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Authors
Goldschmidt, Andrea B
O'Brien, Setareh
Lavender, Jason M
et al.

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Executive functioning in a racially diverse sample of children who are overweight and at risk for eating disorders

Andrea B. Goldschmidt, Ph.D.[a], **Setareh O'Brien, B.A.**[b], **Jason M. Lavender, Ph.D.**[c], **Carolyn M. Pearson, Ph.D.**[d], **Daniel Le Grange, Ph.D.**[e], and **Scott J. Hunter, Ph.D.**[b]

[a]Department of Psychiatry and Human Behavior, Alpert Medical School of Brown University, The Miriam Hospital/Weight Control and Diabetes Research Center, Providence, RI, USA

[b]Department of Psychiatry and Behavioral Neuroscience, The University of Chicago, Chicago, IL, USA

[c]Department of Psychiatry, University of California, San Diego, San Diego, CA, USA

[d]Department of Psychiatry, University of Minnesota Medical School, Minneapolis, MN, USA

[e]Department of Psychiatry, University of California, San Francisco, San Francisco, CA, USA

Abstract

Difficulties with executive functioning may underlie both overweight and loss of control (LOC) eating behavior across the age spectrum, but there is a relative paucity of research in children with both conditions. This study aimed to characterize general executive functioning among children with overweight and LOC eating as compared to their overweight and normal-weight peers. Participants were 75 racially diverse children (58.7% female; 81.3% African-American), aged 9–12y (*M* age=10.5±1.1), of whom 26 were overweight/obese and endorsed LOC eating (OW-LOC), 34 were overweight controls (OW-CON), and 15 were normal-weight controls (NW-CON). All children completed interview-based measures of eating pathology, and behavioral measures of executive functioning. Parents reported on behavioral facets of children's executive functioning. Groups were compared across parent-report measures and behavioral tasks using analyses of covariance (ANCOVAs) and multivariate analyses of covariance (MANCOVAs) which adjusted for general intellectual functioning. Significant group differences were revealed on a behavioral measure of planning, the Tower of London task [$F(5,65)=3.52$; $p=.007$] , and a behavioral measure of working memory, the List Sorting task [$F(2,71)=6.45$; $p=.003$]. Post-hoc tests revealed that OW-LOC and OW-CON performed worse than NW-CON on the Tower of London, with relative decrements in accuracy rather than performance time. Further, OW-LOC performed worse than both OW-CON and NW-CON on the List Sorting task. Overweight with or without concomitant LOC eating in children may characterize a unique pattern of executive dysfunction. Interventions

Corresponding author: Andrea B. Goldschmidt, Department of Psychiatry and Human Behavior, Alpert Medical School of Brown University, The Miriam Hospital/Weight Control and Diabetes Research Center, 196 Richmond St., Providence, Rhode Island, 02903; TEL: (401) 793-8251; FAX: (401) 793-8944; andrea.goldschmidt@lifespan.org.

for eating- and weight-related problems in youth should address underlying deficits in planning and working memory.

Keywords

Loss of control eating; obesity; children; executive functioning; impulsivity

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Pediatric obesity is a major public health concern that is linked to the development of cardiovascular risk factors in childhood (Reilly et al., 2003) and a wide range of health concerns in adulthood (Al Mamun, Cramb, O'Callaghan, Williams, & Najman, 2009; Baker, Olsen, & Sorensen, 2007; Field, Cook, & Gillman, 2005). Loss of control (LOC) eating, characterized by a sense that one cannot control what or how much one is eating, is an obesity-related phenotype that presents in up to 20% of non-treatment seeking youth with overweight or obesity (He, Cai, & Fan, 2016) and is associated with the development of eating disorders and other serious health impairments (Goldschmidt, Loth, et al., 2015; Goossens, Braet, & Decaluwe, 2007; Schluter, Schmidt, Kittel, Tetzlaff, & Hilbert, 2016). Preliminary research suggests that difficulties with executive functioning may underlie both obesity (Fitzpatrick, Gilbert, & Serpell, 2013; Liang, Matheson, Kaye, & Boutelle, 2014) and LOC eating behavior (Van den Eynde et al., 2011) across the age spectrum, with LOC eating in adults characterized by difficulties with problem-solving, decision-making, and inhibition, above and beyond the effects of obesity (Manasse et al., 2015; Manasse et al., 2016; Manasse et al., 2014). However, there is a relative paucity of research in children. Characterizing executive functioning in children with comorbid overweight and LOC eating could have important implications for prevention and treatment development, including helping to identify youth who may be at risk for excess weight gain and eating disorders (Tanofsky-Kraff et al., 2006; Tanofsky-Kraff et al., 2011; Tanofsky-Kraff et al., 2009), and highlighting relevant early intervention targets.

