

PEDIATRIC HIGHLIGHT

Toddler self-regulation skills predict risk for pediatric obesity

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Objective: To investigate the role of early self-regulation skills, including emotion regulation, sustained attention and inhibitory control/reward sensitivity, in predicting pediatric obesity in early childhood.

Method: Participants for this study included 57 children (25 girls) obtained from three different cohorts participating in a larger ongoing longitudinal study. At 2 years of age, participants participated in several laboratory tasks designed to assess their self-regulation skills. Height and weight measures were collected when children were 2 and 5.5 years of age.

Results: Self-regulation skills in toddlerhood were predictive of both normal variations in body mass index (BMI) development and pediatric obesity. Specifically, emotion regulation was the primary self-regulation skill involved in predicting normative changes in BMI as no effects were found for sustained attention or inhibitory control/reward sensitivity. However, both emotion regulation and inhibitory control/reward sensitivity predicted more extreme weight problems (that is, pediatric obesity), even after controlling for 2-year BMI. Thus, toddlers with poor emotion regulation skills and lower inhibitory control skills/higher reward sensitivity were more likely to be classified as overweight/at risk at 5.5 years of age.

Conclusion: Early self-regulation difficulties across domains (that is, behavioral and emotional) represent significant individual risk factors for the development of pediatric obesity. Mechanisms by which early self-regulation skills may contribute to the development of pediatric obesity are discussed.

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The prevalence of pediatric obesity worldwide has increased dramatically in recent decades.¹ In the United States, a 2003–2004 National Health and Nutrition Survey conducted by the CDC indicated that 35% of school-age children were classified as either at risk for being overweight (body mass index (BMI) >85th percentile) or overweight (BMI >95th percentile). Given the significant health and psychosocial problems associated with pediatric obesity and its relatively stable course,^{2–5} it is important to identify its early predictors.

Research on potential risk factors for pediatric obesity has mainly focused on societal and family characteristics. Within the family domain, for example, there is extensive evidence that parental obesity is related to childhood obesity.^{5,6}

In addition to genetic factors, other mechanisms that have been identified as links between parental obesity and childhood obesity include food preference, sedentary lifestyle and feeding styles.^{7,8} Considerably less research has examined individual factors that predict pediatric obesity. One of the few individual factors that have been studied is a child's physical activity level. Not surprisingly, children who engage in less physical activity and prefer sedentary activities are more likely to be overweight compared with active children.⁹

More recently, researchers have acknowledged the importance of examining an individual's self-regulation skills as they relate to eating and subsequent obesity.¹⁰ The regulation of eating generally operates at an automatic level in terms of starting and stopping in response to hunger and satiety cues. However, research has shown that our hunger and satiety signals do not operate as efficiently as we think they may and can be influenced by stress/negative early experiences and social/emotional factors.¹¹ Empirical studies have mainly focused on the link between self-regulation

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and dieting¹² or disordered eating in adolescent or adult populations.¹³ Within the child literature, self-regulation research has mainly focused on children's eating behaviors and response to satiety cues. For example, Birch and colleagues have extensively examined children's ability to self-regulate their energy intake in response to changes in the caloric density of the diet and in responses to parental behaviors.^{8,14} Individual differences in the self-regulation of energy intake have also been documented and linked to adiposity.⁸ Little research, however, has examined whether early individual differences in self-regulation outside the context of food/eating also relate to the development of obesity in children. This question is of fundamental importance to understand the mechanisms related to the development of obesity and to determine whether broad, generalized self-regulation deficits or a more focal deficit within the eating domain places children at risk for becoming obese later in life.

