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## Research report

Overeating phenotypes in overweight and obese children <sup>☆</sup>

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## ABSTRACT

The purpose of this study was to identify overeating phenotypes and their correlates in overweight and obese children. One hundred and seventeen treatment-seeking overweight and obese 8–12 year-old children and their parents completed the study. Children completed an eating in the absence of hunger (EAH) paradigm, the Eating Disorder Examination interview, and measurements of height and weight. Parents and children completed questionnaires that evaluated satiety responsiveness, food responsiveness, negative affect eating, external eating and eating in the absence of hunger. Latent profile analysis was used to identify heterogeneity in overeating phenotypes in the child participants. Latent classes were then compared on measures of demographics, obesity status and nutritional intake. Three latent classes of overweight and obese children were identified: High Satiety Responsive, High Food Responsive, and Moderate Satiety and Food Responsive. Results indicated that the High Food Responsive group had higher BMI and BMI-Z scores compared to the High Satiety Responsive group. No differences were found among classes in demographics or nutritional intake. This study identified three overeating phenotypes, supporting the heterogeneity of eating patterns associated with overweight and obesity in treatment-seeking children. These findings suggest that these phenotypes can potentially be used to identify high risk groups, inform prevention and intervention targets, and develop specific treatments for these behavioral phenotypes.

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## Introduction

Rates of childhood obesity have grown substantially over the past few decades (Ebbeling, Pawlak, & Ludwig, 2002), reaching epidemic proportions. Currently, 31% of children and adolescents in the United States are overweight or obese (Ogden, Carroll, Kit, & Flegal, 2012). Childhood obesity is associated with a number of negative health sequelae including orthopedic and endocrine conditions, cardiovascular disease, cancer, and all-cause mortality (Dietz, 1998; Key et al., 2004; Micic, 2001). Because obesity is potentially a preventable cause of disease risk, a greater understanding of etiological factors could significantly improve child and adult psychological and health outcomes.

Childhood obesity is a complex and heterogeneous condition, and the majority of research studies have examined the relationship between independent variables and weight status (Diamond & Siqueland, 2001; Dunton, Kaplan, Wolch, Jerrett, & Reynolds, 2009; Rosenkranz & Dziewaltowski, 2008). Overeating, or eating past nutritional needs, is considered a significant contributor to the childhood obesity epidemic. There is increasing evidence supporting the influence of appetitive traits such as reward sensitivity, hunger and satiety mechanisms, and food cue responsiveness on obesity risk (Berridge, Ho, Richard, & DiFeliceantonio, 2010; Jansen et al., 2003; Volkow, Wang, & Baler, 2011). These appetitive traits along with an abundance of food (such as in the current food environment) may contribute to differential caloric consumption and increased weight gain in vulnerable children.

Research suggests that there are a number of measures of appetitive traits that are associated with adiposity in children, including external eating, satiety sensitivity, eating in the absence of hunger, loss of control eating, and emotional eating (Barkeling, Ekman, &

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Rossner, 1992; Braet & Van Strien, 1997; Jansen et al., 2003). Compared to healthy weight children, obese children have increased consumption and less reduction of eating rate toward the end of a meal (Barkeling et al., 1992). Studies suggest that overweight children have increased responsivity to food cues (Bruce et al., 2010; Jansen et al., 2003) and that food responsiveness, satiety responsiveness, and emotional eating can differentiate children of different weight status (Crocker, Cooke, & Wardle, 2011; Jansen et al., 2003; Webber, Hill, Saxton, Van Jaarsveld, & Wardle, 2009). Eating related cognitions, such as loss of control eating, have also been associated with increased weight in youth (Tanofsky-Kraff, Marcus, Yanovski, & Yanovski, 2008; Tanofsky-Kraff et al., 2009, 2011). Finally, eating in the absence of hunger is associated with increased adiposity (Faith et al., 2006; Fisher & Birch, 2002; Fisher et al., 2007; Hill et al., 2008; Jansen et al., 2003). Although research to date has carefully controlled for the influence of individual factors associated with childhood obesity, these strategies cannot address multiple factors acting in concert. Additional understanding of the complexity contributing to the heterogeneity among obese children could lead to the identification of high-risk subgroups, facilitate development of targeted treatments, and serve as an index to evaluate responsiveness to those treatments.

In this study we employed latent profile analysis to examine a range of behavioral and psychological variables based on interview-based assessments, laboratory paradigms, and parent and child self-report. Latent structures were identified using child eating in the absence of hunger, child report of loss of control eating, parent report of child food responsiveness, parent report of child food satiety responsiveness, child report of negative affect eating, and child report of external eating. Latent profiles were then compared on standardized BMI, BMI percentile, and dietary intake.

