Weight Gain, Executive Functioning, and Eating Behaviors Among Girls

Andrea B. Goldschmidt, PhD[a], Alison E. Hipwell, PhD[b,c], Stephanie D. Stepp, PhD[b], Kathleen M. McTigue, MD, MPH, MS[d], Kate Keenan, PhD[a]

abstract

OBJECTIVE: Executive functioning and excess weight have been associated in cross-sectional and prospective studies, but mechanisms explaining this relationship are unclear. The current study aimed to further explore the longitudinal relationship between executive functioning and changes in body weight and to determine whether binge eating behaviors mediate this relationship.

METHODS: Community-based girls (N = 2450) were assessed by using the behavioral measure of planning, Mazes subtest, and a parent-report measure of impulsivity at age 10; a self-report measure of binge eating at ages 10, 12, and 14; and investigator-measured BMI annually between ages 10 and 16. Regression and bootstrapping analyses explored the relations among age 10 impulsivity and planning, age 12 and age 14 binge eating frequency, and age 10 to 16 BMI changes.

RESULTS: Age 10 impulsivity and planning each independently predicted age 10 to 16 BMI changes, after accounting for demographics, verbal comprehension, and BMI at age 10 ($Ps < .001$). Binge eating tendencies at age 12 mediated the relation between age 10 impulsivity and age 10 to 16 BMI changes, after controlling for demographics, verbal comprehension, binge eating frequency, and BMI at age 10 (indirect effect estimate = 0.0007; 95% confidence interval = 0.0001–0.0020).

CONCLUSIONS: Results support the hypothesis that poorer executive functioning predicts weight gain from middle childhood through adolescence in girls, and that this effect may be partially explained by binge-eating behaviors in early adolescence.

WHAT'S KNOWN ON THIS SUBJECT: Executive functioning and excess weight have been associated in both cross-sectional and prospective studies, but mechanisms explaining this relationship are unclear.

WHAT THIS STUDY ADDS: Impulsivity and planning at age 10 predicted age 10 to 16 BMI changes, and age 12 binge-eating tendencies mediated the relation between impulsivity at age 10 and changes in BMI change through age 16.

[a]*Department of Psychiatry and Behavioral Neuroscience, The University of Chicago, Chicago, Illinois; and Department of* [b]*Psychiatry,* [c]*Psychology, and* [d]*Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania*

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Address correspondence to Andrea B. Goldschmidt, PhD, Department of Psychiatry and Behavioral Neuroscience, The University of Chicago, 5841 South Maryland Ave, MC 3077, Chicago, IL 60637. E-mail: goldschmidta@uchicago.edu

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Pediatric obesity influences the development of cardiovascular risk factors in childhood,[1] and increasing BMI in youth is linked with a wide range of health concerns in adulthood.[2–5] Left untreated, obese youth are at increased risk for continued obesity in adulthood,[6] leading to additional personal and societal consequences.[7–9] Although the causes of obesity are likely multifaceted, some factors may be particularly useful for identifying at-risk youth and for developing targeted preventive interventions. Poorer executive functioning, characterized in part by difficulties self-regulating or inhibiting one's behavior, has been associated with obesity and with obesigenic eating patterns, including disinhibited eating.[10–13] Yet there is a lack of sufficient prospective data linking executive functioning to excess weight status and weight changes in childhood and adolescence. For example, although several studies have demonstrated cross-sectional associations between lower executive functioning (including attention, eg, D2 attention endurance; inhibition, eg, Stroop performance; inhibition/set-shifting, eg, trail making, 5-digit test, and Wisconsin card-sorting performance; and decision-making, eg, Iowa Gambling Task performance) and excess weight status,[14–17] only 1 study, conducted in a sample of preschool-age children, has demonstrated prospective associations,[18] showing that poorer executive functioning at age 4 (as measured by the McCarthy Scales of Children's Abilities) predicted overweight status at age 6. However, the mechanisms through which executive dysfunction promotes obesity are currently unclear. Moreover, to our knowledge, the prospective relationship between executive functioning and body weight has not been characterized among older children and adolescents.

