	7 (10.00%)		

2. Material and methods

2.1. Participants

One-hundred-seventeen children were recruited from the New Haven, Connecticut community with their parents to participate in a consumer market research study on family dining preferences and eating habits. The initial aim of the study was to look at impact of menu conditions on eating behavior and the YFAS-C was not included at the beginning of data collection, as the scale had not yet been developed. The YFAS-C was added to the questionnaire battery when it became available and 70 children completed the YFAS-C. As shown in Table 1, the sample was racially and ethnically diverse. The average age of participants was 8.34 years ($SD = 2.7$; range 4–16 years of age) and 42.9% were female. Of the 70 children, the majority ($n = 41$) had at least one sibling who also completed the YFAS-C in the study. The Yale University Institutional Review Board approved this study. Parental guardians provided informed consent, and the children provided verbal assent.

2.2. Study procedures

Families were recruited for a consumer market research study on dining preferences and eating habits. Participants arrived at 5:30pm and participated in a focus group-like activity answering questions about their restaurant preferences. At the midpoint of the protocol, participants were asked to order dinner from a restaurant menu and eat a meal provided at no cost. They were told they could not take home leftovers and were not allowed to share food. Participants returned the next day to complete a dietary recall interview. Parents and children were asked to abstain from eating after 3pm on the first day of the study to standardize hunger levels. Participants were debriefed about the study aims at the completion of the protocol.

Although not the focus of this paper, the initial aim of the data collection was to examine how calorie information on restaurant menus impacted parents' and children's eating behavior. Families were randomized to one of three calorie labeling conditions: 1) a menu without calorie labels; 2) a menu with calorie labels and a label stating that the recommended daily caloric requirement for adults; or 3) a menu with calorie labels and labels stating the recommended daily caloric requirements for adults as well as children of different age ranges.

All menus displayed items from Au Bon Pain (including salads, sandwiches, beverages, and desserts) and a non-chain restaurant (including appetizers, entrees, and desserts such as mozzarella sticks, pizza, hamburgers, and cheesecake). The menus had a kid's menu section with items such as chicken fingers, sandwiches, salads, and vegetables. Calorie information was obtained from Au Bon Pain's website and the caloric content of items from the other restaurant was estimated by weighing the food with an Ohaus digital scale accurate up to +0.1 g and using the Food Processor SQL (esha Salem, OR) calorie content database. Unbeknownst to participants, their food was weighed before serving and again once they were done eating. To calculate total calories consumed, the weight of each plate collected after the meal was subtracted from the weight of each plate prior to being served. The weight of the food in conjunction with the caloric density of each item was used to calculate the caloric intake for each parent and child at the study meal.

When the families were done eating, parents received a questionnaire packet asking them to provide demographic information and information about their and their child/children's eating habits. Each child also received a short battery of questionnaires about their eating habits, including the YFAS-C, that parents could help them complete if necessary. Once the questionnaires were completed, research staff scheduled a dietary recall interview for the next day some time between 5:00pm and 8:00pm without letting participants know the interview would be asking them to recall what they ate.

The next evening, families returned to the laboratory to complete a dietary recall interview using the Multiple-Pass Method (Johnson, Driscoll, & Goran, 1996) assisted by pictures and measuring props to illustrate portion sizes. Several studies have found that the multiple-pass method is a valid measure of intake among adults and produces a valid and unbiased estimate of intake in children when parents report the child's intake (Conway, Ingwersen, Vinyard, & Moshfegh, 2003, 2004; Johnson et al., 1996). Parents were instructed to report everything they and their child/children ate the previous night after the study meal. Older children independently completed the dietary recall. Participants were then debriefed and the family was paid $15 (See the Supplement materials for additional study procedure information).

2.3. Study measures

Demographic and Eating Habits Questionnaire was a self-report questionnaire constructed for this study that asked parents to provide age, race/ethnicity, and education level. If both parents were present at the study meal, the highest education level achieved by either parent was used to create a variable reflecting family education as an ordinal variable. Study investigators classified children's race/ethnicity based on their parents' self-report.