Broadly speaking, self-regulation refers to an individual's conscious or unconscious efforts to alter his/her inner states or responses.¹⁰ Self-regulation is a multilevel construct with control efforts that may include the use of physiological, attentional, emotional and behavioral processes that become more sophisticated and integrated through development.¹⁵ In infancy, early regulation efforts rely primarily on innate physiological mechanisms such as sucking.¹⁶ Toward the end of infancy and the beginning of toddlerhood, attentional control processes emerge and are used as a way to control one's emotions and behavior.^{15,17} Two crucial cognitive functions involved in attentional control are sustained attention and inhibitory control. Sustained attention refers to the toddler's ability to maintain his/her focus on a specific stimulus, whereas inhibitory control refers to the ability to withhold prepotent responses that may be inappropriate.¹⁸ Together, sustained attention and inhibitory control facilitate an organism's ability to control his/her attention for the purpose of resolving potential conflicts.^{17,18} Individual differences in attentional control are well documented along with its importance for children's adaptive functioning.^{19,20} However, little research has examined the role of attentional control in pediatric obesity. Theoretically, attentional control may be related to the development of obesity through the former's role in promoting maladaptive eating behaviors. For example, children with poorer attentional control skills may be more likely to engage in maladaptive eating behaviors (for example, impulsive eating). They may also have more difficulty in delaying gratification/resisting snacks.

The effect of attentional control on impulsive behaviors is well documented. For example, inhibitory control abilities have been found to be particularly important for controlling impulsive behaviors such as reactive aggression,²¹ gambling²² and binge drinking.²³ As it relates to obesity, impulsivity has been associated with binge eating and eating disorders in adults.²⁴ Considerably less research has examined the link between attentional control and obesity in children.

Overweight children have been found to have lower levels of behavioral inhibition during a laboratory task.²⁵ A study conducted in Germany also found that children diagnosed with attention deficit/hyperactivity disorder (ADHD) had higher BMIs compared with age-adapted reference values of the German population.²⁶ More recently, Cserjési *et al*²⁷ using a small sample ($n = 12$) of school-age boys found that obese boys performed worse on an attentional endurance task compared with normal weight peers. Impulsivity also has a role in the treatment of pediatric obesity. For example, children with higher levels of impulsivity lost less weight during treatment compared with children with lower levels of impulsivity.²⁸ Whether the attentional control deficits present in obese children are specific to eating/food context or if they occur across contexts remains unclear as older literature on the delay of gratification tasks in obese and lean children have found mixed results.^{29,30} Nevertheless, it seems that children's poor inhibitory control skills facilitate impulsive eating or make it more difficult for them to resist urges for snacks or more food. This may in turn contribute to the development of obesity. However, it remains unclear when these attentional control deficits emerged as all of these past studies were conducted with older school-age children and were cross-sectional in nature.

Although attentional control may relate to pediatric obesity by reducing behavioral impulsivity related to eating, other self-regulation skills such as emotion regulation may operate by controlling affective processes that relate to eating. The adult literature has documented the effects of emotional functioning on eating behavior. For example, although for most individuals emotional arousal lowers one's appetite through a reduction in gastric hunger contractions, obese individuals tend to increase their food intake during periods of emotional arousal and/or stress, a response known as emotional eating.^{31,32} Adults with emotion regulation difficulties also engage in more binge eating behaviors.³³ The few studies that have been conducted with children have focused on the association between emotion dysregulation and eating disorders, especially in adolescent girls.³⁴ No study to date, however, has examined the association between emotion dysregulation and obesity in early childhood. It is also unclear whether early emotion regulation skills can help predict whether children become overweight or are at risk for becoming overweight.

Another mechanism by which emotion regulation skills may influence the development of obesity entails its biological ties through the vagus nerve. The influence of the vagus nerve on cardiac output (for example, vagal regulation) has been conceptualized as a physiological regulation mechanism responsible for facilitating the use of metabolic resources in the service of coping.^{35–37} The vagus nerve, however, also enervates the stomach and has a central role in satiety and short-term regulation of food intake.³⁸ In fact, recent adult studies have found that stimulation of the vagus nerve significantly reduces food cravings in obese adults.³⁹ Greater emotion regulation skills in adults have also been

found to reduce the risk for metabolic syndrome.⁴⁰ Hence, theoretically, it makes sense that children with early emotion regulation difficulties, indicative of an understimulated vagus nerve, may also have difficulties regulating their food consumption and end up overeating because of inaccurate feelings of hunger.

