Self-regulation and Rapid Weight Gain in Children From Age 3 to 12 Years

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Objective: To examine the extent to which self-regulatory capacities, measured behaviorally at ages 3 and 5 years, were linked to rapid weight gain in children from age 3 to 12 years. Self-regulation failure, or the inability to control an impulse or behavior, has been implicated as a mechanism in the development of overweight.

Design: Prospective longitudinal cohort study.

Setting: Home and laboratory-based settings in 10 sites across the United States.

Participants: Data were drawn from 1061 children as part of the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development.

Main Exposure: Self-regulatory capacity was measured in 2 behavioral protocols; children participated in a self-control procedure at age 3 years and a delay of gratification procedure at age 5 years.

Main Outcome Measures: Age- and sex-specific body mass index (BMI) z scores were calculated based on measured BMI at 6 points.

Results: Mixed-modeling analyses were used to examine differences in the rate of weight gain over time based on the extent to which children exhibited the ability to self-regulate in the behavioral procedures. Compared with children who showed high self-regulation in both behavioral protocols at ages 3 and 5 years, children who exhibited a compromised ability to self-regulate had the highest BMI z scores at each point and the most rapid gains in BMI z scores over the 9-year period. Effects of pubertal status were also noted for girls.

Conclusion: Self-regulation failure in early childhood may predispose children to excessive weight gain through early adolescence.


Obesity in childhood and adolescence appears to track into adulthood, increasing the risk of developing cardiovascular disease, diabetes mellitus, and certain cancers in adulthood. To mount effective preventive efforts, we need better information regarding the factors involved in the etiology of childhood overweight and obesity. Self-regulation failure is one such factor that has been implicated in the development of obesity.

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lay of gratification). We tested the hypothesis that children who exhibited self-regulation deficits in these procedures would exhibit problems with energy-balance regulation, characterized by rapid weight gain over a 9-year period. Sex differences were also examined.

METHODS

PARTICIPANTS

Longitudinal data were drawn from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development. Extensive details about study recruitment and data collection procedures and information on measures are available on the study Web site (http://secc.rti.org). Data collected when children were ages 3, 5, 7, 9, 11, and 12 years were used in the current study; data were available for a total of 1061 families when children were aged 3 years. A majority of children in the sample were classified as being non-Hispanic white (80%), followed by black (13%), Asian (2%), and other (5%); 6% of children were Hispanic, and 52% were boys. A series of home and laboratory visits were conducted at each point, and mothers reported information on their families and their child. This study was approved by the Pennsylvania State University institutional review board.

MEASURES

Child Self-regulation

Children’s self-regulatory capacity was measured in 2 video-recorded behavioral procedures designed to assess the extent to which children exhibit self-regulatory skills. Children who did not have a valid response (eg, did not understand instructions) were not given a score on either procedure.

Self-control Procedure at Age 3 Years

In this procedure, the child, mother, and interviewer were together in a private observation room. Mothers were instructed to work quietly on questionnaires in a corner and to avoid interacting with or helping children. The interviewer introduced the children to a target toy that was very appealing and allowed the children to touch and play with the toy before the “waiting game” began. Once the children had an opportunity to play with the toy, the children returned it to the interviewer and the interviewer told the children that he or she was going to leave to do some work in another room. The children were told that they were not allowed to touch the target toy until the interviewer returned but that they could play with other toys that were available to them in the room; the children were left alone with the target toy for 150 seconds. Because the scores for this procedure were highly skewed, children were dichotomized into 2 groups based on their scores in the self-control procedure: children who waited at least 75 seconds before the interviewer returned were classified as high on self-regulation, and children who waited less than 75 seconds were classified as low on self-regulation. The estimate for interrater reliability was 0.92 on this measure.

Delay of Gratification Procedure at Age 5 Years

In this procedure, children were introduced to 3 foods, including M&M’s candies (Mars North America, Hackettstown, New Jersey), animal crackers, and pretzels. Once the children identified their favorite food, small and large piles of the food were placed on the table in front of them. Children were told that they could have the small pile of food any time they wanted after the interviewer left the room but that they must ring a bell for the interviewer to return before they could eat from the small pile. If the child wanted the large pile of food, they had to wait until the interviewer returned on his or her own. Because the scores on this procedure were highly skewed, this variable was also dichotomized: children who waited at least 210 seconds before the interviewer returned were classified as high on self-regulation, and children who waited less than 210 seconds were classified as low on self-regulation. Information on interrater reliability was not available for this measure.

Children were further stratified into 4 groups based on the extent to which they exhibited problems with self-regulation in both procedures: (1) children who were classified as high in self-regulation in both procedures, (2) children who were classified as low in the control procedure only, (3) children who were classified as low in the delay of gratification procedure only, and (4) children who were classified as low in both procedures. These 4 groupings were the major focus of this study.