Parents were also asked to provide self-reported height and weight for themselves and their children, which was used to calculate BMI. Children's calculated BMI was then assigned a BMI percentile based on the Centers for Disease Control age- and sex-specific growth curves, which allows the child's BMI to be compared to other children of the same age and sex (Center for Disease Control and Prevention, 2000). See Table 1 for participant demographics.

Yale Food Addiction Scale for Children (YFAS-C). Adapted from the YFAS (Gearhardt et al., 2009), the YFAS-C (Gearhardt et al., 2013) uses a lower reading level and more age appropriate content to assess signs of addictive-like eating in children. The YFAS-C includes two scoring options: a continuous count of the number of symptoms endorsed and a dichotomous “diagnosis”, which reflects the DSM-IV (American Psychiatric Association, 2000) substance dependence diagnostic criteria (i.e. three or more symptoms and clinically significant impairment/distress). The symptom count version of the YFAS-C was used in the current study to capture the full spectrum of addictive-like eating. The YFAS-C appears to have adequate internal consistency, as well as convergent and incremental validity (Gearhardt et al., 2013). The YFAS-C in the current study had good internal consistency (Cronbach's $\alpha = 0.84$). Parental guardians were given the opportunity to assist their child in completing the YFAS-C if they felt it was beyond their reading comprehension level. The average YFAS-C symptom count score in the current study was 2.2 ($SD = 1.81$, range = 0–7). Of the 70 participants, 7.2% ($n = 5$) met criteria for “food addiction.”

See Table 2 for a description of the outcome measures of ordering behavior and caloric intake.

2.4. Data analytic plan

All variables were examined for missing data and normality. The measure of total dinner calories consumed during the meal and total dinner plus post-dinner calories consumed were positively skewed. One participant's caloric consumption was identified as the single outlier for both variables ($SD > 3$ and $SD > 4$, respectively) and was removed to ensure normal distribution[1]. Of the 70 participants, BMI data were missing for eight participants and post-dinner caloric intake was missing for three participants. Therefore, sample sizes of the analyses differ slightly based on missing data.

To determine which covariates to include in a final model, we examined the relationship between the potential covariates (menu type, age, sex, and race/ethnicity) and our primary predictor variable (the YFAS-C symptom count) as well as our primary outcome variables (food ordering and intake) using t-tests, ANOVAs, and Pearson's correlations. We used generalized estimating equations (GEE) to control for the interdependence related to the inclusion of siblings in the sample SPSS 17.0 and ran two models. The first GEE model investigated the relationship between the YFAS-C and food consumption. The second multivariate GEE model examined this relationship controlling for BMI percentile, race/ethnicity, sex and age. Due to the small sample size of some race/ethnicities, we compared White participants to all non-White participants in the analyses. Although this does not allow for the comparison of effects between different non-White race/ethnicities, we thought it was worthy of exploration because of the higher obesity prevalence among African-American and Hispanic populations relative to White populations (Claire Wang, Gortmaker, & Taveras, 2011; Wang & Beydoun, 2007). Due to the wide range of ages in the current sample, we conducted exploratory analyses to investigate whether age moderated the association between the YFAS-C and our primary outcome variables. To test the interaction between age and YFAS-C, we did a median split by age where younger children (4–8 years old) were in one group ($n = 41$) and older children (9–16 years old) were in another group ($n = 29$). All significant interactions were followed up by stratifying the multivariate GEE models by age. The GEE models were also conducted with standardized variables, which provided standardized betas and confidence intervals for each variable in the model as a measure of effect size.

3. Results

3.1. Examining covariates

Table 3 summarizes the correlational relationships between the study measures of eating behaviors and food consumption with continuous demographic variables. Participants' BMI percentile was positively correlated with YFAS-C scores. Age was significantly correlated with total dinner calories ordered, total dinner calories consumed, and total dinner plus-post dinner calories consumed. Race/ethnicity was significantly associated with total dinner calories consumed ($t(67) = -2.56$, $p = 0.01$) with non-White participants ($M = 1198.90$, $SD = 513.85$) consuming more calories relative to White participants ($M = 924.18$, $SD = 376.85$). Total dinner plus post-dinner calories was also significantly different ($t(64) = -2.17$,

[1] Separate analyses were run with the outlier included in the dataset and removed. When the outlier was included, the only difference found was race/ethnicity was no longer significantly associated with caloric intake outcomes.