In summary, theoretical, physiological and empirical data support the need to examine self-regulation processes in overweight children. Although this area of research has been largely unexplored in children, adult studies have found that obese adults have significant self-regulation/executive functioning deficits.^{32,39,41,42} The few cross-sectional studies with children have documented a link between impulsivity and obesity.^{25,28} However, it remains unclear whether these self-regulation deficits were present before the individuals became obese. It also remains unclear whether other self-regulation skills (for example, sustained attention and emotion regulation) are impaired in children who are overweight. The purpose of this study was to determine whether early individual differences in self-regulation skills outside the context of eating/food constitute significant risk factors for the development of weight problems. It was expected that toddlers with poorer self-regulation skills would experience greater BMI gain and be more likely to be classified as overweight/at risk in early childhood.

Method

Participants

Participants for this study included 57 children (25 girls) obtained from a larger ongoing longitudinal study that was approved by the governing Institutional Review Board. A total of 447 participants were initially recruited at 2 years of age through childcare centers, the County Health Department, and the local Women, Infants and Children program. Further details about the recruitment may be found in Smith *et al.*⁴³ The recruitment sample was diverse with 67% of the children classified as European-American, 27% were African-American, 4% were biracial and 2% were Hispanic. At age 2, the children were primarily from intact families (77%), and families were economically diverse, with Hollingshead (1975) scores ranging from 14 to 66 ($M=39.56$). Of the original 447 participants, 365 participated at 5.5 years of age assessment. There were no significant differences between families who did and did not participate at 5.5 years in terms of gender, race and SES. This study focused on a subgroup of children for whom laboratory measures and height/weight measurements were obtained. Complete data were available on 57 children who were racially (65% Caucasian) and economically diverse (Hollingshead scores range from 14 to 61, $M=38.91$). In addition, complete data, other than 2 years height/weight, were available on 204 children. All available data were used for each analysis. There were no significant differences in terms of gender, race or SES between children with complete versus partial data, and

neither were there any differences between this study's sample and the original recruitment sample.

Procedures

The focus of this study involved several laboratory assessments at the 2-year visit. When children were of 2 years of age, mothers brought their children to the laboratory and were videotaped during several tasks. The order of the tasks were standardized and children were given small breaks at the end of each task to ensure that there were no carryover effects from one task to another. The first task was a sustained attention task in which children were instructed to watch a 5-min segment of the videotape 'Spot', a short story about a puppy that explores its neighborhood. Following this task, children engaged in various mother-child interaction tasks including a teaching task, a free-play session, a compliance task and a puzzle task. Once the mother-child interaction tasks were completed, children participated in two tasks designed to elicit emotion regulation. The prize in a box task, where a desirable toy (puppet) was placed in a clear box that the child was unable to open for 2 min, and a high-chair task, where the child was placed in a high chair without any toys for 5 min, were used to code observed emotion regulation and emotional reactivity (LAB-TAB⁴⁴). The tasks were ended early if the child was highly distressed/cried hard for more than 30 s. Following a more extensive break (5 min), children came back to the laboratory and participated in a delay of gratification task aimed at measuring children's reward sensitivity and to a certain degree their inhibitory control skills. While in the laboratory, mothers completed various questionnaires. Follow-up assessments took place when children were approximately 5.5 years of age. Demographic variables were collected at each visit. Weight and height measures were collected on the entire sample during the 5.5-year visit with a subgroup of children ($n=57$) also having weight/height measures at the 2-year visit.