Child Weight Status

Standing height and weight were measured in duplicate at all 6 points by trained study personnel, using standardized procedures. Age- and sex-specific body mass index (BMI) scores were calculated as weight in kilograms divided by height in meters squared using standardized reference criteria. Children’s BMI z scores were also calculated based on these references, and change in BMI z score was used to examine changes in relative weight over time.

Child Problem Behavior and Temperament

In line with previous studies,18 parent reports of externalizing behavior were used to validate children’s performance in the behavioral procedures. Mothers provided a report of child externalizing behavior and inhibitory control. Externalizing behavior was measured at ages 3 and 5 years using the externalizing scale from the Child Behavior Checklist,17 which measures children’s aggressive and disruptive behaviors. Mothers were asked to provide a rating of how much a behavior (eg, impulsive or attacks people) described their child using a scale ranging from 1 (extremely untrue) to 7 (extremely true). The stability coefficient for mothers’ report of children’s externalizing behavior at ages 3 and 5 years was 0.67 (P < .001). Child inhibitory control was also measured at age 5 years using the Children’s Behavior Questionnaire.19 Mothers completed 10 of the original 13 items on the inhibitory control scale and responded to questions about their child’s behavior in the past 6 months on a scale from 1 (extremely untrue) to 7 (extremely true). An example of an item is “My child is usually able to resist temptation when told he/she is not supposed to do something.” Internal consistency estimates for the Children’s Behavior Questionnaire subscales in this sample of mothers ranged from 0.60 to 0.85.

Pubertal Status

Children’s pubertal status was measured beginning at age 9 years during an annual health and physical development assessment conducted by a nurse or pediatric endocrinologist. Tanner criterion staging was used to assess boys’ and girls’ pubertal development; the original protocol proposed by Tanner19 was used to measure genital and pubic hair development in boys, and an amended version proposed by Herman-Giddens and Bourdony20 was used to measure breast and pubic hair development in girls. Thirty-four
Table 1. Family Demographic Informationa

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Self-regulation Group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Full Sample</td>
<td>Low Both Proceduresb</td>
</tr>
<tr>
<td>Maternal education, y</td>
<td>14.2 (2.5)</td>
<td>13.4 (2.38)*</td>
</tr>
<tr>
<td>Family income, $1000</td>
<td>53.5 (43.8)</td>
<td>41.2 (36.2)*</td>
</tr>
</tbody>
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a Different superscript symbols denote significant differences between groups.
b Evidence of problems with self-regulation in the self-control procedure at age 3 years and the delay of gratification procedure at age 5 years.
c \( P < .001 \).

Girls were excluded from analyses examining the effects of pubertal status on weight gain because they were early mature, with breast development classified as greater than Tanner stage 2 at age 9 years. Previous studies have shown a link between earlier maturation and elevated weight status, so we wanted to remove this confound.21-23

Family Demographics

Combined family income and maternal education were reported at each measurement occasion. For the purposes of the present study, family demographic information reported at the age 3 years visit was used in analyses.

STATISTICAL ANALYSES

Data were analyzed using SAS version 9.1 (SAS Institute, Cary, North Carolina). Descriptive information was generated for all variables of interest, and each variable was assessed for normality. Analysis of covariance with Tukey post hoc tests was used to assess BMI \( z \) score differences between self-regulation groups. We also examined whether children who exhibited a compromised ability to self-regulate in the behavioral procedures were rated by mothers as higher in externalizing behaviors at ages 3 and 5 years. Mixed modeling (SAS Proc MIXED) was used to assess the effects of child self-regulation group on the patterns of change in BMI \( z \) scores from age 3 to 12 years. Main effects of time, self-regulation group, and a self-regulation group \( \times \) time interaction were tested in this model. A significant interaction effect provides evidence for a differential rate of growth in relative weight over time for children in different self-regulation groups. Mixed modeling is a useful statistical tool for examining group (self-regulation) differences in patterns of change in BMI over time, and it is particularly useful for its ability to handle missing data using full information maximum likelihood estimation. Identical models were also run separately for girls and boys.

RESULTS

FAMILY BACKGROUND CHARACTERISTICS

Information on family demographics appears in Table 1. Overall, families reported an average combined family income of approximately $54 000/y; 17% of families were living below the poverty level. Mothers reported an average of approximately 14 years of education. Demographic differences between self-regulation groups were noted; children who were classified as low in both procedures had mothers who reported significantly lower levels of education \( (P < .001) \) and combined family income \( (P < .001) \) compared with children classified as high in both procedures. Thus, all analyses were adjusted for maternal education and family income.