Table 2
Descriptive of the ordering behavior and caloric intake measures.

Measure name	Measure description	Mean	*SD*	Range
Total Dinner Calories Ordered	Sum of the calories of each menu item selected for the study meal	1869.50	739.49	630.00–4520.00
Total Dinner Calories Consumed	Computed by weighing all of the food before and after the meal	1047.82	461.20	205.42–2370.42
Total Calories Consumed Post-Dinner	Calculated based on reported intake during the dietary recall interview	68.30	135.95	0.00–661.73
Total Dinner Calories and Post-Dinner Calories Consumed	Calculated by adding total dinner calories consumed to total calories consumed post-study meal	1105.39	420.61	378.80–2370.42

Table 3
Correlations among food consumption outcome variables, BMI, age, and food addiction measured by the YFAS-C.

	YFAS-C	Total Calories Ordered	Total Dinner Calories Consumed	Total Calories Consumed Post-Dinner	Total Dinner Plus Post-Dinner Calories Consumed	Age	BMI Percentile
YFAS-C	–						
Total Calories Ordered	0.15	–					
Total Dinner Calories Consumed	0.25*	0.63**	–				
Total Calories Consumed Post-Dinner	0.03	−0.18	−0.33**	–			
Total Dinner Plus Post-Dinner Calories Consumed	0.23	0.63**	0.96**	−0.04	–		
Age	−0.01	0.29*	0.50**	0.02	0.50**	–	
BMI Percentile	0.29*	0.10	0.14	0.09	0.18	−0.04	–

*$p < 0.05$, **$p < 0.01$.

$p = 0.03$) with non-White participants ($M = 1214.88$, $SD = 478.34.61$) consuming more calories relative to White participants ($M = 1014.14$, $SD = 346.61$). Race/ethnicity was not associated with other variables of interest (all p-values > 0.12). Sex was associated with total dinner plus post-dinner calories consumed ($t(64) = 2.10$, $p = 0.04$) with male participants consuming more calories ($M = 1204.56$, $SD = 402.00$) relative to female participants ($M = 982.02$, $SD = 456.64$). Sex was not associated with all other variables of interest (all p-values > 0.24). Menu condition was not associated with the variables of interest (all p-values > 0.10). Based on these analyses, BMI percentile, race/ethnicity, sex, and age were included as covariates in the multivariate GEE models.

3.2. Outcomes

Table 4 summarizes the relationship between "food addiction" with the amount of food ordered and food consumption while controlling for covariates (i.e. BMI percentile, race/ethnicity, and age).

3.3. Total dinner calories ordered

In the first GEE model, YFAS-C was not found to be significantly associated with total calories ordered. In the multivariate GEE model, age was significantly related to ordering behavior such that older children ordered more food. The YFAS-C was a trend-level, but was not significantly associated with total calories ordered. BMI percentile, race/ethnicity, and sex were also not significantly related to total calories ordered.

3.4. Total dinner calories consumed

The YFAS-C was significantly associated with total dinner calories in the first GEE model, such that those children who consumed more calories at dinner had scores indicating a greater level of "food addiction" (see Fig. 1). After controlling for covariates, the YFAS-C continued to be significantly related to total dinner calories consumed. Age and race/ethnicity were significantly associated dinner calories eaten such that older children ate more calories as did non-White children relative to White children. BMI and sex were not significantly related to dinner calories consumed.

3.5. Total calories consumed post-dinner

The YFAS-C was not significantly associated with total calories consumed post-dinner in the first GEE model or the multivariate model. Age, BMI percentile, sex, and race/ethnicity also were not significantly related to food consumed after dinner.

