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Low inhibitory control and restrictive feeding practices predict weight outcomes

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Abstract

Objective—A priority for research is to identify individuals early in development who are particularly susceptible to weight gain in the current, obesogenic environment. This longitudinal study investigated whether early individual differences in inhibitory control, an aspect of temperament, predicted weight outcomes and whether parents' restrictive feeding practices moderated this relation.

Study design—Participants included 197 non-Hispanic White girls and their parents; families were assessed when girls were 5, 7, 9, 11, 13, and 15 years old. Measures included mothers' reports of girls' inhibitory control levels, girls' reports of parental restriction in feeding, girls' body mass indexes (BMIs), and parents' BMIs, education, and income.

Results—Girls with lower inhibitory control at age 7 had higher concurrent BMIs, greater weight gain, higher BMIs at all subsequent time points, and were 1.95 times more likely to be overweight at age 15. Girls who perceived higher parental restriction exhibited the strongest inverse relation between inhibitory control and weight status.

Conclusion—Variability in inhibitory control could help identify individuals who are predisposed to obesity risk; the current findings also highlight the importance of parenting practices as potentially modifiable factors which exacerbate or attenuate this risk.

Keywords

temperament; obesity; individual differences; self-regulation; feeding practices; restriction; goodness of fit

Inhibitory control is defined as the ability to restrain a dominant response and execute a sub-dominant response (1). This behavioral construct is an aspect of temperament that overlaps with impulse control, self-regulation, and executive function and has implications for social, intellectual, and behavioral outcomes which represent important developmental goals in childhood. Specifically, lower inhibitory control has been linked to difficulties with prosocial development, moral development, and memory performance (2,3) and a higher likelihood of unintentional injury and later substance dependence (4,5). Thus, inhibitory control is an

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important contributor to many aspects of healthy development. However, little is known about its implications for child weight outcomes in the current environment.

The current environment has been conceptualized as obesogenic, promoting excessive intake and sedentary behavior in many individuals (6). Individual differences in behavioral styles could help to explain why some individuals become obese in such an environment, whereas others do not. A small body of research implicates poor self-regulation in childhood overweight (7–9). For example, intervention studies have demonstrated effects of self-regulation training on reduced overweight and weight gain (9,10), and Nederkoorn (11) found that obese children tended to have lower inhibitory control and higher impulsivity. Whereas self-regulation and impulsivity overlap with inhibitory control, there are few studies which look specifically at the dimension of inhibitory control as a predictor of weight outcomes. Inhibitory control falls under the rubric of temperament, or variables which tap behavioral style, and thus inhibitory control is relatively stable, biologically based, and can be measured early in life (12).

Inhibitory control's implications for weight outcomes could interact with parenting, as optimal parenting strategies in many contexts depend on the child's behavioral style. In the developmental literature, this is referred to as goodness of fit (13). For example, intrusive parenting does not seem to be a good fit for children low on self-regulation. Rubin et al (14) found that children's poor self-regulation was associated with more behavior problems when mothers were also intrusive. The primary aim of the current study was to determine whether children's inhibitory control levels at age 7 specifically predicted: 1) concurrent weight status, 2) change in weight status, 3) later weight status, and 4) likelihood of being overweight at study termination in a sample of 197 non-Hispanic, White girls, measured at ages 5, 7, 9, 11, 13, and 15. Additionally, to investigate interactions with parenting, we included parents' restrictive feeding practices, which have been implicated in problems with self-regulation, particularly children's overeating and overweight (15–18).

Methods

Participants were 197 Caucasian girls and their parents, who were from central Pennsylvania and were part of a longitudinal study of the health and development of young girls. The girls were assessed at ages 5, 7, 9, 11, 13, and 15; eighty-five percent of the sample was retained over the ten-year period. Independent sample t-tests were used to compare the 161 participants with full BMI data to a group of 36 participants who were missing BMI data in order to investigate selective attrition. There were no significant differences between these groups on inhibitory control ($p=.83$), baseline BMI (age 5; $p=.43$), or parental restriction ($p=.34$). Eligibility criteria for girls' participation at the time of recruitment included living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products; families were not recruited based on weight status or concerns about weight. Families were recruited for participation in the study using flyers and newspaper advertisements. In addition, families with age-eligible female children within a 5-county radius received mailings and follow-up phone calls.