## Methods

### Participants

One hundred and seventeen overweight or obese (>85 BMI-percentile) children aged 8–12 years and their parents were recruited through media announcements, advertisements, direct mailing and physician referrals in Minneapolis for two treatment studies focused on reducing overeating. Exclusion criteria included parent or child involvement in another weight loss treatment, medications that affect weight or appetite, and psychiatric and physical conditions (e.g., eating disorder, psychosis) that could interfere with participation. Participants provided written informed consent (participating parent) and assent (child). This study obtained approval through the Internal Review Board of the University of Minnesota. All participants who completed the baseline evaluation were included in this analysis. Demographics of the sample are provided in Table 1.

### Measures

#### Indicator variables

**Child eating in the absence of hunger (EAH).** The EAH paradigm was initially described by Birch and colleagues (Birch & Fisher, 2000; Fisher & Birch, 2002). Each child in this study participated in a standard ad libitum pizza dinner with their parents. Self-reported post-meal satiety was assessed with a cartoon representation of three levels of fullness (Faith et al., 2006) and two questions; children rated their level of hunger and fullness via a 1–5 scale with 1 being “not at all hungry/full” and 5 being “extremely hungry/full.” Endorsement of a 4 or 5 in fullness was required to move onto the next task. If the child was not full at a 4 or 5 level, they were encouraged to return to the meal until they were full.

**Table 1**  
Demographic characteristics of children and parents.

	N = 117 pairs
<i>Child</i>	
Sex (% female)	53%
Mean age (SD)	10.42 (1.35)
Race	
Caucasian	54%
African American	14%
Multi-Race	20%
Other	12%
BMI	27.22 (4.56)
BMI-Z	2.06 (.39)
EAH (percent of daily caloric needs)	M = 15.22 (SD = 11.60) Range = .24–96.25
<i>Parent</i>	
Gender (% female)	91%
Marital status (% currently married)	68%
Education (% college graduates)	57%
Race	
Caucasian	70%
African American	14%
Multi-Race	8%
Other	8%
BMI	31.53 (7.09)

Note: Values in parentheses are standard deviation.

Ten minutes following the completion of the meal, each child tasted and rated the palatability of small samples of 11 sweet and savory snack foods (popcorn, Cheez-its, Cheetos, potato chips, pretzels, Skittles, Hershey bars, chocolate chip cookies, Fig Newtons, jelly beans, M&M's) using cartoon illustrations of faces depicting “yummy,” “just ok,” and “yucky” (Faith et al., 2006). Following the rating of foods, the child was left alone in a room with containers holding generous pre-weighed portions of the same snack foods as well as toys and games. The child was told that s/he could play with the toys or eat any of the foods while the coordinator worked in the adjacent room. After 10 min, the coordinator returned to the room and ended the free access session. The amounts of remaining food items were measured. The total snack food calories consumed by each child was calculated from the amount consumed, and this total was divided by child's estimated daily caloric needs to derive the percent of caloric needs consumed during the free access period. Daily caloric needs were estimated using age-specific formulas for calculating estimates of energy requirements according to weight, age, height, and physical activity level (EAH%). To be conservative, a physical activity level of “low active” was used for all children in this study (National Academy of Sciences, Institute of Medicine, Food and Nutrition Board, 2005).

**Child loss of control eating (LOC).** The presence or absence of LOC eating in the past month was assessed using the Eating Disorder Examination (EDE) (Fairburn & Cooper, 1993), adapted for children (ChEDE) (Bryant-Waugh, Cooper, Taylor, & Lask, 1996). All interviewers attend a two-day training prior to administration. The ChEDE has strong inter-rater reliability and discriminant validity for eating episodes when administered in youth (Bryant-Waugh et al., 1996; Glasofer et al., 2007; Tanofsky-Kraff et al., 2004; Watkins, Frampton, Lask, & Bryant-Waugh, 2005). Children who reported either objective or subjective bulimic episodes were categorized as engaging in LOC eating, whereas children who only reported objective overeating or no episodes of overeating or LOC were classified as not endorsing LOC eating.

**Negative Affect Eating (EAH NAE).** Negative affect eating was assessed using the negative affect scale from the Eating in the Absence of Hunger Questionnaire for Parents. The Eating in the Absence of Hunger Questionnaire for Parents is a 14-item questionnaire completed by parents about their child's eating which

is designed to assess precipitants of eating when not hungry (Cronbach's alphas: 0.80–0.88) (Tanofsky-Kraff, Ranzenhofer, et al., 2008).