3.6. Total dinner plus post-dinner calories consumed

In the first of the two GEE models, the YFAS-C was significantly associated with the total number of calories consumed at dinner plus any calories consumed after dinner (see Fig. 2). The YFAS-C continued to be significantly related to dinner plus post-dinner calories after controlling for covariates. In the multivariate GEE model, age, and race/ethnicity were both significantly associated with dinner plus post-dinner calories consumed with older children having greater food intake as did non-White participants relative to White. BMI percentile and sex were not significantly related to dinner plus post-dinner calories consumed.

3.7. Moderation effects by age

The interaction between YFAS-C and age dichotomized by a median split was significant when added to the multivariate GEE models for Total Dinner Calories Consumed ($\chi 2(1) = 7.76$; $B = -129.12$, $p = 0.005$), Total Calories Consumed Post-Dinner ($\chi 2(1) = 4.43$; $B = 48.55$, $p = 0.035$), and Total Dinner Plus Post-Dinner Calories Consumed ($\chi 2(1) = 5.37$; $B = -96.77$, $p = 0.02$). There was no significant interaction for Total Calories Ordered ($\chi 2(1) = 0.75$; $B = -104.22$, $p = 0.39$). Follow up analyses indicated that food addiction was more strongly associated with caloric intake for younger relative to older children (see Table 5). In younger children (ages 4–8), there were positive associations between the YFAS-C and Total Dinner Calories Consumed and Total Dinner plus Post-Dinner Calories Consumed, but not with Total Calories Consumed Post-Dinner. In contrast, in older children (ages

Table 4
GEE models of the amount of food ordered and food consumption.

Model/ independent variables & covariates	Total dinner calories ordered					Total dinner calories consumed					Total calories consumed post-dinner					Total dinner plus post-dinner calories consumed				
	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI
1st Model – Univariate																				
YFAS- C Total Score	1.42	0.17	−0.11 to 0.44	61.09	−39.42 to 161.59	6.37	0.25*	0.06 to 0.45	63.94*	14.3 to 113.59	0.04	0.03	−0.23 to 0.28	1.91	−17.92 to 21.75	4.71	0.23*	0.02 to 0.44	55.27*	5.36 to 105.19
2nd Model – Multivariate																				
YFAS-C Total Score	2.95	0.24	−0.03 to 0.52	88.78	−12.57 to 190.12	5.37	0.21*	0.03 to 0.38	52.61*	8.12 to 97.09	0.08	0.04	−0.22 to 0.29	2.85	−16.63 to 22.34	6.81	0.22**	0.06 to 0.39	53.65**	13.34 to 93.96
Age	11.30	0.40**	0.17 to 0.64	88.96**	37.12 to 140.81	23.71	0.58**	0.34 to 0.81	88.83**	53.08 to 124.59	0.10	0.04	−0.74 to 0.15	1.69	−9.10 to 12.49	22.00	0.62**	0.36 to 0.87	89.93**	52.36 to 127.50
BMI Percentile	0.28	0.06	−0.16 to 0.28	1.22	−3.30 to 5.58	0.87	0.10	−0.11 to 0.30	1.37	−1.50 to 4.24	1.16	0.08	−0.07 to 0.22	0.34	−0.28 to 0.95	1.42	0.12	−0.08 to 0.32	1.62	−1.05 to 4.296
Sex	0.03	−0.04	−0.59 to 0.50	−29.11	−388.30 to 330.09	1.49	0.24	−0.14–0.61	108.47	−65.63 to 282.57	0.37	0.17	−0.37 to 0.71	23.48	−51.79 to 98.75	3.32	0.33	−0.03 to 0.69	144.39	−10.97 to 299.76
Race/Ethnicity	0.94	−0.23	−0.70 to 0.24	−152.65	−460.89 to 155.60	8.69	−0.59**	−0.98 to −0.20	−270.56**	−450.41 to −90.72	1.17	0.29	−0.23 to 0.80	39.38	−31.86 to 110.62	9.07	−0.55**	−0.91 to −0.19	−239.66**	−395.67 to −83.65

*$p < 0.05$, **$p < 0.01$; Note: β = Standardized Regression Coefficient, B = Unstandardized Regression Coefficient.