The mean family income level was \$35,000–\$50,000 when girls were 5 years old. Parents were well-educated; mothers' reported mean education was 14.5 ± 2.3 years (range = 12–20) and fathers' was 14.7 ± 2.6 years (range = 12–20). Parents were on average slightly overweight when girls were 5 years old, with a mean body mass index (BMI, weight (kg)/height (m)²) of 26.4 ± 6.1 for mothers, and 28.1 ± 4.4 for fathers. The Pennsylvania State University Institutional Review Board approved all study procedures, and parents provided consent for their family's participation before the study began.

Inhibitory control was assessed with The Child Behavior Questionnaire (CBQ), a reliable and valid temperament instrument, which measures 15 temperament subscales (19). Parents rate how well each statement represents their child on a scale of 1 (extremely untrue of your child) to 7 (extremely true of your child). In this study, mothers reported on girls' inhibitory control levels when the girls were 7 years old. Items that load highly on this subscale include: "Is able to resist laughing or smiling when it isn't inappropriate," and "Can easily stop an activity when s/he is told 'no.'" It should be noted that items attempt to tap a global indication of inhibitory control; none of the subscale's 13 items mention food or eating.

When the girls were 7 years old, they completed the child-report version of the Child Feeding Questionnaire (KCFQ), a self-report measure, based on the parent-report version of the measure (CFQ; 20). Both the child and adult versions of this measure are intended to tap perceptions of parents' controlling feeding practices, such as restriction and pressure to eat. In this study, the KCFQ subscale of interest was restriction. Girls indicated the extent to which they perceived parental restriction in feeding by responding to 10 items (i.e., "If you ask for a snack, does mommy let you have it?"). Composite scores on this subscale can range from 1 (low restriction) to 3 (high restriction).

Heights and weights were measured in triplicate when girls were 5, 7, 9, 11, 13, and 15. BMI was calculated from the average height and weight values using the equation: $BMI = kg/m^2$. Because the sample was uniform in age and sex, we used BMI as the primary outcome. All analyses were also conducted using BMI z-scores, and results were similar. Additionally, results were plotted on the CDC Growth Charts, so that the reader can interpret our results relative to normative data. The CDC Growth Charts (21) were used to calculate BMI z-scores and percentiles, and girls with a BMI at or above the 85th percentile for age and sex were considered overweight.

Girls' mothers reported their own and fathers' income and education levels when girls were 5 years old. At this time point, mothers' and fathers' heights and weights were also measured, and their body mass indexes were calculated. All analyses were conducted using SAS Version 9.1. A series of regression analyses were used to determine whether mothers' ratings of girls' inhibitory control at age 7 predicted BMI at age 7, BMI change from age 7 to age 15, and subsequent BMI at age 9, 11, 13, and 15.

To prepare for analyses testing whether inhibitory control predicted average BMI change, a repeated measures ANOVA was first conducted to determine how change should be conceptualized. This analysis showed significant linear time effects and did not show any significant higher-order trends in BMI change (quadratic, cubic, quartic). Thus, linear regression was used to estimate slopes for each individual from their repeated BMI measurements. The data were stacked in the univariate format and BMI was regressed on time point (age 7, 9, 11, 13, 15), yielding individual slope estimates for each girl, representing with one number the average magnitude and direction of her linear BMI change from age 7 to age 15. These individual slopes were calculated for girls with BMI data at four or more time points, including age 15 ($n=166$). For clarity, these slopes will be referred to as average BMI change scores from this point forward. These BMI change scores were regressed on inhibitory control to investigate whether girls' inhibitory control levels predicted average change in BMI from age 7 to age 15.

Finally, a dichotomous variable was created to distinguish girls who were overweight at age 15 (at or above the 85th percentile on the CDC growth charts) from those who were underweight or normal weight, and logistic regression was used to determine whether inhibitory control predicted likelihood of being overweight at age 15. The following covariates were added to

the analyses with outcomes of average BMI change and age 15 BMI: age 5 BMI, family income, maternal and paternal education levels, and maternal and paternal BMI.