Executive functioning refers to cognitive activities directed towards achievement of a desired goal and involves a range of processes such as decision-making, planning, attention, problem-solving, inhibition, and cognitive flexibility, among others (Anderson, 2008; Chan, Shum, Toulopoulou, & Chen, 2008). Healthy regulation of eating behavior and body weight involves several aspects of executive functioning (e.g., generating a meal plan, inhibiting goal-incompatible responses to food cues). Poorer performance on behavioral measures of executive functioning has been related to obesity in both children (Liang et al., 2014; Verbeken, Braet, Claus, Nederkoorn, & Oosterlaan, 2009) and adults (Fitzpatrick et al., 2013). While few prospective studies have investigated the relation between obesity onset and executive functioning (Graziano, Calkins, & Keane, 2010), performance on respondent-based and behavioral measures of goal-oriented behavior appears to predict overweight status (Guxens et al., 2009) and weight change (Bub, Robinson, & Curtis, 2016; Duckworth, Tsukayama, & Geier, 2010; Francis & Susman, 2009; Goldschmidt, Hipwell, Stepp, McTigue, & Keenan, 2015; Groppe & Elsner, 2015; Koike, Hardy, & Richards, 2016) in children and adolescents.

In addition to its associations with body weight and weight gain, poor executive control appears to be predictive of increased food intake in adults (Guerrieri et al., 2007; Houben, 2011), suggesting that one possible pathway to obesity may involve disinhibited eating (i.e., eating in response to stimuli other than physiological hunger) as a result of poorer executive functioning. Indeed, adults with overweight/obesity and LOC eating show poorer performance on executive functioning tasks relative to controls with overweight/obesity only (Duchesne et al., 2010; Manasse et al., 2015; Manasse et al., 2016; Manasse et al., 2014; Mobbs, Iglesias, Golay, & Van der Linden, 2011). Similarly, recent data on children and adolescents also suggest that LOC eating is both concurrently related to diminished performance on measures of inattention/impulsivity (Hartmann, Czaja, Rief, & Hilbert, 2010; Reinblatt et al., 2014; Reinblatt et al., 2015), and may mediate the prospective association between impulsivity and weight gain (Goldschmidt, Hipwell, et al., 2015). However, research in children has typically been constrained by self-report data or by the use of a limited number of domain-specific measures of executive functioning. Therefore, it is largely unknown how children with overweight and LOC eating perform across the spectrum of executive functioning constructs, which could inform screening and suggest relevant targets for early intervention programs.

Given that executive functioning deficits appear to be related to both obesity and eating disorders, there is a need to better characterize executive functioning in the subset of youth with comorbid obesity and LOC eating. Therefore, the aim of the current study was to assess performance on a range of executive functioning measures among children with obesity and LOC eating as compared to overweight and normal-weight controls without LOC eating. Because no other studies, to our knowledge, have investigated executive functioning in children with both overweight and LOC eating, we focused on non-food-specific executive functions as a first step in this line of research to establish whether more general executive functioning deficits characterize this subset of youth with overweight. Furthermore, previous data in adults suggest that some executive dysfunctions associated with LOC eating are not food specific (Manasse et al., 2016). We hypothesized that children with overweight, regardless of LOC eating status, would show poorer performance across executive functioning assessments as compared to healthy controls, and that those with comorbid obesity and LOC eating would show the poorest performance.