9–16) there was no relationship between YFAS-C scores and calories consumed at any time point. For older children, BMI percentile was significantly associated with Total Calories Consumed Post-Dinner, but not any other measure of caloric intake.

4. Discussion

The current study is the first to explore the association of "food addiction" and objectively measured food consumption and to investigate this relationship among children. Although children with higher food addiction scores did not order more food, they did consume more calories at a dinner meal, while controlling for BMI percentile, race/ethnicity, sex and age. However, the size of the effect was small. For each additional "food addiction" symptom, a child consumed 63.94 additional calories during dinner. Although the size of the effect is small, some estimates suggest that the intake of only 148 extra calories per day can lead to a gain of 15 pounds per year (Schulte, Joyner, Schiestl, & Gearhardt, 2017). If children with higher "food addiction" symptoms consistently have greater caloric intake (even if it is relatively small in magnitude) at snacks and meals, this may result in a greater propensity for weight gain. When we examined age as a moderator, we found that this significant relationship between YFAS-C and caloric intake only occurred among the younger (not older) children. This suggests there may be important developmental contributors to consider. Developmental changes in inhibitory control may help explain this finding (Best & Miller, 2010). Younger children may be less able to inhibit their eating behavior, compared to older children. Future research is needed to investigate whether higher "food addiction" scores in younger children are associated with a positive energy balance over time and excessive future weight gain to more fully evaluate the clinical significance of the current findings. It would also be valuable to better understand how the association of the YFAS-C and food intake may change over development. Given that concerns about body weight and shape and dieting behavior increase as children get older (Davison, Markey, & Birch, 2003; McCabe & Ricciardelli, 2004; Packard & Krogstrand, 2002), it is possible older children with more addictive-like eating may have more successfully inhibited their eating behavior in this public eating context than younger children. The role of dietary restraint in the eating behavior of older children with more addictive-like eating may be an important area for future research. It is possible that older children with more addictive-like eating may be more prone to overeat in private relative to public settings.

Prior research observed that elevated "food addiction" scores in children were associated with greater emotional eating and decreased satiety responsiveness (Gearhardt et al., 2013). In adults, higher "food addiction" scores are associated with decreased activation of a neural region implicated in inhibitory control (i.e. lateral orbitofrontal cortex) during food consumption and greater activation in reward-related regions (e.g. striatum) in response to food cues (Gearhardt et al., 2011). Thus, when food is present, children with more addictive-like eating may be prone to consume more calories due to increased reward responsivity to the food, coupled with lower sensitivity to satiety cues and decreased inhibitory control. However, more research is needed to understand the mechanisms underlying the association between addictive-like eating in children and greater caloric intake.

Higher "food addiction" scores in younger children were associated with food consumption, but BMI percentile was not. Further, the association between YFAS-C scores and BMI percentile was relatively small in the current study, which further highlights the importance of considering food addiction and obesity as related, but distinct constructs. Elevated BMI can be the result of many heterogeneous contributors that can include factors other than