Binge eating, which involves consuming an objectively large amount of food while experiencing a sense of loss of control while eating,[19] is associated with both obesity[20] and poorer executive functioning[11,12] and may be a potential pathway to elevated weight status among those with preexisting executive function difficulties. Children reporting binge eating behaviors frequently present with concomitant obesity in cross-sectional studies[20] and also are at risk for excess gains in weight and body fat over time.[21,22] Research has demonstrated poor performance on executive functioning tasks in adults with binge-eating problems,[23–26] and preliminary data suggest similar patterns in youth.[27–30] There is some indication that binge eating may mediate the relationship between executive function impairments (such as those seen in attention-deficit/hyperactivity disorder) and overweight status,[12,31] although currently there are no longitudinal data substantiating this model.

Poorer executive functioning may manifest in disturbed eating behaviors via multiple pathways. Both executive functioning and binge eating are moderately to highly heritable,[32,33] suggesting potential genetic contributions. Exposure to an environment in which palatable foods are easily accessible may also contribute to dysregulated eating in individuals who experience difficulties with inhibition and other executive functions.[34] This may be especially pertinent among individuals who experience food as highly rewarding.[35,36] Finally, there are data supporting a positive association between dietary restraint and binge eating. Thus, an additional pathway might involve depletion of executive resources via restrained or restricted eating, which then promotes binge eating upon an event or state necessitating additional cognitive effort[37] (eg, occurrence of a negative mood stressor[38]). Studies of community-based and college adults suggest that individuals with poorer overall executive control may be even more vulnerable to the effects of such depletion,[39] which highlights the need to further examine the relationship between executive functioning and binge eating, and its subsequent effects on body weight.

The purpose of the current study was twofold. First, we aimed to examine the longitudinal relationship between executive functioning and changes in body weight among community-based female youth. Next, we investigated whether binge-eating behaviors explain the relationship between executive functioning and body weight changes. We chose to focus on the domains of planning and impulsivity because these constructs have been relatively consistently linked with elevated body weight[40,41] and binge eating.[25,42] Moreover, planning and impulsivity could directly affect weight via poor and impulsive decision-making regarding the type and amount of food consumed. We hypothesized that poorer executive functioning in middle childhood would predict greater weight increases in adolescence and that this relationship would be mediated by binge-eating tendencies. Results could inform the elaboration of onset and maintenance models for pediatric obesity and aid in the development of preventive interventions for eating- and weight-related problems.

METHODS

Participants

Data were drawn from the Pittsburgh Girls Study, a community-based longitudinal study of psychosocial functioning from childhood through the transition to adulthood.[43] Face-to-face interviews were conducted annually with girls (starting at age 7) and their caregivers (from wave 1 through girls' age 17), although the current analyses used data collected at ages 10, 12, 14, and 16 due to the availability of measures relevant to the study aims. A stratified, random household sampling method, with oversampling of households in low-income neighborhoods, was used to identify girls for the first wave of data collection. All homes in neighborhoods in which at least 25% of the families were living at or below the poverty level were contacted to determine the presence of an eligible girl. A randomly selected 50% of the households in nonrisk neighborhoods were contacted during 1998 and 1999. A total of 3118 households in which an age-eligible girl resided were identified (representing 83.7% of all age-eligible girls in contacted neighborhoods, according to Census data), of which 2450 were ultimately included in the study; the other 668 households were either excluded (based on the presence of mental retardation in the age-eligible girl or plans to relocate during the study period) or were unwilling to participate. In homes in which >1 eligible girl resided, 1 girl was randomly selected for participation. The girls were, on average, 10.1 ± 0.4 years at the first assessment point in the current set of analyses, and most were Caucasian (49.7%; *n* = 1217) or African American (43.8%; *n* = 1074; see Table 1 for descriptive information). More than half (57.6%; *n* = 1412) of the caregivers were cohabiting with a husband or partner, and 30.5% (*n* = 747) of the families were receiving public assistance (ie, Women, Infants, and Children, food stamps, welfare). Retention has typically been high, ranging from 85% to 97%.[44] Attrition has been due in part to difficulty tracking participants, with little dropout due to refusal to participate.