Measures

Anthropometrics. Trained research assistants measured children's height and weight during their 2- and 5.5-year laboratory visit. Degree of overweight was calculated on the basis of age norms from the Centers for Disease Control.⁴⁵

Two-year emotion regulation. Previous research has shown relations between emotion regulation and emotion reactivity measures where reactivity is a part of the response to the contextual demands that require regulatory strategies to adjust for this change in reactivity.⁴⁶ Thus, both degree of distress and specific regulatory behaviors are considered evidence of emotion regulation processes. Consequently, both emotional reactivity and regulation were coded from videotapes of the frustration tasks (Prize in the Box and High Chair). For reactivity, distress was defined as when the

child whined, fussed, cried or threw a tantrum. A global measure of negative reactivity was coded on a scale from 0, meaning no negative response, to 4, meaning task ended with the child in extreme distress. Regulation was defined as the overall effectiveness of using various strategies (for example, self-stimulation, self-soothing and distraction). A global measure of regulation was coded on a scale from 0, meaning dysregulated or no control of distress, to 4, when the child seemed to completely regulate their distress during most of the task. The reliability Kappas for global codes were all above 0.80. The reactivity and regulation codes were averaged across tasks to produce a separate mean score for each. As expected, the measures of emotion regulation and emotional reactivity were highly correlated ($r = -0.91$, $P < 0.001$). Consequently, these constructs were combined by creating Z scores of both variables and averaging these standardized scores to create a single measure of emotion regulation.

Two-year sustained attention. Children were instructed to watch a 5-min segment of the videotape 'Spot', a short story about a puppy exploring a neighborhood. The overall duration—proportion of time the child spent looking at the video—was used as this study's laboratory measure of sustained attention. The reliability among coders for the overall duration was excellent ($r = 0.98$).

Two-year inhibitory control/reward sensitivity. Children participated in a delay of gratification task in which they were presented with an appealing gift-wrapped box and told there was a gift inside for them but that they could not open it for 2 min. The overall total time touching gift—combined time the child was in contact with the box—was used as this study's measure of inhibitory control/reward sensitivity. This overall time was reversed score with higher numbers indicating better inhibitory control skills or lower reward sensitivity. The reliability among coders for the overall time was excellent ($r = 0.99$).

Two-year child behavior problems. Mother-reported 2-year total behavior problems measured by the child behavior checklist (CBCL; 2–3⁴⁷) was used as a control variable. The CBCL has been widely used by researchers studying early social adjustment and has adequate reliability and validity.⁴⁸

Results

Preliminary analyses

Descriptive Statistics. Descriptive statistics for all of the study's variables are presented in Table 1. First, it was important to determine whether any of the demographic variables related to children's 2 and 5.5 year BMI. These analyses revealed no significant association between gender ($F(2, 59) = 0.572$, $P > 0.05$), race ($F(4, 116) = 1.08$, $P > 0.05$) or

Table 1 Descriptive statistics for all variables

	M	SD	Min	Max	N
<i>2-year measures</i>					
CBCL-total behavior problem t-score (P)	50.21	9.20	27	74	204
Emotion reactivity (L)	0.66	0.76	0	4	204
Emotion regulation (L)	3.34	0.79	0	4	204
Sustained attention (L)	0.80	0.18	0.16	1	204
Inhibitory control (L)	0.82	0.29	0	1	204
Height in inches (L)	37.18	1.95	34	43	57
Weight in pounds (L)	31.50	4.20	22	44	57
BMI (L)	15.98	1.30	10.17	18.49	57
<i>5.5-year measures</i>					
Height in inches (L)	46.32	2.49	36.5	57	204
Weight in pounds (L)	50.57	9.78	35	116	204
BMI (L)	16.50	2.32	12.20	27.45	204

Abbreviations: BMI, body mass index; CBCL, child behavior checklist; L, laboratory measure; P, parent report.

SES ($r = -0.05$ and -0.02 , $P > 0.05$) and children's 2 and 5.5 year BMI. However, there was a positive association between children's overall behavior problems at age 2 and their 2 year BMI ($r = 0.27$, $P < 0.05$). No association between children's overall behavior problems at age 2 and their 5.5 year BMI was found ($r = -0.01$, $P > 0.05$).