Regression analyses were used to test whether inhibitory control at age 7 and girls' reports of parental restriction in feeding at age 7 interacted to predict age 15 BMI, as well as the average BMI change from age 7 to 15. These analyses were repeated using the following covariates: maternal and paternal education levels, family income, and maternal and paternal BMI. Additionally, four groups were created by splitting the girls on both inhibitory control level and level of perceived parental restriction (at the mid-points of the questionnaires' response scales), and these groups were compared to detect group differences in 1) age 15 BMI and 2) average BMI change, using one-way analysis of variance.

Results

Descriptive statistics for inhibitory control and restriction, as well as background characteristics and covariates, are reported in the Table. On average, girls' inhibitory control levels approximated normative data provided by Rothbart et al (19). The median inhibitory control score was 5.1 (range = 2.0–6.8). Girls' BMI data also were consistent with national data, on average (21). Girls' mean BMI percentiles were around 60 at all ages, with a mean BMI percentile of 59.7 at age 7 and a mean BMI percentile of 61.5 at age 15. Approximately 20% of the girls were classified as overweight at the end of the study.

Girls' inhibitory control at age 7 significantly predicted girls' BMI at all time points: at age 7, $\beta = -.25$, $p < .001$, age 9, $\beta = -.26$, $p < .001$, age 11, $\beta = -.31$, $p < .001$, age 13, $\beta = -.27$, $p < .001$, and age 15, $\beta = -.30$, $p < .001$. Thus, girls rated low on inhibitory control at age 7 tended to have higher BMIs concurrently and at all follow-up measurements. Girls' inhibitory control at age 7 also significantly predicted average BMI change, $\beta = -.21$, $p < .01$. In other words, girls with lower inhibitory control levels tended to experience greater weight gain from age 7 to 15. Results did not change when controlling for girls' age 5 BMI; furthermore, the analyses with age 15 BMI and average BMI change as outcomes did not change when including the following covariates: family income level, maternal and paternal education level, and maternal and paternal BMI (all at study entry, when girls were 5 years old). Inhibitory control also significantly predicted likelihood of overweight at age 15, $\beta = -.28$, $p < .01$. For each unit decrease on inhibitory control, girls were 1.95 times more likely to be overweight at age 15 (95% CI: 1.18–3.21). Compared with the rest of the sample, the girls with the lowest inhibitory control levels (bottom quartile) had significantly higher age 15 BMIs ($t(49.6) = 2.76$, $p < .01$) and average BMI change scores ($t(56.9) = 2.72$, $p < .01$) than the rest of the sample, suggesting the possibility of a threshold effect such that the lowest levels of inhibitory control could be driving these relations. For these analyses, the degrees of freedom reflect an adjustment for unequal variances in the two groups.

The relation between girls' inhibitory control at age 7 and BMI at age 15 was moderated by girls' reports of parental restriction in feeding at age 7 ($\beta = .18$, $p < .05$); girls who perceived higher restriction tended to exhibit the strongest relations between lower inhibitory control and higher weight status. In general, the pattern of results did not change when adding income, parent education, or parent BMI variables to the model, although maternal and paternal education reduced significance to a trend level. The interaction between inhibitory control and restriction also predicted average BMI change at a trend level ($\beta = .14$, $p < .10$).

To further examine maternal restriction as a moderator of inhibitory control's relation with girls' weight status, the sample was divided into as four discrete groups: 1) low inhibitory control/low restriction ($n = 15$), 2) low inhibitory control/high restriction ($n = 21$), 3) high inhibitory control/low restriction ($n = 69$), and 4) high inhibitory control/high restriction ($n = 62$).

The mean inhibitory control score for girls lower on inhibitory control was 3.9; the mean for girls higher on inhibitory control was 5.3. The mean restriction score for girls lower on restriction was 1.7; the mean for girls higher on restriction was 2.3. Overall differences in the four groups' age 15 BMI ($F(148,3)=4.83, p<.01$) and average BMI change scores ($F(145,3)=3.42, p<.05$) were demonstrated (Figure 1). The low inhibitory control/high restriction group was significantly different from both of the high inhibitory control groups (high inhibitory control/low restriction, high inhibitory control/high restriction), such that this group had higher age 15 BMI values ($p<.01$), as well as greater weight gain ($p<.05$). The low inhibitory control/low restriction group was not significantly different from any of the other groups on age 15 BMI or BMI change.

