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Eating Responses to External Food Cues in Weight Discordant Siblings

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Abstract

Background: Heightened responsivity to external food cues may promote energy intake and account for differences in weight status between non-overweight and overweight adolescents. Studies of weight-discordant fraternal siblings control for some genetic and shared within-family factors, which allows for testing of other non-shared factors relevant to sibling weight differences.

Objective: To determine whether same-sex weight-discordant (one non-overweight, one overweight) adolescent siblings differ in responsiveness to external food cues.

Methods: Weight-discordant siblings' (n = 38 pairs) energy consumption was compared following both an appetizing food (pizza) on one day and a control activity (reading) on another day. Multilevel models examined intrafamily similarity and regressions examined associations with adiposity.

Results: Siblings shared little similarity in cue responsivity ($\rho = 0.10$). However, sibling zBMI difference was not associated with differences in cue responsivity. Moreover, when tested as groups, non-overweight and overweight siblings did not differ for cue responsivity ($p > 0.84$).

Conclusion: Weight-discordant adolescent siblings show little similarity in responses to food cues. Differences in sibling weight status were not predicted by differences in responses to food cues. Thus, non-shared factors other than cue responsivity must contribute to weight differences of adolescent siblings.

Keywords

adolescence; obesity; food cue; weight discordance; dietary restraint

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More than one-third of American youth are overweight or obese (1). Much research has examined the etiology of childhood obesity (2), but less with adolescents (3). During adolescence, youth make a greater number of autonomous decisions, including energy balance choices (4). Non-overweight children may become overweight adolescents because of changed eating habits (5). Overweight adolescents are likely to become overweight adults (6) and suffer life-long health concerns (7). Therefore, it is important to understand the factors contributing to adolescent obesity.

Overweight adolescents may respond differently to the obesogenic food environment than their non-overweight peers. Incentive sensitization, a theory often applied to drug addiction, predicts that vulnerable individuals show increased responsivity to food cues, resulting in overeating (8). Overweight adults show an enhanced reactivity to food cues (9) and a meta-analysis examining overweight and mixed samples, calculated a medium effect of cue reactivity ($r = 0.33$, approximately 11% of variance) on eating behaviors, such as calories consumed, and weight-related outcomes, such as BMI changes (10). Although results did not vary by BMI, most studies were cross-sectional, suggesting longitudinal studies may be necessary to observe associations between enhanced cue reactivity and increased BMI.

Fewer studies have examined individual differences in food cue responsivity among youth. Among adolescent girls, BMI positively correlated with speed of reaction time towards foods cues. These faster reactions predicted future weight gain (11). Thus, enhanced responsivity to food cues may originate in childhood. Overweight children (aged 9–11 years) are more likely to recognize environmental eating cues (12) and consume more calories following cue exposure (13). In overweight children, the magnitude of cue reactivity correlates with subsequent energy intake (13). Collectively, these results suggest a mechanism of excessive weight gain in highly food cue reactive children, and possibly adolescents.

Certain psychological characteristics may correlate with food cue reactivity. Dietary restraint, the cognitive effort to eat less, predicts adiposity, with overweight individuals showing greater dietary restraint (14). Differences in responsivity to food cues between non-overweight and overweight youth might be better explained by dietary restraint than by adiposity. Many overweight individuals restrain their eating to prevent further weight gain. Unfortunately, this often backfires, as lapses in restraint lead to distress and emotional eating (14). These same individuals may be more responsive to cue-induced eating (15). However, it is difficult to separate the effects of adiposity and restraint on responsivity because dietary restraint is usually greater among overweight individuals and they are also more likely to be more responsive to external food cues (14). Alternatively, dietary restraint might increase responsivity to cues for such foods (16).

Youth diets and eating habits are also determined by external factors, most notably parental feeding practices, such as restricting access to desirable, calorie-dense foods. Parents may control their children's eating patterns and inadvertently attenuate children's ability to base their eating habits upon internal signals. For example, parental food restriction is positively associated with restrained eating (17), increased energy intake, and child weight gain (18).

Further research must examine how dietary restraint and parental feeding strategies interact with cue responsiveness.