Next, the associations among predictors were examined. Children's emotion regulation skills were positively associated with sustained attention ($r = 0.18$, $P < 0.001$) and inhibitory control/reward sensitivity ($r = 0.22$, $P < 0.001$). This indicates that children with better emotion regulation skills had higher levels of sustained attention and inhibitory control skills/lower reward sensitivity. Finally, sustained attention was positively related to inhibitory control/reward sensitivity ($r = 0.36$, $P < 0.001$) indicating that children with higher levels of sustained attention had higher levels of inhibitory control skills or lower levels of reward sensitivity.

Early self-regulation skills and 2-year BMI

Regression analyses were conducted to determine whether 2-year self-regulation skills were associated with children's BMI at age 2. First, 2-year total behavior problems were placed in the first step of the regression analyses as a control variable because of its earlier relation to 2-year BMI. The main effects of the three self-regulation variables—sustained attention, emotion regulation and inhibitory control/reward sensitivity—were then placed in the second step of the analyses. After controlling for total behavior problems, this analysis revealed a marginal effect for the self-regulation variables on 2-year BMI ($F(3, 69) = 2.26$, $P < 0.09$, total $R^2 = 0.15$, $\Delta R^2 = 0.08$). Specifically, only inhibitory control/reward sensitivity significantly predicted 2-year BMI ($\beta = -0.28$, $P < 0.05$). Thus, children with better inhibitory control skills or lower reward sensitivity at age 2 had lower levels of BMI at age 2. It is important to point out that

2-year total behavior problems were also a significant predictor of 2-year BMI ($\beta = 0.26$, $P < 0.05$) indicating that children with higher levels of behavior problems had higher levels of BMI at age 2.

Early self-regulation skills as predictors of BMI change

Regression analyses were conducted to determine whether 2-year self-regulation skills could predict changes in children's BMI from age 2 to 5.5 years. Thus, 2-year BMI along with 2-year total behavior problems were placed in the first step of the regression analyses as control variables. The main effects of the three self-regulation variables were then placed in the second step of the analyses. First, it is important to note that 2-year BMI was a significant and positive predictor of 5.5-year BMI ($\beta = 0.30$, $P < 0.05$). Most importantly, however, even after controlling for 2-year BMI and total behavior problems, this analysis revealed a significant effect for the self-regulation variables on 5.5-year BMI ($F(3, 51) = 3.32$, $P < 0.05$, total $R^2 = 0.22$, $\Delta R^2 = 0.15$). Specifically, emotion regulation was a significant predictor of 5.5-year BMI ($\beta = -0.41$, $P < 0.01$). Thus, children with better emotion regulation skills at age 2 were less likely to have increases in BMI from age 2–5.5 years. No effects were found for sustained attention or inhibitory control/reward sensitivity. It is noted that 2-year self-regulation skills continued to significantly predict 5.5-year BMI, even when not controlling for 2-year BMI ($F(3, 199) = 2.87$, $P < 0.05$, total $R^2 = 0.04$). However, only inhibitory control/reward sensitivity was a significant predictor ($\beta = -0.17$, $P < 0.05$).

Early self-regulation skills as predictors of pediatric obesity

It was also important to determine whether early self-regulation skills can differentially predict which children develop significant weight problems at 5.5 years of age. Hence, on the basis of CDC age norms,⁴⁵ children whose BMI were in the 85th percentile or greater were classified as overweight/at risk for overweight ($n = 71$), whereas children between 6th and 84th percentiles were classified as normal ($n = 124$). Nine children had a BMI < 6th percentile and were excluded from the analyses. As expected, the overweight/at-risk group had a significantly higher BMI ($M = 17.55$, $s.d. = 0.41$) compared with the normal group ($M = 15.36$, $s.d. = 0.80$), $t = 27.71$, $P < 0.001$. Children in the overweight/at-risk group and children in the normal weight group did not significantly differ on any demographic variable. Table 2 depicts descriptive statistics according to the weight group.