All study procedures were approved by the University of Pittsburgh Institutional Review Board. All primary caretakers provided written informed consent, and assent was obtained from the girls at age 10 and thereafter. Girls and their mothers were reimbursed for their time completing the interviews.

TABLE 1 Descriptive Statistics

Variable	Normal Weight	Overweight or Obese	Full sample
Demographic factors			
BMI			
Age 10	17.26 ± 1.83	25.20 ± 4.15	20.16 ± 4.82
Age 12	18.88 ± 1.98	27.57 ± 4.89	22.45 ± 5.59
Age 14	20.45 ± 2.01	29.62 ± 5.77	24.13 ± 6.02
Age 16	21.35 ± 2.12	31.41 ± 6.30	25.32 ± 6.56
Race/ethnicity, % (*n*)			
Caucasian	53.5 (741)	41.9 (338)	49.7 (1217)
African American	41.3 (573)	50.2 (405)	43.8 (1074)
Asian	1.1 (15)	0.2 (2)	1.1 (26)
Multi-racial/other	4.1 (57)	7.7 (62)	5.2 (127)
Public assistance, % receiving	31.6 (437)	35.3 (285)	30.5 (747)
Psychological factors			
WISC-III-R			
Mazes (planning) scaled score	10.3 ± 3.6	9.8 ± 3.6	10.1 ± 3.6
Verbal comprehension index score	99.7 ± 17.9	98.0 ± 17.0	98.9 ± 17.6
CSI-4 impulsivity *T* score	50.9 ± 8.7	51.5 ± 9.0	51.1 ± 8.8
ChEAT binge-eating frequency			
Age 10	1.4 ± 1.0	1.5 ± 1.0	1.5 ± 1.0
Age 12	1.3 ± 0.8	1.5 ± 1.0	1.4 ± 0.9
Age 14	1.5 ± 0.9	1.6 ± 1.0	1.5 ± 1.0
Age 16	1.4 ± 0.9	1.5 ± 1.0	1.4 ± 0.9

M ± SD, unless otherwise indicated. All values are weighted to account for oversampling in low-income neighborhoods. Mazes range = 1–19; verbal comprehension range = 51–149); CSI-4 range = 40–97; ChEAT range = 1–6. For BMI and ChEAT binge-eating frequency, means correspond to normal weight or overweight/obese status measured at the same time point (eg, mean BMI at age 10 is reported for girls who were normal weight versus overweight/obese at age 10; mean BMI at age 12 is reported for girls who were normal weight versus overweight/obese at age 12). All other values reflect measurement at age 10. Subgroup %/*n* values do not add up to full sample %/*n* values because of missing data.

Measures

Measured height and weight at ages 10 through 16 years were used to determine BMI. According to age- and gender-specific Centers for Disease Control and Prevention normative data, a BMI ≥85th percentile and <95th percentile was considered overweight, and a BMI ≥95th percentile was considered obese.[45] Girls' age, race/ethnicity, and socioeconomic status (SES) were based on parent-report.

The Wechsler Intelligence Scale for Children-Third Edition, Revised (WISC-III-R)[46] was administered by trained interviewers in the home when the girls were age 10 years. The Mazes subtest, which requires participants to find their way out of a pencil-and-paper maze as quickly as possible, was used as a measure of planning (range = 1–19, with lower scores indicating poorer planning abilities). The Mazes subtest has adequate reliability (published reliability coefficient = 0.70 and interrater reliability = 0.62 for 10-year-old children[46]) and validity, showing significant correlations with other measures of executive functioning (eg, Rey-Osterrieth Complex Figure[47]) and distinguishing well among subgroups of children with behavioral disorders.[48] The Vocabulary and Similarities subscales were combined to derive a short-form verbal comprehension index (range = 51–149; lower scores indicate poorer verbal comprehension), based on well-validated procedures (published reliability = 0.91 and concurrent validity = 0.90).[49,50] Verbal comprehension served as a proxy for general intellectual functioning based on its high correlation with Full Scale IQ (published r = 0.91), and its small correlation with Mazes performance (published r = 0.21).[46] The Attention-Deficit/Hyperactivity Disorder Hyperactive-Impulsive Scale of the Child Symptom Inventory, 4th edition (CSI-4) was completed by parents to assess girls' impulsivity symptoms at age 10 (current study α = 0.89; published test-retest reliability = 0.82 and concurrent validity range = 0.49–0.55); responses range from 0 (“never”) to 3 (“very often”), with higher scores (T score range = 40–97) indicating greater impulsivity. Planning and impulsivity were modestly correlated in this sample (r = –0.07; $P < .001$).