The etiology of obesity-promoting behaviors involves both environmental and genetic factors. The unique contributions of these factors are usually examined via comparisons of non-overweight and overweight youth from different families (19). However, inter-family comparisons do not provide information on non-shared experiences within the family that may explain why one sibling remains normal weight while the other becomes overweight (20). There is a need to study differences among children within the same family. Non-twin discordant sibling designs control for approximately 50% genetic variability (21), and shared environmental factors (22), allowing researchers to focus upon putative non-shared environmental factors responsible for making siblings discordant for adiposity (23). For example, sibling differences in physical activity, energy intake, and parent monitoring of child eating have only slight familiarity and these factors were associated with sibling differences in adiposity (23). Similar work found high food reinforcement and an inability to delay gratification contributed to siblings' discordance in obesity (24). In addition, individual differences in the ability to compensate for high energy intake have been noted (25), even for children within the same family (26).

Thus, discordant sibling designs allow investigators to study two important steps in determining the experiences that make siblings different for adiposity (20). First, they allow investigators to determine which experiences are not shared among discordant siblings raised in the same family. Secondly, they allow the study of whether these non-shared experiences are associated with differences in adiposity. If weight-discordant siblings show little similarity in an experience, that experience may be a contributing factor in their differing weight status. However, if differing experiences are not associated with the sibling difference in weight status, that experience is unlikely to be the primary contributor to siblings' discordance in weight status.

The purpose of this study was to determine weight-discordant siblings' similarity in responsivity to food cues. A second aim was to determine whether siblings' differences in food-cue responsivity, parental control of child feeding, or dietary restraint were associated with siblings' differences in adiposity.

Method

Participants

Participants were 40 same-sex adolescent sibling pairs. Two pairs did not complete the experiment and their data were excluded from major analyses for a final N of 38 pairs (total N = 76). Siblings were balanced with 23 pairs consisting of a non-overweight younger sibling (BMI <70th %ile) and an overweight older sibling (BMI > 85th %ile), and 17 pairs consisting of an overweight younger sibling and non-overweight older sibling. Siblings were age 13–17 years, with less than 4 years age difference. Male siblings were at least genital stage II and female siblings were at least breast stage II via self-assessment of stage of development of secondary sex characteristics (27). Participants were screened for eligibility via parental report. Exclusion criteria included current psychiatric diagnoses, dieting to lose

weight, tobacco/nicotine use, dietary restrictions, food allergies or medications which might influence taste or appetite, and medical conditions which might cause obesity. Participants were required to have the same biological parents and at least a moderate liking (at least 5 on a 10-point scale) of study food. Study hypotheses focused on the influences of social contexts on usual eating and active behaviors have been published (28, 29).

Participants were recruited via both direct mailings to families listed in a marketing database of local addresses (infoUSA, Omaha, NE) or phone calls to families listed in a database of past participants who had expressed interest in research participation at the University at Buffalo. At least one parent provided written informed consent and adolescents provided written assent. Study procedures were approved by the University at Buffalo Institutional Review Board.

Procedure

Siblings were measured on the same days and times in identical, separate rooms. Parents were instructed to not give their children any of the cued food the day before or prior to the study on the day of testing. Participants fasted for three hours prior to testing, as confirmed by the parents. To simulate a dinner meal, testing occurred at the families' usual dinner time. Participant height/weight, questionnaires, and liking of study food were completed prior to the experiment.

Food Cue Reactivity.—Participant reaction to food cues was measured with procedures similar to Jansen et al (13). Hunger via the VAS scales (see Measurements below) was measured after 10 minutes of quiet time reading magazines devoid of food cues. In the food cue (experimental) condition siblings were presented slices of warm cheese pizza and instructed to smell and think about the taste of the pizza for five minutes. The experimenter modeled smelling a separate plate of pizza (D'Journé,® 290 kcal, 131 g total, 10.0 g fat, 36.0 g carbohydrate, 14.0 g fat for 1/6 pie). For the control condition, siblings continued to read the magazines for an additional 5 minutes.