A multivariate analysis of variance (MANOVA) was then conducted to determine whether 2-year self-regulation skills differentiated children classified as overweight/at risk compared with normal weight children at 5.5 years of age. The dependent variables were the three self-regulation variables, whereas the weight groups were the between-subject variables. To ensure that any association between early self-regulation and later pediatric obesity was independent from

Table 2 Demographic characteristics and self-regulation measures according to weight group

	Normal weight (n = 124)	At risk for overweight/ overweight (n = 71)
<i>Demographics</i>		
Gender		
Male	63	32
Female	61	39
Race		
Caucasian	93	46
African-American	25	19
Other	6	6
SES	40.36	39.53
CBCL-total behavior problem <i>t</i> -score (P)	50.07	50.41
2-year BMI (L)	15.76	16.37
<i>2-year self-regulation measures</i>		
Emotion reactivity (L)	0.55	0.87
Emotion regulation (L)	3.45	3.15
Sustained attention (L)	0.82	0.76
Inhibitory control (L)	0.87	0.74

Abbreviations: BMI, body mass index; CBCL, child behavior checklist; L, laboratory measure; P, parent report; SES, socioeconomic status.

early weight problems, we controlled for 2-year BMI. First, this analysis revealed no effect of 2-year BMI on 5.5-year weight groups ($F(3, 51) = 1.54$, $P > 0.05$) indicating that both children classified as overweight/at risk or normal weight at age 5.5 years had similar 2-year BMI levels. However, there was a significant main effect for the weight groups ($F(3, 51) = 2.97$, $P < 0.05$, partial eta squared = 0.15) on early self-regulation measures. Follow-up ANOVAs indicated a significant effect on emotion regulation ($F(1, 53) = 6.74$, $P < 0.05$, partial eta squared = 0.11) and inhibitory control/reward sensitivity ($F(1, 53) = 3.94$, $P < 0.05$, partial eta squared = 0.07). As indicated by the standardized scores in Figure 1, children classified as overweight/at risk at 5.5 years of age had significantly poorer emotion regulation ($M = -0.36$, $s.e. = 0.18$) and inhibitory control skills ($M = -0.57$, $s.e. = 0.23$) at age 2 compared with children in the normal weight group ($M = 0.24$, $s.e. = 0.14$ and $M = 0.01$, $s.e. = 0.17$, respectively). Weight groups did not significantly differ on early sustained attention abilities ($F(1, 53) = 2.41$, $P > 0.05$). It is noted that the significant main effect for weight groups on early self-regulation skills occurred even when we did not control for 2-year BMI ($F(3, 193) = 4.86$, $P < 0.01$, partial eta squared = 0.07). In addition, all three self-regulation variables significantly differentiated between the weight groups, $P < 0.05$.

Discussion

This study examined the role of early self-regulation skills in the development of pediatric obesity. First, it is important to

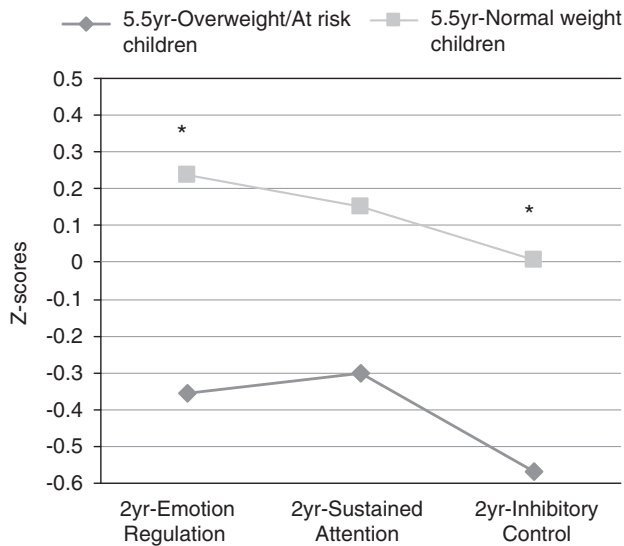


Figure 1 Differentiating overweight/at-risk children from normal weight children based on early self-regulation skills (* $P < 0.05$).