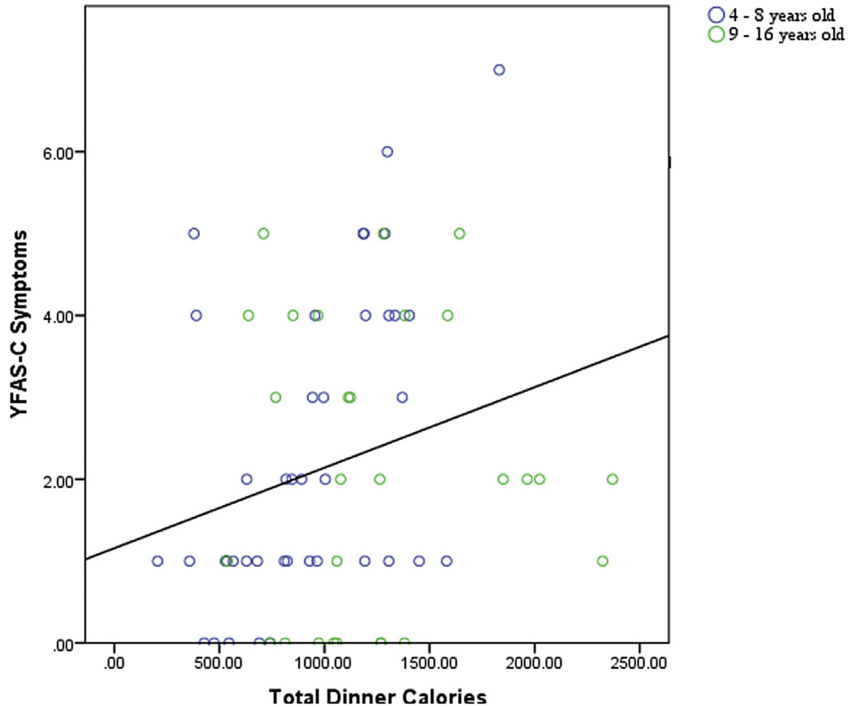

Fig. 1. Relationship between YFAS-C symptoms and Total Dinner Calories.

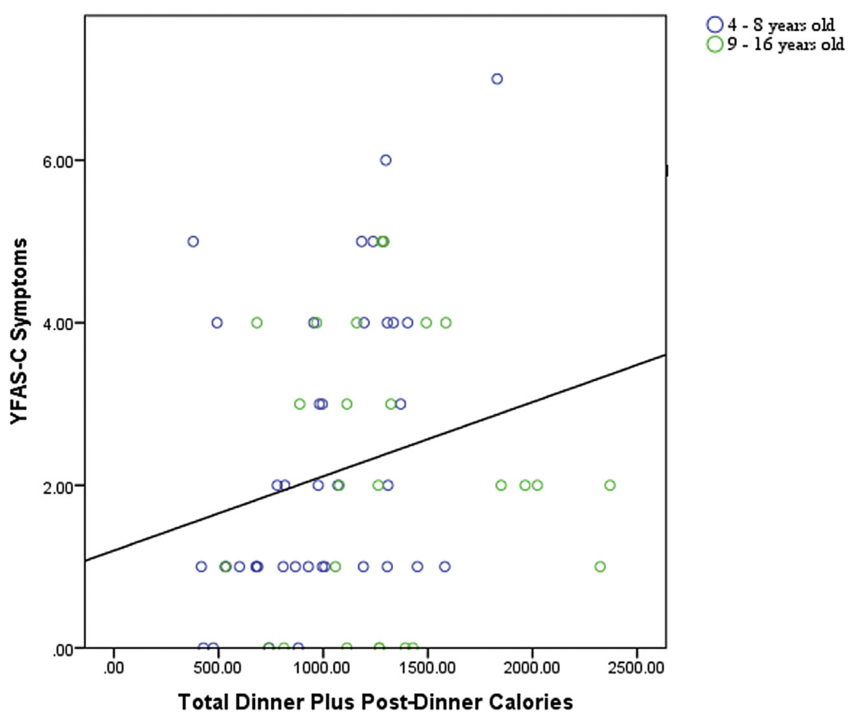

Fig. 2. Relationship between YFAS-C symptoms and Total Dinner Plus Post-Dinner Calories.

high caloric intake (e.g. genetic conditions (Frayling et al., 2007), medication side effects (Martínez-Ortega et al., 2013), physical inactivity (Williamson et al., 1993), increased muscle mass (Prentice & Jebb, 2001)). To more fully understand excess food consumption, it may be important to assess different phenotypes of eating behavior in addition to BMI. For example, Eisenstein and colleagues (Eisenstein et al., 2015) found that an emotional eating phenotype, but not BMI, was associated with dysfunction in reward-related neural functioning implicated in problematic eating (i.e. central dopamine D2 receptor binding). Thus, the assessment of behavioral phenotypes (e.g. "food addiction," emotional eating) in young children may be important for understanding risk factors for over eating behavior. In contrast, among older children (ages 9–16), there was no relationship between YFAS-C scores and caloric

Table 5
Association of YFAS-C with caloric intake stratified by age.