The Children’s Eating Attitudes Test (ChEAT),[51] a self-report measure of eating disturbance for children, was administered at ages 10, 12, and 14 years. This measure has adequate internal reliability (published α = 0.87) and concurrent validity (published correlations with weight management behavior = 0.36, and with body dissatisfaction = 0.39).[52] Binge eating is ascertained by asking the respondent how often, in the past year (ranging from 1, “never,” to 6, “always”), she has “gone on eating binges where [she] feel[s] that [she] might not be able to stop.”

Statistical Analysis

All data were analyzed in SPSS 22.0. χ^2 and t tests were used to assess demographic and psychosocial factors related to SES and missing BMI data. Separate linear regression models were used to examine whether planning or impulsivity at age 10 predicted BMI slope (which was fit for each individual participant based on BMI at each time point and hence reflects each participant’s unique trajectory of BMI change) from age 10 to age 16. We elected to use BMI slope as the dependent variable rather than using time series analyses, because these latter analyses often assume independence of the dependent variables over time, making them inappropriate for measurement of BMI. The independent construct of executive functioning was operationalized as performance on the WISC-III-R Mazes subtest at age 10 in the first model or parent report of impulsivity on the CSI-4 at age 10 in the second model. For each model, binge-eating tendencies at ages 12 and 14 were tested as potential mediators of the association between executive functioning and increases in BMI over time. Bootstrapping methods with k = 1000 resamples and 95% bias-corrected confidence intervals (CIs) were used to evaluate indirect effects. Bootstrapping has been recommended as the most powerful method for estimating indirect effects, even in large samples, in part because it does not rely on assumptions of normality.[53] Mediation was considered to have occurred if the 95% CIs for the indirect effect generated by the bootstrapping method did not contain zero. All models controlled for BMI at age 10, as well as race/ethnicity, SES, and verbal comprehension at age 10. Mediation models additionally controlled for age 10 binge-eating tendencies. Data were weighted to account for oversampling in low-income neighborhoods.

RESULTS

Descriptive Characteristics

Between 30% to 35% of the sample met criteria for being overweight or obese between ages 10 and 16 years, which is consistent with population-based data[54] (age 10 = 33.0%; age 12 = 35.0%; age 14 = 33.1%; age 16 = 31.4%). χ^2 tests revealed that participants missing BMI data at age 10 were more likely to be African American, and less likely to be Caucasian, than those with complete data ($P < .001$). They did not differ on SES, binge-eating tendencies, planning, or impulsivity at age 10 (all Ps $> .05$). Approximately 10% of the sample reported “sometimes” to “always” engaging in binge eating at any given time point, which is also consistent with community findings[55] (age 10 = 11.0%; age 12 = 8.6%; age 14 = 9.3%; age 16 = 8.2%). Approximately 11% to 16% of these participants were receiving public assistance at age 10, and binge eating “sometimes” to “always” at any given time point was significantly more common among participants receiving public assistance at age 10 (Ps $< .03$). Receiving public assistance was also associated with both poorer planning ($P < .001$) and greater impulsivity ($P < .001$) at age 10.

Prediction of BMI Changes From Age 10 to 16 Years

Age 10 planning and age 10 impulsivity each independently (beyond the effects of age 10 BMI, race/ethnicity, SES, and verbal comprehension) predicted changes in BMI from age 10 to 16 (see Table 2). Specifically, the full model including planning accounted for 5.3% of the variance in BMI change ($P < .001$), with planning independently accounting for an additional 0.3% of the variance beyond the effects of the control variables (P = .009). Similarly, the full model including impulsivity accounted for 5.5% of the variance in BMI change ($P < .001$), with

TABLE 2 Summary of Hierarchical Regression Analysis for Age 10 Variables Predicting BMI Changes From Age 10 to 16