note that as early as 5.5 years of age, 31% of the children in this study were found to be either overweight/at risk for being overweight. This prevalence rate is relatively similar to those found in previous studies with older children,⁴⁹ suggesting that pediatric obesity may be identified as early as kindergarten. Entrance to kindergarten marks a time when parents and teachers assess children's cognitive and socio-emotional abilities as they relate to the child's readiness to learn.²⁰ This study suggests that it may also be important to assess children's physical functioning at this time, as a significant portion of children are already classified as overweight/at risk for being overweight by kindergarten.

Second, given the theoretical notion that self-regulation skills consist of multifaceted control systems, this study examined multiple aspects of toddler's self-regulation skills. Results revealed positive associations between children's emotion regulation skills, sustained attention and inhibitory control/reward sensitivity. These results are consistent with the notion that self-regulation skills become more integrated and sophisticated through development, as toddlers' abilities to control their affective state, attention and behavioral impulsivity were positively related to one another. These associations are consistent with previous research linking attentional control processes to affect regulation, especially within the ADHD¹⁹ and aggression literature.⁵⁰

Consistent with this study's hypotheses, self-regulation skills in toddlerhood were predictive of both normal variations in BMI development and pediatric obesity. Specifically, emotion regulation seems to be the primary self-regulation skill involved in predicting normative changes in BMI as no effects were found for sustained attention or inhibitory control/reward sensitivity. However, both emotion regulation and inhibitory control/reward sensitivity

predicted more extreme weight problems, even after controlling for 2-year BMI. Thus, toddlers with poorer emotion regulation skills and lower inhibitory control skills/higher reward sensitivity were more likely to be classified as overweight/at risk for being overweight in early childhood. Self-regulation/executive functioning difficulties in overweight/obese individuals have been recently documented within the adult⁴¹ and adolescent literature.^{33,34} The few self-regulation/executive functioning studies conducted with children have mainly been cross-sectional and have focused on school-age children^{27,29,30} or were part of an intervention.^{25,28} The current longitudinal study extends such findings to the toddlerhood and early childhood period and suggests that early self-regulation skills constitute an important individual factor to consider when examining both normal variations of BMI and the development of obesity. In addition, early self-regulation skills were stronger predictors than 2-year BMI in determining which children were classified as overweight/at risk at 5.5 years. Such finding highlights the importance of early self-regulation skills and that early deficits serve as significant risk factors for the development of obesity.

Multiple measures of self-regulation, outside the context of eating, were found to predict children overweight/at risk for being overweight. These results extend previous self-regulation studies by Birch and colleagues^{8,14} in two major ways. First, it shows the association between self-regulation and obesity outside the context of eating, highlighting the complexity of such association and indicating that overweight children may have more general self-regulation deficits. Second, it also shows the multiple domains (that is, behavioral and emotional) in which regulatory functions may contribute to the development of obesity. Deficits in sustained attention skills were not predictive of obesity. This finding is counter to a previous study indicating that school-age children with ADHD had higher BMIs compared with age-adapted reference values.²⁵ It may be the case that it is only the behavioral disinhibition/impulsivity aspect of ADHD, not the inattention, which is associated with obesity. This study extends the literature by showing that higher reward sensitivity, indicative of lower inhibitory control skills, as early as during the toddlerhood period represents a significant risk factor in the development of pediatric obesity. Children with higher levels of reward sensitivity are more likely to engage in impulsive behaviors. Although binge eating episodes have mostly been documented within the adult or adolescent literature,¹³ children may also engage in impulsive eating behaviors. In addition to impulsive eating, children with higher levels of reward sensitivity may end up preferring food that are sweet and fat, which tend to be reported as tastier compared with healthier/bland food.⁵¹ Although a causal link between impulsivity and overeating has been suggested by experimental manipulation designs⁵² along with a link between reward sensitivity and food choices,⁵¹ these studies have mainly focused on adults. The results of our study suggest that toddlerhood may be an

important period for future studies to examine these key questions.