After five minutes, hunger was measured again. For participants in the food cue condition, the pizza was present during the second measurement. Participants in both conditions were then allowed to eat a warm plateful of pizza and 500 mL of water. To avoid ceiling effects, boys were presented with 7 slices (1400 kcal) and girls with 5 slices (1000 kcal) or 4 times the median amount consumed per occasion for boys aged 12–19 (30). To blind participants to the purpose of the food intake session, siblings were instructed to taste as much pizza as they wanted or needed to fill out a taste questionnaire. Siblings were given 15 minutes to eat; afterwards perceived hunger was measured for a 3rd time. Participants were left alone to eat, with researcher staff available via intercom. The pizza was weighed before and after consumption. Eating in response to the food cue (*cue responsiveness index*) was determined by subtracting calories consumed in the control condition from calories consumed in the experimental condition. Greater responsiveness indicates a greater amount of food consumed following exposure to food cues. Parents waited in a nearby room and were not given an opportunity to influence their children's responses. Parents and participants were told during the informed consent that the study's purpose was a taste test. Neither were informed that

their food intake was being measured, until the post-study debriefing. IRB permission for this deception was obtained a priori.

Design

This study was utilized a repeated measures design. Each sibling was exposed to both conditions. Both siblings received either the experimental or the control condition during the same testing session. Testing sessions occurred on separate days approximately one week apart, unless illness or a holiday forced a longer interval. Siblings were separated for the duration of each testing session. Condition order was counterbalanced with an equal number of overweight older sibling/non-overweight younger sibling pairs and non-overweight older sibling/overweight younger pairs receiving the experimental condition first. This was further subdivided by sibling gender. The described experiment was part of a larger study (28, 29).

Measurements

Food hedonics and subjective rating of hunger/fullness.—Liking of study foods was screened over the phone followed by a laboratory screening where participants sampled 50 g servings of study food and asked to indicate liking on a 10-point scale (1 = do not like at all; 10 = like very much). Participants used a 10-point Likert scale rating to indicate their level of hunger/fullness (1 = very hungry; 10 = very full).

Parental Control of Child Feeding.—Each sibling completed a Kid's Child Feeding Questionnaire (KCFQ) to measure perceived parental control of their eating habits (16). Questions in the subscales measuring pressure to eat (KCFQP) ("does your daddy make you eat all the food on your plate") and restriction from certain foods (KCFQR) ("If you're with your mommy and you want something to eat, does she let you pick what you want to eat") were answered twice, once for each parent. A third subscale measured food restriction in general (KCFQG) ("are you allowed to get your own snacks"). Subscales have been found to have adequate internal validity and to be associated with the parental version of the same questionnaire (16).

Dietary Restraint.—Dietary restraint was measured with the restrained eating subscale of the Dutch Eating Behavior Questionnaire (DEBQ or Restraint). Revised versions of this questionnaire have been utilized with children as young as 8 years of age (31). The revised subscale retains 6 of the original 10 questions, modified for younger participants ("if I feel fat, I try to eat less") and 3 additional questions related to weight loss via exercise and perceived parental dietary restraint ("if my dad feels fat, he tried to eat less"). Answers are scored as "never," "sometimes," or "very often." Greater scores indicate greater restraint. Validity was demonstrated via inverse correlations with body shape satisfaction, body esteem, physical appearance, self-worth, and social acceptance (31).

Anthropometrics.—Height and weight were assessed using a digital scale (Tanita, Tokyo) and stadiometer (Seca, NY). Weight was measured to the nearest 0.01 kg and height to the nearest 0.1 cm. Height and weight measurements were used to calculate BMI percentiles, based upon the 50th percentile for their age and sex. BMI percentiles were then standardized

into BMI z-scores (zBMI) (30). Participants were measured once, at the screening appointment.

Food consumption.—Pizza eaten was weighed to the nearest 0.1 g both before and after each study condition. Grams and percentages of protein, fat, carbohydrate, and as energy intake were determined with food labels or the Minnesota Nutrition Data System for Research (NDS-R, Version 4.06).

Analytic Plan

Preliminary Analyses.—Initial analyses examined skew, kurtosis, linearity, and homogeneity of variance. Low correlations between predictors showed collinearity was not a concern (32). Multilevel models compared the effect of gender and adiposity group on age and pubertal status. Similar multilevel models tested gender and adiposity group differences in potential covariates including liking of food choices. For dummy-coded categorical variables, the control group was male (gender), older sibling (age group), and non-overweight (weight group). Analyses used SAS 9.4. The final 38 sibling pairs provided 80% power to reliably detect pair resemblance at an intra-class correlation coefficient (ICC) as low as 0.40 ($p < 0.05$). ICC were interpreted as no family similarity for scores ranging 0.00–0.10, slight similarity for scores ranging 0.11–0.40, fair amounts of similarity for scores ranging 0.41–0.60, moderate similarity for scores ranging 0.61–0.80, and high similarity for amounts exceeding 0.81 (23, 33). Thus, the study was powered to detect slight to high similarity in discordant sibling outcomes.