CHILD BMI \( z \) SCORES AND MATERNAL REPORTS OF CHILD BEHAVIOR

Mean differences across groups in weight status and mothers’ reports of child externalizing behavior and inhibitory control are listed in Table 2. On average, children who exhibited low self-regulation in both procedures had significantly higher BMI \( z \) scores at all points, compared with children classified as high in both procedures. Combined with all other groups, children with low self-regulation in both procedures were rated by mothers as higher on externalizing behaviors at ages 3 and 5 years \( (P < .001) \) and lower on inhibitory control \( (P < .001) \) at age 5 years, validating the outcomes measured in the self-control and delay of gratification procedures.

SELF-REGULATION AND CHILD BMI \( z \) SCORE INCREASES FROM AGE 3 TO 12 YEARS

In childhood, BMI increases steadily, reflecting normative changes in height and weight. For these analyses, we were specifically interested in group differences in the rate of growth in BMI over time. Results revealed that patterns of BMI change differed for children based on the extent to which they exhibited low or high self-regulation in the behavioral procedures, as shown in Figure 1. Results of the mixed-model analyses revealed a significant self-regulation group \( \times \) time interaction \( (F = 1.97; P < .05) \). Children who were low in self-regulation in both procedures had the most rapid gains in BMI \( z \) score from age 3 to 12 years \( (BMI \ z \text{score}_{3-12} = 0.57 + 0.05) \). Children who were low on both procedures gained significantly more weight over time than children who were low on the delay of gratification procedure only \( (BMI \ z \text{score}_{3-12} = 0.40 + 0.05; t = 0.06; P < .05) \) and children who were high on both procedures \( (BMI \ z \text{score}_{3-12} = 0.32 + 0.05; t = 3.76; P < .001) \). Children who were low on the self-control procedure only had significantly greater BMI \( z \) score gains over time \( (BMI \ z \text{score}_{3-12} = 0.50 + 0.07) \) compared with children who...
were high on both procedures ($t = 1.95; P < .05$). No other significant differences were noted between groups.

**SEX DIFFERENCES IN SELF-REGULATION AND BMI CHANGE OVER TIME**

*Table 3* provides descriptive information on sex differences in the self-control and delay of gratification procedures, as well as BMI $z$ scores. Boys exhibited significantly lower levels of self-regulatory skills in the self-control procedure ($P < .001$); sex differences in the delay of gratification procedure approached significance ($P = .07$), with boys waiting for shorter periods, compared with girls. Sex differences in BMI $z$ score were noted at ages 9 ($P < .01$) and 11 ($P < .05$) years; boys had significantly higher BMI $z$ scores than girls at both points. No other sex differences were noted in weight status.

We were also interested in examining whether the relation between self-regulation and BMI $z$ score change differed by sex; mixed models were run separated for girls and boys. In boys, there was a significant main effect of self-regulation group on BMI $z$ score change over time ($F = 3.51; P < .05$); however, this effect was no longer significant after adjusting for BMI $z$ score at 24 months ($P = .57$). In girls, there was a significant self-regulation group $\times$ time interaction, with the greatest gains in BMI $z$ score by age 12 years in girls who exhibited low self-regulation in both procedures, compared with girls who were high on both procedures ($t = 2.65; P < .01$). This interaction effect was reduced to a trend after controlling for BMI at 24 months ($F = 1.59; P = .07$). Because the interaction effect was only present for girls, we examined the influence of pubertal status at age 9 years on these relations, while controlling for the influence of initial BMI. We consider puberty a growth and psychosocial transition that contributes to brain development, psychological functioning, and behavior that reflects more than merely a change in weight and weight gain. Thus, it seemed important to control for pubertal stage so as to
rule out confounding influences of puberty-related changes and weight gain. There was a significant pubertal status × time interaction \( F = 6.40; P < .001 \), which indicates that girls with a stage 2 Tanner rating (breast development) at age 9 years showed the greatest gains in BMI over time, compared with girls with a stage 1 rating. In addition, these results show that girls with a stage 2 Tanner rating at age 9 years were gaining weight at a faster rate over time than girls with a stage 1 rating (Figure 2). The self-regulation × pubertal status interaction was not significant.

This objective of this report was to examine patterns of weight gain in children from age 3 to 12 years based on the extent to which they exhibited self-regulation in a self-control procedure at age 3 years and a delay of gratification procedure at age 5 years. The findings show that indeed children who exhibited low self-regulation in both procedures had significantly higher BMI at all points. In addition, children who exhibited low self-regulation in both procedures had the most rapid gains in BMI from age 3 to 12 years. These findings advance the literature on childhood obesity in at least 2 important ways. First, early childhood self-regulatory problems are important longitudinal predictors of weight problems in early adolescence. Second, self-regulation failure in the behavioral procedures appears to generalize to regulatory problems in the energy-balance domain of development, as evidenced by higher weight status and more rapid weight gain from early childhood through adolescence. While the delay of gratification procedure measured the ability to delay immediate gratification for a larger food reward, this procedure was not intended to measure energy-balance regulation. There is a specific behavioral protocol that measures eating (or overeating) in the absence of hunger, which is a more accurate indicator of self-regulation failure in the energy-balance domain.\(^{24,25}\) We are limited by the fact that there were no steps taken to standardize children’s hunger levels before the delay of gratification procedure, so the extent to which hunger played a role in children’s decision to choose an immediate reward is unclear.