This study also found an important link between the self-regulation of affective processes and both normal variations in BMI development and pediatric obesity. Past research had established a strong link between emotion dysregulation and overeating in adult and adolescent population.^{13,33} The current findings extend this link to the child population and suggest that poor emotion regulation skills may be an important risk factor for the development of obesity and not merely a consequence of it. Although this study cannot address the mechanisms by which poor emotion regulation skills contribute to obesity, adult studies have suggested an important physiological link through the vagus nerve.³⁹ Specifically, the vagal pathways have been shown to have a crucial role in facilitating metabolic resources in the service of coping, as well as in satiety and short-term regulation of food intake.^{15,38} Thus, it may be that children with poor emotion regulation have a difficult time assessing whether they are satiated. Children's abilities to determine whether they are satiated are especially important, given that the portion size of the average meal has increased dramatically over the last two decades.⁵³ Given that the vagal pathways show considerable growth from birth to the early childhood years,⁵⁴ it will be important for future research to examine the link between the development of physiological regulation and children's eating behaviors.

The other potential mechanism by which emotion regulation relates to obesity is through the concept of eating as a way to cope with stressors/negative emotions. Emotional eating has been clearly documented within the adult/adolescent literature,³² and a recent study documented emotional eating in children as young as 9 years of age.⁵⁵ However, it remains unclear whether young children engage in emotional eating as a coping strategy. Given that young children do experience various stressors as they enter school, such as peer victimization and learning difficulties,⁵⁶ it is important for future studies to assess whether children are using eating as an emotion regulation strategy.

In summary, this study found that toddlers' self-regulation skills across behavioral and emotional domains significantly differentiated which children at 5.5 years were classified as overweight/at risk of being overweight compared with normal-weight children. Measuring toddlers' self-regulation skills via laboratory tasks represents a significant strength of this study as the majority of past studies relied on parental report of children's functioning. In terms of this study's limitations, it is important to point out that we did not have information on either child eating behaviors or parental weight as this was not the primary aim of the study design. Given that parental weight status is one of the strongest predictors of child weight status,⁵ it is difficult to know whether self-regulation skills would continue to predict children's weight status above and beyond the shared genetic effects of their parents' weight status. However, parental weight status not only predicts children's weight

status through genetics, but also influences children's eating behavior.⁶ Thus, it may be that the socialization of eating behavior that occurs between an overweight parent and his/her child is mediated through regulatory processes. For example, children may watch their overweight parents eat to cope with stress or watch their parents consistently eat large portions. In turn, children may engage in similar behaviors and their regulatory abilities to detect when they are satiated may worsen. The effects of parental behaviors on regulatory processes are well documented within the human¹⁵ and animal literature.⁵⁷ Future research should examine whether parental eating behavior has an effect on children's early regulatory skills. Finally, it is important to point out that despite our longitudinal design and attempts in controlling early weight status, we cannot affirm a causal link between self-regulation and the development of obesity.

Nevertheless, our results do provide initial evidence for the importance of examining toddlers' early self-regulation skills as risk factors for the development of obesity. These findings may also be relevant for the treatment of pediatric obesity. For example, in addition to helping children and their families make lifestyle changes in terms of dieting/exercise, future treatment may want to teach children how to better monitor their emotional state as it relates to eating behavior, how to identify when they are feeling satiated, and how to reinforce them for inhibiting additional eating.

Conflict of interest

The authors declare no conflict of interest.

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