Predictor	B	SE	β	P	ΔR^2
Model 1					
Step 1					0.050***
BMI	0.04	0.01	0.14	<.001	
Public assistance	0.15	0.07	0.05	.021	
Race/ethnicity	0.03	0.02	0.03	.194	
WISC-III-R Verbal comprehension	−0.01	0.00	−0.13	<.001	
Step 2					0.003**
WISC-III-R Mazes (planning)	−0.02	0.01	−0.06	.009	
Model 2					
Step 1					0.048***
BMI	0.04	0.01	0.14	<.001	
Public assistance	0.16	0.07	0.06	.013	
Race/ethnicity	0.03	0.02	0.03	.150	
WISC-III-R Verbal comprehension	−0.01	0.00	−0.12	<.001	
Step 2					0.007***
CSI-4 Impulsivity	0.01	0.00	0.08	<.001	

** $P < .01$; *** $P < .001$.

impulsivity independently accounting for an additional 0.7% of the variance beyond the effects of the control variables ($P < .001$).

Mediation Analyses

Bootstrapping analyses indicated that binge eating tendencies at age 12 mediated the relation between impulsivity at age 10, and changes in BMI from age 10 to 16, after controlling for age 10 BMI, race/ethnicity, SES, verbal comprehension, and binge-eating tendencies (indirect effect estimate = 0.0007; 95% CI = 0.0001–0.0020). Binge-eating tendencies at age 14 were not a significant mediator (see Table 3). Neither binge-eating tendencies at age 12 nor at age 14 mediated the association between planning at age 10 and change in BMI from age 10 to 16. Of note, age 10 binge-eating tendencies did not contribute to any of the mediation models (Ps $> .05$).

DISCUSSION

The current study examined the prospective relations among BMI, executive functioning, and binge eating in a community-based sample of girls. We found that higher parent-reported impulsivity and poorer behaviorally measured planning at age 10 predicted greater increases in BMI from age 10 to 16 and that age 12 self-reported binge-eating tendencies mediated the relation between impulsivity at age 10 and changes in BMI change through age 16. Although the effects were modest, results indicate that for every 1-unit decrease in planning or every 1-unit increase in impulsivity, the change in BMI from age 10 to 16 increased by 0.06 to 0.08. For many individuals, small but consistent increases in BMI, as opposed to acute changes, are what confer risk for overweight.[56] Furthermore, the relationship between parent-reported impulsivity and weight gain may be partially explained by binge-eating behaviors in early adolescence, suggesting that individuals experiencing greater difficulties with planning and impulsivity may be appropriate targets for obesity and eating disorder prevention programs.

Similar findings have been reported in previous studies of adults[31] and children,[10] indicating that one manifestation of impulsive tendencies may be a lower ability to inhibit oneself around food. It is important to note that binge eating was reported by only a minority of participants at any given time point, which is consistent with other studies of community-based youth[55]; thus, future studies should assess the full range of eating behaviors to better understand whether other disinhibited eating patterns (eg, overeating without loss of control, eating in the absence of hunger) explain the association between impulsivity and weight gain among adolescent girls. Further exploration of the age-related effects of binge eating as a mediator between impulsivity and BMI change is also warranted; the lack of consistent findings at ages 12 and 14 may reflect that binge eating-related weight gain later in adolescence is driven by other factors besides impulsivity.

Poor executive control is, to some extent, characteristic of childhood and adolescence, reflecting immaturity in forebrain structures responsible for goal-directed behavior.[57] Our findings indicate that poorer behavioral regulation as early as age 10 may lead to greater weight gain over the course of adolescent development. Interestingly, studies of adults suggest that excess weight status itself predicts worsening cognitive functioning[58]; taken together, this may indicate a self-perpetuating cycle in which poor executive control and excess weight gain maintain or exacerbate each another over time. It will be important in future studies to model the trajectory of impulsivity and other execution functioning domains to determine if declining performance