**External Eating (EAH EE).** External eating was assessed using the external eating scale from the Eating in the Absence of Hunger Questionnaire for Children and Adolescents. The Eating in the Absence of Hunger Questionnaire for Children is similar to the parent rating form above, but children rate their own behavior (Tanofsky-Kraff, Ranzenhofer, et al., 2008).

**Food Responsiveness (CEBQFR).** Response to external food cues was assessed using the Child Eating Behavior Questionnaire (CEBQ) food responsiveness scale (FR). The CEBQ is a 35-item parent-report measure that was designed to measure individual differences in child eating behaviors, which has good internal consistency and test–retest reliability (Wardle, Guthrie, Sanderson, & Rapoport, 2001).

**Child Eating Behavior Questionnaire Satiety Responsiveness (CEBQ SR).** The ability of a child to reduce food intake after eating to fullness was assessed using the CEBQ satiety responsiveness scale (SR).

#### Outcome variables

**Child usual dietary intake.** Dietary intake data for a subsample of the children ( $n = 82$ ) were collected and analyzed using Nutrition Data System for Research (NDSR) software version 2007, developed by the Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN. Utilizing the multiple-pass system of the NDS-R interview methodology, a trained interviewer conducted one 24-h recall in-person at the assessment visit, along with two subsequent 24-h recalls over the phone within the following two weeks. During the in-person interview, children used both food models and a food amounts booklet to help them estimate quantities of foods/drinks consumed; the booklet alone was used for the recalls conducted by phone. Parents were consulted to verify aspects of the food (e.g. butter or margarine, brand names) if needed. The three dietary recalls were averaged together to generate an estimate of total daily caloric intake.

**Anthropometry (BMI-Z and BMI percentile).** Height was measured in duplicate using a standard stadiometer. Weight was measured in duplicate on a calibrated slide scale without shoes. The average of the two values was used for analysis. BMI ( $\text{kg}/\text{m}^2$ ) was calculated from measured height and weight. Child BMI was translated to BMI-for-age percentile scores using the CDC growth charts (Kuczmarski et al., 2000) and to BMI-Z scores.

**Demographics.** Demographics of the parent and child (i.e. child gender, child race, child age, parent gender, parent age, family income, and parent education) were determined based on parent self-report.

#### Statistical analysis

Latent profile analysis (LPA) was used to identify overeating phenotypes in obese children, using the software Latent GOLD 4.5. The following indicator variables were used for the LPA analysis: EAH%, LOC, CEBQ FR, CEBQ SR, EAH NAE, and EAH EE. Several series of LPA models were fit with increasing numbers of classes until a minimum was found for Bayesian Information Criteria (BIC) and Bozdogan's Consistent Akaike's Information Criterion (cAIC); consideration for model fit was also given to Sample Size Adjusted Bayesian Information Criteria (aBIC) and classification error (i.e., entropy). Potential indicators for these models were selected based on expert consensus regarding measures of appetitive traits. Several variables in each conceptual category were considered (i.e. parent or child report of emotional overeating). To address the issue of the conditional independence assumption, pair-wise bivariate residuals were evaluated, with values of 4.0 or greater considered evidence of violating the assumption. To evaluate the stability of the LPA results, a bootstrapping procedure

(Wonderlich et al., 2007) was conducted where LPA analysis was repeated on 100 consecutive random samples consisting of 90% of the original sample. Results were evaluated in terms of the number of identified clusters in each of the bootstrapped replications and classification discrepancies between the original and bootstrapped samples. Once a latent structure model was finalized, subjects were assigned to classes based on maximum posterior probability and compared on measures of overweight in children (BMI-Z, BMI percentile) and average caloric consumption per day.

## Results

### Latent profile analysis

Examination of fit indices revealed a 3-class solution. All pairwise residuals were less than 3.56, supporting the assumption of conditional independence. The LPAs for 98 of the 100 bootstrapped replications supported an unambiguous 3-class solution, while the remaining two replications suggested better fit for a 2-class solution. The number of classification discrepancies between the original LPA and the 100 bootstrapped replications ranged from 0 to 26 (out of 105 participants included in each replication set), with an average of 6.5. The overall classification agreement between the original and bootstrapped LPAs was 93.8%.