Cue Responsivity.—To account for the interdependence of siblings, data were analyzed using multilevel regression models (MLM). Within-family variance in each dependent variable was determined with ICCs (32, 34) and ‘pseudo R^2 ’ (35). Multilevel models were run using both maximum likelihood (ML) and REML estimation, controlling for adiposity group and age group in each model.

Other analyses.—The effect of age, gender, DEBQ restraint subscale (restraint), KCFQ subscales parental pressure to eat (KCFQP), parental eating restriction (KCFQR), and general eating restrictions (KCFQG) predictors on cue responsiveness were examined with multilevel models. The covariates adiposity group and age group were included in each equation. Each predictor was first run individually within the multilevel model. Next backwards regression was used to confirm nonsignificant predictors and control variables.

Multiple linear regression models were used to examine whether differences in sibling eating behavior predicted differences in zBMI (overweight sibling minus non-overweight sibling) (Dzbmi). Regressions predicted Dzbmi based upon differences, in age, cue responsivity, restraint, KCFQ subscales, and interactions. Results were considered statistically significant at $p < 0.05$. Predictors were both examined individually and collectively with backwards regression.

Results

Demographic and physical characteristics

58% of participants were male. Ages ranged from 13.0 to 17.8 years. Participants identified as Caucasian (92.5%), African-American (5%), Hispanic (2.5%), and multiracial/other (2.5%). Most parents (54%) had completed at least a 4-year degree and had an annual income of at least \$70,000 per year. As shown in Table 1, the overweight siblings had a greater BMI percentile and zBMI. Genital (boys)/breast (girls) stage did not differ between adiposity groups.

Hunger, eating behaviors, and liking of study foods

Differences were noted across adiposity groups for restraint scores, KCFQR scores, and KCFQG scores, but not for KCFQP scores ($p = 0.82$) (Table 1). Sibling adiposity groups did not differ in liking of the pizza (overweight 8.3 ± 1.7 ; non-overweight 8.5 ± 1.2 ; $p > 0.63$). Sibling groups also did not differ in self-reported hunger before ($p = 1.00$, $p = 0.42$), during ($p = 0.76$, $p = 0.36$), and after ($p = 1.00$, $p = 0.39$) both the control and food cue conditions, respectively. Therefore, food liking and hunger were not included as covariates in subsequent analyses, while the KCFQ subscales and restraint were included.

Energy Consumed

Intra-class correlations showed a slight sibling resemblance for energy consumed in the no cue condition and fair resemblance in the pizza cue condition (Table 2). Sibling adiposity groups did not differ in kcal consumed on both the no cue and pizza cue days ($p = 0.76$). On both days there were no adiposity group differences for grams of food consumed ($p = 0.77$) (data not shown). None of the participants ate all the pizza on either day, indicating absence of a ceiling effect.

Cue Responsivity

ICC indicated no sibling resemblance in food cue responsivity (Table 2). As shown in Table 3, adiposity group ($p = 0.95$), gender ($p = 0.84$), age ($p = 0.82$), eating restraint ($p = 0.75$), perceived parental pressure to eat (KCFQP, $p = 0.14$), perceived parental restriction of food (KCFQR, $p = 0.65$), and perceived parental general restriction (KCFQG, $p = 0.34$) were not predictors of cue responsivity. The covariate, age group predicted cue responsivity, $p < 0.05$, indicating younger siblings consumed more energy following food cues. These results were confirmed by backwards regression. Interactions were not significant.

Differences in zBMI

The only significant predictor of sibling differences in zBMI was differences in restraint scores (Table 4). Greater differences in restraint predicted greater differences in zBMI, although the effect size was small. Cue responsivity did not predict differences in zBMI.