Discussion

Evidence that individual differences in inhibitory control were precursors of differences in weight outcomes was provided by the finding that inhibitory control predicted average BMI change, as well as the finding that relations between BMI, BMI change, and inhibitory control were maintained after adding age 5 BMI as a covariate. This directionality is consistent with experimental studies on self-regulation. For example, Israel et al reported that 8- to 13-year-old obese children showed reduced overweight and tricep skinfolds after the administration of a behavioral treatment program where the children were randomly assigned to groups. In this study, the effects persisted longest in the treatment group whose intervention included greater training in child self-regulation (9). Further research is needed to investigate whether there is a reliable threshold effect in the relation between inhibitory control and weight outcomes, such that these relations are consistently driven by participants with the lowest levels of inhibitory control. Such research has implications for targeted interventions.

The relations between restriction and weight outcomes are consistent with previous research, which demonstrated that high parental restriction was related to increased intake and higher weight statuses among children (16–18,22–24). These researchers hypothesized that restriction interfered with children's abilities to self-regulate their intake. The current results indicate that high restriction in combination with low inhibitory control sets the most at-risk group apart, highlighting that some individuals may be more susceptible to risky weight outcomes than others, even when experiencing the same parenting practices. Similarly, restrictive parenting practices may only be problematic if the child is low on inhibitory control. The important point inherent in both of these interpretations is that it is the combination of both low inhibitory control and high restriction which is most problematic, and that neither of these constructs may be a problem without the other.

This study demonstrates that, in addition to predicting outcomes related to healthy social, intellectual, and moral development, inhibitory control also has implications for children's healthy weight outcomes. Although this is one of the first studies to focus on inhibitory control and weight outcomes specifically, the demonstrated relations are consistent with previous research using the related construct of self-regulation. Interventions involving self-regulation training have resulted in less weight gain (7,9,10). Previous research on self-regulation and intake and on eating behavior and weight status implicate excessive caloric intake as the behavior linking inhibitory control and weight outcomes. Consistent with this hypothesis, relations between eating in the absence hunger (a behavioral measure of disinhibited eating) and weight status have been demonstrated in the same sample of girls (16,24,25).

The current study has a number of limitations and strengths. Although inhibitory control has demonstrated relative stability (2,26), additional inhibitory control measurements, especially before age 7, would be useful to test these assumptions. Second, causality cannot be established in an observational study, even though longitudinal and covariate analyses reveal that

individual differences in temperament preceded differences in weight outcomes. Alternative interpretations include: 1) a higher weight status leads girls to exhibit less inhibitory control, or 2) both weight and inhibitory control are inherited from parents and do not causally affect one another. Finally, it is unclear whether these results would be replicated in future studies or in other populations. The homogeneity of the current sample can be interpreted as both a strength and a limitation. It is a limitation in that these results cannot be generalized beyond White girls living in well-educated, middle-to-upper SES families, but it is beneficial to initially examine relations in a homogeneous population to avoid demographic confounds (27). Other strengths of this study include 1) the specificity used in operationalizing inhibitory control, 2) the use of mother- and child-report measures, instead of self-report measures from the same individual, 3) the longitudinal nature of the study, and 4) the use of previously validated measures.

What alternative feeding practices could decrease the risk of these negative weight outcomes? One possible approach would be to target girls' inhibitory control level through self-regulation training. Prompting and practicing such skills have been shown to lead to improvements in children's innate predispositions to regulate their behaviors, both in general and in the context of eating behavior. For example, Johnson (10) demonstrated that children's abilities to self-regulate their intake could be improved through training to focus on internal hunger and satiety signals. It is possible that parents could help teach their children self-regulation skills. The body of work relating to this possibility is small (e.g., 28), but the effectiveness of such strategies could be tested.

Another possibility is to communicate to parents that they should help regulate what their children eat, but that this restriction should be discreet instead of overt. For example, parents can control which foods are available in the home, allowing children to choose within constraints and helping to cultivate healthy habits (29,30). By controlling what foods are available, the parent avoids overt restriction and exposes the child to nutritious foods; there is evidence that exposure produces familiarization, leading to food preferences and acceptance (31). Although such practices would be advantageous for all children, our research suggests that alternatives to restrictive feeding practices are especially important when children are low on inhibitory control. The idea that optimal parenting practices depend on children's behavioral styles is consistent with goodness of fit theory (13). In cases where discreet restriction may not be adequate, additional approaches that may be effective include setting limits, being sure to follow them with explanations and expressions of warmth. Although research has not investigated restriction against the backdrop of differing parenting styles, this advice is consistent with the broader parenting literature (32) and with findings that the relation between parenting and child outcomes is moderated by the quality of the parent-child relationship (e.g., 33).