Material and Methods

Participants

Participants were 75 children (58.7% female; *n*=44), aged 9–12y (*M* age=10.5±1.1), who self-identified as African-American (81.3%; *n*=61), non-Hispanic Caucasian (12.0%; *n*=9), non-Caucasian Hispanic (5.3%; *n*=4), or Asian (1.3%; *n*=1), which reflects the demographics of the study site. The sample was comprised of 26 youth with overweight/ obesity (body mass index [BMI; kg/m^2] ≥ 85th percentile for age and sex according to Centers for Disease Control and Prevention (CDC) normative data; Kuczmarski et al., 2000) who reported recent LOC eating (i.e., ≥ 1 episode of LOC eating in the 3 months prior to assessment; OW-LOC), 34 controls with overweight who reported no history of LOC eating (OW-CON); and 15 (BMI < 85th percentile for age and sex) controls who were normal-weight and denied any history of LOC eating (NW-CON). Within the OW-LOC sample, 5 participants (19.2%) reported objectively large LOC episodes only, 17 (65.4%) reported subjectively large LOC episodes only, and 4 (15.4%) reported both objectively and subjectively large LOC episodes. The sample size was selected to provide 80% power to detect a moderate effect (Cohen's d=0.69), based on effect sizes reported in a previous study of neurocognitive functioning among youth with disordered eating (Allen et al., 2013). Because the primary comparisons of interest concerned OW-LOC and OW-CON, effect sizes and power calculations were based on these two groups.

Participants were recruited from the community via flyers distributed throughout The University of Chicago Medicine and surrounding areas, and from direct pediatrician referrals. Participants were excluded if they had medical conditions or were taking medications known to influence weight or appetite; met criteria for an eating disorder other than binge eating disorder (BED); or had a diagnosis of attention deficit-hyperactivity disorder (ADHD). Interested individuals completed a phone screen to assess basic study entry criteria, and eligible participants were invited to attend a study visit, along with a parent or guardian, in the Department of Psychiatry and Behavioral Neuroscience at The University of Chicago Medicine. Each participant and his/her caregiver provided written informed assent/consent, respectively. Study procedures were approved by The University of Chicago Institutional Review Board.

Measures

Anthropometric and sociodemographic variables—Height and weight were measured in light indoor clothing by a trained research assistant via stadiometer and calibrated digital scale, respectively. Child z-BMI was calculated using CDC growth charts and accompanying procedures (Kuczmarski et al., 2000). Demographic data were reported by children and parents, and included children's age, gender, race/ethnicity (White, Black/African-American, Hispanic/Latino, Asian, Native Hawaiian or Other Pacific Islander, American Indian or Alaska Native, or multi-racial/other), current medications, and medical problems.

Eating behavior—Diagnostic items from the Child Eating Disorder Examination 12.0 (Child EDE; Bryant-Waugh, Cooper, Taylor, & Lask, 1996) were used to assess current and lifetime LOC eating and rule out other eating disorders. The Child EDE is a semi-structured, interviewer-based instrument based on the well-validated adult EDE, with modifications including the use of simpler language appropriate for a younger audience. The Child EDE has adequate reliability and validity (Bryant-Waugh et al., 1996; Decaluwe & Braet, 2004; Watkins, Frampton, Lask, & Bryant-Waugh, 2005).