Discussion

Overall results indicate little familial resemblance in cue responsivity among adolescent siblings discordant for adiposity. At first pass, this suggests that cue responsiveness might be

non-shared factor that explains the discordance in adiposity of adolescent siblings. However, sibling differences in cue responsiveness were not associated with sibling zBMI differences. Moreover, there were no significant differences between adiposity groups in cue responsivity. As such, cue responsiveness may not be an important contributor to discordance in adolescent adiposity. This present work extends past studies using a discordant sibling design that found greater energy intake in response to increased food variety (23) did not explain differences in sibling adiposity.

While prior research suggests overweight persons are more likely to overeat as a result of food cues (9) and some research in young children has confirmed this (13), other research noted that overweight persons are not more affected by external cues (10, 19). In line with these divergent results, cue responsivity showed a wide range of individual differences within both adiposity groups in the current study, but these differences are not consistently greater in overweight adolescent siblings and cannot explain discordance in adolescent adiposity.

An alternate explanation may be reinforcement pathology, a combination of high reinforcement value and reduced ability to delay gratification (24). This ability increases with age (36) but even adults struggle with delaying gratification. In women, high reinforcement of energy-dense foods and greater delay discounting, independently and synergistically predicted BMI (37). Furthermore, high dietary disinhibition and food reinforcement predicted weight gain in non-obese women over a 12 month period (38). Both the overweight and non-overweight siblings in the present study expressed great liking for pizza (see Results). Furthermore, younger siblings showed greater responsiveness to the pizza cue, possibly reflecting an age-related inability to delay gratification. Because our study is cross-sectional, we are unable to determine if participants showing greater cue responsivity would learn to delay gratification or if cue responsivity in the presence of favorite foods would continue and lead to future weight gain. Future studies should use longitudinal methods to examine age related changes in cue responsivity, both for palatable and non-palatable foods

Cue responsivity may also vary based upon gender. Males require more calories than same-age females (39), and whether this translates into greater reactivity towards food cues is unknown. While no gender effects were found, within gender analyses were not possible, due to sample size. Future studies may wish to examine variation in cue responsivity by gender.

This study has several limitations. The sample was limited to same-sex siblings within four years in age, limiting generalizability to singletons, opposite gender siblings, and siblings with concordant adiposity status (22). Participant eating behaviors were measured in a laboratory-based setting and may differ from more naturalistic environments. This study focused on short-term eating behaviors. Youth might respond differently to the ubiquitous food cues of a long-term obesogenic environment (12). This study was also cross-sectional; longitudinal studies spanning childhood (40) and adolescence are necessary to demonstrate changes in cue responsivity contributing to changes in BMI.

This study had several strengths, including a weight-discordant biological sibling design that provides greater statistical power per subject pair by controlling for shared environmental factors and, on average, 50% of genetic differences. This study focused on adolescence, a developmental period often overlooked, yet critically important for obesity etiology. Factors previously linked to overweight, but not yet studied in weight discordant siblings, such as dietary restraint, and those which may contribute to overweight, such as cue responsiveness, were examined.

In summary, the minimal shared family effects of cue responsiveness suggest that these traits are determined by the non-shared environment. However, these differences did not predict differences in sibling adiposity; instead dietary restraint was the sole significant predictor. Therefore, future studies may wish to further investigate the relationship between dietary restraint and overweight, as well as other sources of non-shared variation in sibling adiposity.

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Implications and Contributions

This study compared how much overweight and not overweight siblings overeat after being exposed to an appetizing meal. Siblings showed little within-family similarity, but sibling weight status was not associated with cue responsivity. These results imply that cue responsivity is not responsible for differences in siblings' weights.

Table 1.

Adolescent physical characteristics by adiposity group

	Non-overweight (N = 38)	Overweight (N = 38)	Sibling difference
Age (years) ^a	15.7 ± 1.4	15.1 ± 1.4	-0.6 ± 1.4
Genital/breast stage	3.9 ± 0.9	3.9 ± 0.9	0.0 ± 0.9
BMI %ile ^a	50.3 ± 17.8	92.5 ± 3.9	42.3 ± 18.1
zBMI ^a	0.01 ± 0.5	1.5 ± 0.3	1.5 ± 0.6
Restraint ^a	8.97 ± 3.0	11.34 ± 3.16	2.37 ± 3.08
KCFQP	0.59 ± 0.4	0.60 ± 0.4	0.0 ± 0.4
KCFQR ^a	1.35 ± 0.2	1.23 ± 0.4	-0.1 ± 0.3
KCFQG ^a	1.61 ± 0.4	1.39 ± 0.5	-0.2 ± 0.5

Data are mean ± SD

^aMain effect of adiposity group (p < 0.05)

Restraint comprises the restraint subscale score of the Dutch Eating Behavior Questionnaire (DEBQ).