Because we live in an environment in which obesity rates continue to escalate, and cognitive control is required in order to maintain a healthy weight status (6), a priority for research is to elucidate which individuals are predisposed to weight gain when faced with an endless supply of inexpensive, palatable foods and pervasive sedentary lifestyles. An acknowledgement of such individual differences can help to determine whether previously-identified correlates of obesity are specific to individuals with a certain temperamental standing, to elucidate the various paths that lead to the common outcome of obesity in the current environment, and to identify individuals who are predisposed to obesity risk at an early age as potential targets for intervention. Interventions designed to target inhibitory control and/or restrictive feeding practices would have far-reaching benefits for the whole child's well-being, given relations between inhibitory control and social, academic, and behavioral outcomes, and given the benefits of a synchronous parent-child relationship.

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List of abbreviations

BMI	Body Mass Index
CBQ	Child Behavior Questionnaire
KCFQ	Child Feeding Questionnaire (kid-report version)
CDC	Centers for Disease Control and Prevention
IC	inhibitory control
res	restriction

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Figure 1.

BMI over time in girls with low and high inhibitory control. Girls with lower inhibitory control tended to have a higher BMI at each time point, as well as a faster rate of BMI increase over time. Although the corresponding analyses reported in this manuscript were conducted using a continuous measure of inhibitory control, the categorical comparisons depicted in this figure were also statistically significant, including the comparisons between low and high inhibitory control groups at each time point (represented by the asterisks, all $p < .05$), as well as the comparison of the slopes of the two lines ($p < .05$; low inhibitory control group $n=41$; high inhibitory control group $n=151$).

Figure 2.

Average BMI change by inhibitory control and restriction groups, with corresponding BMI percentiles. Girls with lower inhibitory control *and* higher parental restrictive feeding tended to show the most weight gain over time and the highest BMIs at study termination. This group's average BMI crosses into the overweight range over time (greater than the 85th percentile for age and sex; CDC Growth Charts). This group's BMI and BMI change were significantly different from those of girls with higher inhibitory control (the two gray lines). Different subscripts to the right of the lines indicate statistically significant differences between groups on average BMI change (slope) and age 15 BMI ($p < .05$; low IC/low res $n=15$; low IC/high res $n=21$; high IC/low res $n=69$; high IC/high res restriction $n=62$).

Table 1
Background Characteristics at Study Entry and Descriptive Statistics for Key Variables

Variable	Mean $\pm$ SD	Range
Background characteristics (<i>n</i> =197)		
Family income	\$35–50,000	>\$20,000–<\$50,000
Mothers' years of education	14.5 $\pm$ 2.3	12–20
Fathers' years of education	14.7 $\pm$ 2.6	12–20
Girls' age 5 BMI percentile ¹	60.3 $\pm$ 26.5	1.5–99.7
Moms' BMI	26.4 $\pm$ 6.1	17.7–56.5
Dads' BMI	28.1 $\pm$ 4.4	18.7–42.0
Key variables		
Inhibitory control ^{2, 3}	5.0 $\pm$ 0.8	2.0–6.8
Parental restriction in feeding ⁴	2.0 $\pm$ 0.4	1.0 – 2.9

¹ Percentiles were calculated using the CDC growth charts. Analyses were conducted using raw BMI scores, which was permissible due to the sample's common age and sex. Percentiles are provided here, so that the descriptive data can be interpreted relative to normative data.

² Main effect variables were centered in analyses involving interactions in order to avoid Heywood cases. Descriptive statistics are provided for raw variables, which are also used in the figures for interpretability.

³ Possible scale values = 1–7; 1 = low inhibitory control. These results are similar to normative data from a sample of 341 6- and 7-year-olds: *M*=4.9, *SD*=0.8, *Range*=2.5–6.8 (19).

⁴ Possible scale values = 1–3; 1 = low restriction.