LC1, which included 56 (47.9%) children, characterized by low EAH% and a moderate level of food responsiveness and satiety responsiveness (see Table 2), was labeled "Moderate Satiety and Food Response". LC2, which included 48 (41.0%) children, characterized by a moderate level of EAH% (although not significantly different than Moderate Satiety and Food Response LC on EAH), low level of food responsiveness, and high level of satiety responsiveness, was labeled "High Satiety Response". LC3, which included 13 (11.1%) children, characterized by highest EAH%, highest level of food responsiveness and lowest level of satiety responsiveness, was labeled "High Food Response". The three classes accounted for 24% of the variance in the laboratory measurement of EAH%, 71% of food responsiveness and 49% of satiety responsiveness.

### Evaluation of the association between classes and variables associated with obesity

The three classes were associated with significant differences on BMI percentile and standardized BMI (BMI-Z; see Table 3). The High Satiety Response class was associated with the lowest BMI-Z score and BMI percentile, while the High Food Response class was associated with the highest BMI-Z score and BMI percentile. The Moderate Satiety and Food Response class was associated with a moderate (compared to the other two classes) BMI-Z and BMI percentile. Although not significant, the Moderate Satiety and Food Response class had the highest reported level of negative affect eating, and the High Food Response class had the highest prevalence of LOC eating.

Finally, we evaluated the subsample of 82 children who had three 24-h recalls. Of these 82, 38 were in LC1, 31 in LC2 and 12 in LC3. Comparison of these data showed no significant differences among the three classes on the average number of calories consumed.

## Discussion

This study identified three overeating phenotypes in treatment-seeking overweight and obese children based on a combination of indicators from child self-report, parent report of child behavior, EAH paradigm, and interview-based measures. The classification of these overweight and obese children on appetitive factors was

**Table 2**  
Latent class means on indicator variables for three classes.

	Moderate Satiety and Food Response N = 56	High Satiety Response N = 48	High Food Response N = 13	F (sig)/chisq Eta-squared
EAH percent	11.44 <sup>a</sup> (5.37)	15.59 <sup>a</sup> (10.14)	30.28 <sup>b</sup> (21.53)	17.86 ( <i>p</i> < .01) $\eta^2 = .239$
LOC	33.9%	35.4%	53.8%	1.86 ( <i>p</i> = .39) $\eta^2 = .016$
CEBQ FR	4.24 <sup>a</sup> (.39)	3.28 <sup>b</sup> (.40)	4.92 <sup>c</sup> (.19)	135.95 ( <i>p</i> < .01) $\eta^2 = .705$
SR	1.78 <sup>a</sup> (.41)	2.39 <sup>b</sup> (.47)	1.15 <sup>c</sup> (.20)	54.03 ( <i>p</i> < .01) $\eta^2 = .487$
EAH NAE	13.49 (4.51)	11.28 (3.68)	13.13 (6.06)	2.52 ( <i>p</i> = .08) $\eta^2 = .059$
EE	10.16 (3.25)	9.52 (3.29)	11.15 (2.91)	1.40 ( <i>p</i> = .25) $\eta^2 = .024$

<sup>a,b,c</sup> Letters signify differences on Tukey's post hoc.

**Table 3**  
Latent class means on body weight and nutritional intake for three classes.

	Moderate Satiety and Food Response N = 56	High Satiety Response N = 48	High Food Response N = 13	F (sig)/chisq Eta-squared
BMI-Z	2.12 <sup>a,b</sup> (.38)	1.95 <sup>a</sup> (.40)	2.28 <sup>b</sup> (.27)	4.94 ( <i>p</i> < .01) $\eta^2 = .080$
BMI percentile	97.66 <sup>a,b</sup> (2.04)	96.47 <sup>a</sup> (3.14)	98.63 <sup>b</sup> (.90)	5.11 ( <i>p</i> < .01) $\eta^2 = .082$
kcal/day <sup>*</sup>	1901.44 (648.05)	1972.62 (583.59)	1901.55 (478.97)	.053 ( <i>p</i> = .95) $\eta^2 = .001$

<sup>a,b</sup> Letters signify differences on Tukey's post hoc.

<sup>\*</sup> Nutritional analyses conducted on subsample of 82 (N = 38, 31, 12 respectively).

influenced by their responsiveness to external food cues and their internal satiety responsiveness. Interestingly, these three classes also differentiated children by body weight, even though the sample included only overweight and obese children. Not surprisingly, the High Food Responsive class was also associated with the highest BMI/BMI-Z, while the High Satiety Responsive class was associated with the lowest BMI/BMI-Z. Although the entire sample was overweight and engaged in some overeating in the EAH paradigm, these groups differed significantly on eating characteristics, supporting the importance of identifying distinctive phenotypes of eating behavior in overweight and obese children.