TABLE 3 Summary of Mediation Results

IV	MV	DV	Effect of IV on MV (a)	Effect of MV on DV (b)	Direct Effect (c′)	Indirect Effect (a * b)	Total Effects (c)
Age 10 WISC-III-R Mazes (planning)	Age 12 ChEAT binge eating	Age 10–16 BMI change	−0.0073 (SE = 0.0063)	0.1046** (SE = 0.0341)	−0.0209* (SE = 0.0090)	−0.0008 (SE = 0.0008)	−0.0217* (SE = 0.0090)
	Age 14 ChEAT binge eating	—	−0.0036 (SE = 0.0066)	0.0150 (SE = 0.0326)	—	0.0001 (SE = 0.0003)	—
Age 10 CSI-4 Impulsivity	Age 12 ChEAT binge eating	Age 10–16 BMI change	0.0065** (SE = 0.0024)	0.1019** (SE = 0.0341)	0.0130*** (SE = 0.0035)	0.0007[a] (SE = 0.0004)	0.0137*** (SE = 0.0035)
	Age 14 ChEAT binge eating	—	0.0060* (SE = 0.0026)	0.0176 (SE = 0.0323)	—	0.0001 (SE = 0.0002)	—

—, value refers to the entire row for the corresponding IV and DV, rather than the individual MVs; a, b, c′ and c indicate the pathways corresponding to the preceding labels; DV, dependent variable; IV, independent variable; MV, mediating variable.
* $P < .05$; ** $P < .01$; *** $P < .001$.
a Significance levels are determined by 95% CIs not containing zero.

(or lack of normative improvements in self-regulation) is responsible for weight gain trajectories in adolescence (or serves as a barrier to weight loss, as has been found in adults[59]). Clinically, youth with poorer executive control may benefit from interventions designed to foster healthy eating and physical activity patterns to curb unhealthy weight gain, although such interventions may require tailoring to address impulsive features. For example, recent research has found that inhibitory control training leads to reduced consumption of palatable foods,[60] although it is unknown whether such an intervention could reverse overweight status or minimize weight gain over time.

There are several notable strengths of the current study, including the large, diverse sample of community-based girls and the repeated, objective measures of BMI. Moreover, executive functioning was operationalized using performance on a standardized assessment and parent-reported behaviors. There are also a number of limitations. First, because of the epidemiologic nature of the study, a self-report questionnaire was used to assess binge eating. Because constructs involved in binge eating (ie, overeating and loss of control) may be difficult for children to report on accurately,[61] it is unknown whether similar results would emerge if binge eating had been identified by practitioners in clinical settings or using other assessment tools. Furthermore, participants were asked to report on their binge-eating tendencies over the past year, which may have introduced recall biases. Therefore, future replication studies should use investigator-based interviews or other, more objective measures of eating pathology. On a related note, measurement of eating pathology was limited to binge eating and did not address other eating-related constructs that may be relevant to both executive functioning and obesity (eg, excessive snacking,[62,63] more generally disinhibited eating patterns[17]). Similarly, the assessment of executive functioning was limited to planning (as assessed by performance on the Mazes subtest, which has not been widely used in neuropsychological research and thus may limit cross-study comparisons) and impulsivity (as measured by parent report and thus potentially subject to parental biases) and did not address other potentially related domains (eg, inhibitory control). In addition, scores across measures of planning and impulsivity were in the normative range,[46,64] and thus results do not reflect those that might be observed in girls with clinical impairments in these domains (although, importantly, results are generalizable to nonclinical, albeit low-income, samples). Finally, the exclusively female sample precludes the ability to generalize our findings to boys.

In general, impulsivity and poorer functioning in other executive domains may increase risk for weight gain throughout adolescence, and this relationship may be partially accounted for by poorly controlled eating behavior. Future research should test whether obesity and weight gain prevention programs would benefit from focusing on enhancing impulse control, particularly among girls who demonstrate poorer functioning in this domain. Future studies should also explore other potential mechanisms involved in the relation between executive functioning and weight gain among youth to improve weight outcomes and related health markers.

ABBREVIATIONS

ChEAT: Children's Eating Attitudes Test
CI: 95% confidence interval
CSI-4: Child Symptom Inventory, 4th edition
SES: socioeconomic status
WISC-III-R: Wechsler Intelligence Scale for Children-Third Edition, Revised

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