Younger Children (4–8 years old)															
Model/Independent Variables & Covariates	Total Dinner Calories Consumed					Total Calories Consumed Post-Dinner					Total Dinner Plus Post-Dinner Calories Consumed				
	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI
YFAS-C Total Score	9.73	0.36**	0.13 to 0.59	92.24**	8.12 to 97.09	1.92	−0.15	−0.37 to 0.06	−11.86	−28.62 to 4.91	7.91	0.18**	0.06 to 0.31	80.39**	24.39 to 136.39
BMI Percentile	2.07	0.17	−0.06 to 0.41	2.45	−0.88 to 5.78	0.02	−0.01	−0.20 to 0.17	−0.06	−0.85 to 0.73	2.43	0.01	−0.001 to 0.01	2.39	−0.62 to 5.40
Sex	2.23	0.32	−0.10 to 0.74	147.69	−46.15 to 341.53	0.78	0.26	−0.32 to 0.83	35.92	−43.79 to 115.63	4.11	0.42*	0.01 to 0.83	183.62*	6.05 to 361.18
Race/Ethnicity	2.82	−0.37	−0.79 to 0.06	−168.90	−366.17 to 28.36	0.10	0.10	−0.50 to 0.70	13.66	−69.41 to 96.73	2.97	−0.36	−0.76 to 0.05	−155.24	−331.75 to 21.27
Older Children (9–16 years old)															
Model/Independent Variables & Covariates	Total Dinner Calories Consumed					Total Calories Consumed Post-Dinner					Total Dinner Plus Post-Dinner Calories Consumed				
	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI	$\chi 2(1)$	β	95% CI	B	95% CI
YFAS-C Total Score	0.83	−0.17	−0.54 to 0.20	−43.60	−137.22 to 50.02	3.09	0.45	−0.05 to 0.95	34.53	−3.98 to 73.04	0.19	−0.08	−0.45 to 0.28	−19.48	−107.47 to 68.51
BMI Percentile	0.07	−0.06	−0.49 to 0.38	−0.84	−6.99 to 5.31	5.32	0.30*	0.04 to 0.55	1.26*	0.19 to 2.34	0.0	0.03	−0.41 to 0.46	0.34	−5.47 to 6.15
Sex	1.67	0.32	−0.24 to 1.17	214.70	−111.13 to 540.53	0.17	−0.17	−1.00 to 0.66	−24.06	−139.36 to 91.24	1.5	0.49	−0.29 to 1.26	211.43	−126.63 to 549.49
Race/Ethnicity	4.74	−1.02*	−0.1.95 to −0.10	−472.13	−897.13 to −47.12	1.03	0.47	−0.43 to 1.36	64.59	−59.88 to 189.07	3.81	−0.92	−1.84 to 0.00	−401.41	−804.45 to 1.63

$^*p < 0.05$, $^{**}p < 0.01$; Note: β = Standardized Regression Coefficient, B = Unstandardized Regression Coefficient.

intake, but BMI percentile was significantly associated with total calories consumed after dinner. Thus, a tendency to overeat may be more likely to be reflected in elevated BMI, instead of other behavioral phenotypes, as a child grows older.

The current study adds to the limited literature on "food addiction" in children. The foods that are most associated with addictive-like eating are those high in added fats and refined carbohydrates (e.g. ice cream, pizza, chocolate) (Schulte, Avena, & Gearhardt, 2015). Unlike drugs of abuse, which are more commonly used for the first time in adolescence and early adulthood (Meyers & Dick, 2010), exposure to potentially addictive foods occurs earlier in development (Bowman, Gortmaker, Ebbeling, Pereira, & Ludwig, 2004; Nickelson, Lawrence, Parton, Knowlden, & McDermott, 2014). For example, Pan and colleagues (Pan et al., 2014) found that 25.9% of infants had been fed a sugar-sweetened beverage in their first year of life. Therefore, even if foods high in added fats and refined carbohydrates are less addictive than drugs of abuse, children are being exposed to them earlier in development when their neural and psychological systems are more vulnerable (Crews, He, & Hodge, 2007; Dobbing, 1990). This earlier age of exposure may increase the likelihood that children at-risk for addictive-like eating will develop problematic patterns of food consumption.