Interestingly, these subgroups of overweight and obese children represent differences in responding to external cues to overeat and lack of responsiveness to internal cues of satiety. Schachter's externality theory of obesity (Schachter, 1971; Schachter & Rodin, 1974) states that obese humans are more reactive to external cues to eat (e.g., time, presence and quality of food) and less sensitive to internal hunger and satiety signals than their lean counterparts. According to Schachter's theory, this over-responsiveness to external food cues and decreased responsiveness to hunger and satiety signals could lead to significant overeating in the current environment given the abundance of palatable food stimuli. These differentiations among subgroups are consistent with data suggesting that overweight children are hypersensitive to food cues in neuroimaging studies (Bruce et al., 2010).

It is noteworthy that the three groups of overeating phenotypes differed on measures of obesity status even though all children in this sample were overweight, indicating that these overeating patterns could influence or compound obesity status. The High Food Responsive group was significantly higher on BMI and BMI-Z than the High Satiety Responsive group, while the Moderate Satiety and Food Response group was not significantly different than either of the other two groups. Most likely, the lack of significance with the Moderate Satiety and Food Response group was related to power given the sample size as well as the wide variability in the data. The three groups accounted for approximately 8% of BMI status.

To date, childhood obesity interventions, including Family-Based Therapy (Epstein, 1996) do not directly target internal hunger and satiety cues or responsiveness to food cues. Considering the apparent importance of eating in the absence of hunger, satiety responsiveness and food responsiveness, treatments targeting these variables are needed. Studies targeting appetite awareness training have shown some promise in adults (Craighead & Allen, 1995) and children (Bloom, Sharpe, Mullan, & Zucker, 2013). We have targeted both satiety responsiveness and food responsiveness in two promising pilot studies (Boutelle et al., 2011, 2014).

Surprisingly, our study did not show significant differences among the three groups on loss of control eating, negative affect EAH and external EAH. This finding was unexpected as children



with LOC eating, compared to those without LOC eating gain more weight over time than those without LOC (Tanofsky-Kraff et al., 2009). Additionally, eating in response to negative emotional states is associated with obesity (Braet & Van Strien, 1997), overeating (Van Strien, Engels, Van Leeuwe, & Snoek, 2005), and eating in the absence of hunger in children (Moens & Braet, 2007). Although these factors have emerged in other studies, they did not seem to play a role in differentiating the three groups in this sample. It is possible that these variables are more cognitive in nature, and it may be that these types of cognitive variables are better assessed in older youth.

It is also important to note that the three groups did not significantly differ on daily nutritional intake. It is believed that children with higher BMI/BMI-Z scores would consume more calories on average than those with lower weight status. Although the lack of differences among the three classes may be the result of limitations in the reliability of self-reported nutritional intake among children (Burrows, Martin, & Collins, 2010), differences in BMI may be the result of eating differences among phenotypes that have a subtle but definitive influence on overall energy intake over time. Alternatively, differences in BMI may be the result of variability in energy expenditure, a variable that was not assessed in the current investigation.

This study had several strengths, including state of the art assessments of eating pathology, overeating and nutritional intake in children that included questionnaires, standardized interview protocols, and behavioral paradigms, as well as the use of latent profile analysis to identify appetite phenotypes in these children. This is the first study of which we are aware that evaluates how these appetite characteristics interact in obese children. However, several limitations to this study need to be noted. First, this sample was limited to overweight and obese children who were recruited for the treatment of overeating, and may not generalize to non-treatment seeking samples or to more heterogeneous samples of treatment-seeking and non-treatment-seeking overweight and obese children. Lastly, this study is cross sectional, and causation cannot be determined. It is not clear whether the variables that distinguish between the three groups are causes or consequences of overeating.

Despite these limitations, this study is the first to focus specifically on overeating phenotypes in overweight and obese children using a range of self-report, interview, and behavior measures as indicator variables. Future research should evaluate the effect of coexisting overeating characteristics on child BMI in larger samples of overweight youth, in samples that include a wider range of weight status (including non-overweight youth), and in community as well as treatment-seeking samples. It is also important to evaluate these overeating phenotypes as predictors of weight change in youth, and as predictors of weight loss in behavioral treatment studies. Although further studies are clearly needed to replicate these findings, treatment development and matching based on satiety responsiveness and food responsiveness may be warranted. The identification of phenotypic classes of overeating in youth can potentially guide the development of prevention and intervention programs by targeting the drivers of these appetite pathways.

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