KCFQP comprises the parental pressure to eat subscale of the kid's version of the Child Feeding Questionnaire.

KCFQR comprises the parental food restriction subscale of the kid's version of the Child Feeding Questionnaire.

KCFQG comprises the general food restriction subscale of the kid's version of the Child Feeding Questionnaire.

All KCFQ subscales were completed by the child.

Table 2.

Energy intake in response to a food cue of the non-overweight and overweight siblings

	Non-overweight	Overweight	Sibling difference	ICC (ρ)	Resemblance
Total kcal (no cue day)	781.2 $\pm$ 42.4	774.7 $\pm$ 45.3	-6.5 $\pm$ 62.0	0.38	slight
Total kcal (pizza cue day)	773.9 $\pm$ 42.9	759.2 $\pm$ 46.2	-14.6 $\pm$ 48.2	0.40	fair
Cue responsiveness	-7.2 $\pm$ 28.0	-15.1 $\pm$ 32.2	-7.9 $\pm$ 42.7	0.10	none

M $\pm$ SE

Cue responsiveness is calculated as energy intake on the pizza cue day minus energy intake on the no cue day.

No significant differences were found between overweight and non-overweight siblings.

Table 3.

Demographics and eating behaviors from the Dutch Eating Behavior Questionnaire and Child Feeding Questionnaire (kid's version) as predictors of food cue responsiveness

Predictors	Non-Overweight	Overweight	Difference	Predictor estimate	Pseudo R ²
Gender ^a				−8.99	0.001
Age ^a	12.8 ± 2.5	12.4 ± 2.1	−0.4 ± 2.9	3.48	0.001
Restraint	8.90 ± 0.48	11.41 ± 0.50	2.51 ± 0.70	−2.21	0.001
KCFQP	0.58 ± 0.07	0.60 ± 0.07	0.02 ± 0.10	75.74	0.029
KCFQR ^a	1.35 ± 0.04	1.23 ± 0.06	−0.12 ± 0.07	−32.25	0.003
KCFQG ^a	1.62 ± 0.06	1.41 ± 0.08	−0.21 ± 0.11	−45.16	0.014

M ± SE

Restraint comprises the restraint subscale score of the Dutch Eating Behavior Questionnaire (DEBQ).

KCFQP comprises the parental pressure to eat subscale of the kid's version of the Child Feeding Questionnaire.

KCFQR comprises the parental food restriction subscale of the kid's version of the Child Feeding Questionnaire.

KCFQG comprises the general food restriction subscale of the kid's version of the Child Feeding Questionnaire.

All KCFQ subscales were completed by the child.

Presented results are from equations with each individual predictor (Restraint, KCFQ subscales) and the covariates adiposity group and age group.

Results were then confirmed with backwards regression (data not presented).

^a significant effect of age group

Pseudo R² is an effect size for multilevel models

Table 4.

Demographics and eating behaviors from the Dutch Eating Behavior Questionnaire and Child Feeding Questionnaire (kid's version) as predictors of sibling differences in zBMI *

Predictors	B	SE	β	p	R ²
Age	-0.028	0.043	-0.104	0.522	0.011
Cue responsiveness	0.0002	0.0004	0.082	0.616	0.007
Restraint	0.047	0.023	0.321	0.044	0.103
KCFQP	0.075	0.237	0.051	0.755	0.003
KCFQR	-0.395	0.289	-0.216	0.181	0.047
KCFQG	-0.142	0.212	-0.108	0.508	0.012

* overweight minus non-overweight sibling scores

Restraint comprises the restraint subscale score of the Dutch Eating Behavior Questionnaire (DEBQ).

KCFQP comprises the parental pressure to eat subscale of the kid's version of the Child Feeding Questionnaire.

KCFQR comprises the parental food restriction subscale of the kid's version of the Child Feeding Questionnaire.

KCFQG comprises the general food restriction subscale of the kid's version of the Child Feeding Questionnaire.

All KCFQ subscales were completed by the child.

Results are from regressions with each predictor run individually (no covariates).