However, it is also important to consider that the effect size of the association between "food addiction" scores and caloric intake was small in the current study. It may not only be the quantity of food that is consumed, but the relationship or attitudes towards the food that may be important in whether a child experiences clinically meaningful problems. For example, in the context of binge eating episodes, the subjective feeling of being out-of-control may be an even more important predictor of the severity of pathology than the amount of calories consumed (Himes, 2009–09). Future research would benefit from assessing how food addiction scores in children are associated with attitudes towards food and subjective experiences when eating, such as guilt, a loss of control, or a desire to restrain.

There are several limitations to consider for the current study. First, the study was cross-sectional, which limits our ability to make causal inferences. Longitudinal studies are needed to investigate whether addictive-like eating in children predicts future excessive weight gain and health-related illness. Additionally, our study relied on parent-reported height and weight to calculate participants' BMI. Participants were recruited to participate in a study regarding consumer preferences (not a study on body weight or food intake) to reduce the influence of demand characteristics on eating behavior. Given these expectations, participants may have experienced being weighed and measured as invasive. To reduce potential participant discomfort, parent-reported height and weight was used to calculate child BMI. Error in parent-reported height and weight vary in direction and magnitude across studies with an estimated average discrepancy between mean measured and mean parent-reported height and weight of ±1 cm and ±1 kg, respectively (Niego, Pratt, & Agras, 1997). The largest error of parent-report height and weight occurs in young, preschool-aged children (Akinbami & Ogden, 2009; Weden et al., 2013) and decreases with older children (Shields, Gorber, Janssen, & Tremblay, 2011; Skinner, Miles, Perrin, Coyne-Beasley, & Ford, 2013). Studies using objectively measured height and weight to calculate BMI are needed to further investigate the relationship between BMI, "food addiction", and caloric intake. The significance of these findings for clinical populations is unknown, as study participants were drawn from a community sample and only a small percentage of participants qualified for the YFAS-C "diagnostic" threshold. To understand the clinical utility of the YFAS, it will be important to examine the association of "food addiction" with caloric intake in children receiving treatment for eating-related problems (e.g. obesity). In addition, although the sample was relatively diverse, we were underpowered to directly compare different racial/ethnic minority groups. Further evaluation of the relationship between race/ethnicity and additive-like eating will be an important next step. A potential limitation of the current study is the wide age range of participants (4–16 years of age). To address potential comprehension issues for younger participants, parents were instructed that they could help their children in completing questionnaire if the child needed assistance. Parental assistance could impact the interpretation of the questionnaire; however, information regarding whether parents assisted their child was not assessed at the time of data collection. Another study limitation is that parental control over eating behavior was not assessed. Parental behavior may impact the likelihood that children will exhibit addictive-like eating and the amount of food they consume. Understanding the impact of parenting behavior on addictive-like eating behaviors in children will be an important future direction.

5. Conclusion

The current study is the first to examine whether elevated YFAS "food addiction" scores are related to objectively measured eating behavior; moreover, it is the first study to do so in children. We found that addictive-like eating in young children was positively associated with increased caloric intake, but BMI percentile was not. This was not true for older children. This highlights the importance of assessing behavioral phenotypes of eating behavior early in development. This suggests a need for future research to better understand addictive-like eating among younger children, as well as for longitudinal research that can examine whether early patterns of addictive-like eating predict future problematic eating behaviors. Future research would also benefit from investigating how developmental differences in inhibitory control and dietary restraint could impact the association between addictive-like eating and eating behavior. Although the association was relatively small, if an addictive process is contributing to higher caloric intake for some children, it will be important to develop prevention and intervention approaches that target these mechanisms.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.appet.2017.06.002.

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