Our findings support recent studies showing that obesity is a problem that has its roots early in life\(^ {26}\) and that early self-regulation failure may play a role in predicting overweight and obesity in the adolescent years.\(^ {24}\) Already at ages 3 and 5 years, children who exhibited signs of self-regulation failure had higher BMI \( z \) scores and rapid weight gain into early adolescence. Failure to self-regulate energy balance in the early years is likely to be stable over time. Findings from studies on the same sample of children used in this study showed that 60% of children who were overweight at any time during the preschool years and 80% of children who were overweight at any time during the elementary period were overweight at age 12 years.\(^ {24}\) Taken together, these findings highlight the need for future research to examine the role of self-regulation in the etiology of overweight and obesity.

Our findings also support the perspective that self-regulation in one domain generalizes to other domains as well. In the current instance, a diminished capacity to self-regulate behavior in laboratory-based tasks generalized to failure of energy-balance regulation, evident by higher BMI \( z \) scores and more rapid weight gain over time. Johnson and colleagues\(^ {27}\) examined the ability to delay gratification in normal-weight and obese children and found that obese children had greater problems delaying gratification for a food item than for a nonfood item; similar findings have been reported by others.\(^ {28-30}\) In a study with early adolescents, compared with normal-weight adolescents, obese adolescents exhibited greater levels of impulsivity and lower levels of inhibitory control in 2 laboratory-based behavioral tasks.\(^ {31}\) We propose that self-regulation problems in laboratory tasks and behavior reflect an underlying disposition or phenotype to poor self-regulation in other domains.

The sex differences in the patterns of weight gain are important. The weight gain and self-regulation findings held only for girls, despite the finding that boys exhibited greater problems with self-regulation in the self-control and delay of gratification procedures. However, this effect could partially be attributed to BMI \( z \) scores at 24 months, suggesting that early weight remains a significant factor in predicting weight gain even into the early adolescent years. Girls are especially vulnerable to the consequences of obesity, with the negative psychological consequences, such as poor self-image, being more severe in girls than in boys.\(^ {32-35}\) The importance of available energy for reproduction may also be a factor contributing to a faster weight gain in girls. Earlier onset of puberty in girls who rapidly gained weight suggests the importance of energy availability and reproduction in heavier girls.

The timing of pubertal maturation emerged as a potentially important consideration in weight gain over time, with earlier maturers gaining the most amount of weight at a faster rate compared with later maturers in girls, but not in boys. The greater weight gain in earlier-maturing girls is supported by earlier studies.\(^ {21-23}\) However, we advance the literature by the current findings as we show that earlier timing of puberty also predicted a faster weight gain. To our knowledge, the link between rate of weight gain and earlier timing of puberty has not previously been considered, although the causal relationship between weight and
the onset of puberty has been a long-standing question over decades. Current perspectives suggest that weight gain may be a permissive signal to initiate the resurgence of gonadotropin-releasing hormone, as many of the permissive signals for the onset of puberty, insulin, glucose, and leptin, are related to energy balance in females. For successful reproduction, these must be present in quantities for growth that are necessary to support pregnancy. These permissive signals may be pivotal regulators for the integration of energy homeostasis and reproduction. Earlier puberty in heavier girls may reflect the availability of fat-derived permissive signals.

The findings reported herein have potential for early prevention of obesity. The implication is that interventions to enhance energy-balance regulation in young children will benefit from efforts to encourage self-regulation in other domains, such as encouraging self-control and delay of gratification, both of which are important factors in regulating energy intake. Promising intervention findings show that programs designed to improve self-regulation skills in general domains of behavior produced significant decreases in weight status and adiposity, as well as improvements in children’s attitudes toward appetite control, and obesity-promoting behaviors (ie, food choices and television viewing). Taken together, these findings highlight the importance of obesity prevention programs that include components designed to improve self-regulatory capacities in youth. As suggested by Nader and colleagues, clinicians can be confident in counseling parents to begin to address the at-risk child’s eating and self-regulatory behaviors rather than delaying with the hope that overweight and the behaviors that support it will disappear with passing time.

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Author Contributions: Both authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Francis and Susman. Acquisition of data: Susman. Analysis and interpretation of data: Francis and Susman. Drafting of the manuscript: Francis and Susman. Critical revision of the manuscript for important intellectual content: Francis and Susman. Statistical analysis: Francis and Susman. Obtained funding: Susman. Study supervision: Francis and Susman.

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