Neuropsychological functioning—Parents completed the Conners Rating Scale-3rd Edition (CRS; Conners, Sitarenios, Parker, & Epstein, 1998), a well-validated, 43-item measure of child behavior symptoms that can be used to assess ADHD. CRS subscales include inattention (reflecting poor concentration and attention, distractibility, and carelessness; current α=.88), hyperactivity (reflecting restlessness and impulsivity; current α=.79), and executive functioning subscales (reflecting poor organization and difficulties planning/initiating tasks; current α=.76). Items are rated from "0" (not true at all) to "3" (very much true). Parents also completed the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquick, Guy, & Kenworthy, 2000), an 86-item, psychometrically sound (Gioia et al., 2000; Jarratt, Riccio, & Siekierski, 2005; McCandless & L, 2007) measure of child executive function behavior symptoms including inhibition, set-shifting, and emotional control, along with other constructs (current α=.98). Items are scored from "1" (never) to "3" (often). Higher *T*-scores on both the CRS and BRIEF reflect poorer functioning.

Children completed the following computer-based executive functioning tasks: 1) the Flanker Test (Eriksen & Eriksen, 1974), a validated visual search task measuring attention and response inhibition (Posner & DiGirolamo, 1998) in which participants quickly identify a stimulus surrounded by either distracting or facilitating items; 2) the Dimensional Change Card Sort task (DCCS; Zelazo, 2006) a measure of inhibitory control and cognitive flexibility which has been used in multiple studies of children (Beck, Schaefer, Pang, & Carlson, 2011; Morton, Bosma, & Ansari, 2009) in which respondents sort cards according to different dimensions; 3) the List Sorting task, a measure of working memory which was adapted from psychometrically sound Spanish and English Neuropsychological Assessment Scales (Mungas, Reed, Crane, Haan, & Gonzalez, 2004; Mungas, Reed, Haan, & Gonzalez, 2005) in which respondents are required to mentally retain and sequence items according to pre-specified characteristics (e.g., reciting a list of animals from memory in size order); and 4) the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), a widely-used measure of decision-making (Dunn, Dalgleish, & Lawrence, 2006) in which participants aim to maximize financial earnings by making card choices which lead to either variable reward or combined reward and penalty. For the Flanker Test and DCCS, scoring incorporates both accuracy and reaction time, while scoring on the List Sorting task reflects accuracy only. Higher scaled scores on all three measures indicate better performance. For the IGT, higher *T*-scores reflect more impulsive decision-making.

In addition to the computer-based tasks, participants completed the Tower of London (TOL) disk-transfer task (Culbertson & Zilmer, 2005), a behavioral measure of planning and problem-solving in which participants are required to transfer objects to a specified position while following a series of rules. TOL scoring generates a total correct score (tasks performed in the fewest number of moves possible), total move score (number of moves, above the minimally required steps per task), initiation time (time before the first move), execution time (time from the first move to task completion), and total time (initiation time plus execution time). Higher scaled scores reflect better performance.

Finally, participants completed the Wechsler Abbreviated Scale of Intelligence-First Edition (WASI; The Psychological Corporation, 1999) a measure of general intellectual functioning with good reliability and validity in children. The WASI generates a total IQ score based on performance across measures of vocabulary (measuring basic and advanced word knowledge, and purported to reflect verbal concept formation), similarities (measuring ability to identify commonalities between known objects or concepts, and purported to reflect verbal concept formation and reasoning), block design (measuring ability to re-create increasingly complex designs in a specified time frame, and purportedly reflecting analysis and synthesis of abstract information), and matrix reasoning subtests (measuring recognition of complex patterns, and purportedly reflecting fluid/visual intelligence, classification and spatial ability, knowledge of part–whole relationships, simultaneous processing, and perceptual organization). Higher scaled scores reflect better performance.

Statistical Analysis

All analyses were conducted in SPSS 19.0. Group differences on sociodemographic and anthropometric variables were assessed using chi-square and analysis of variance (ANOVA) tests. All data were normally distributed with the exception of TOL initiation time scaled score, and LOC eating frequency in the 3 months prior to assessment, which were natural log-transformed and square-root transformed, respectively, to correct for positive skew. Two separate multivariate analyses of covariance (MANCOVAs), adjusting for WASI full scale IQ scores (which showed small- to medium-sized correlations with the other executive functioning measures; see Table 2), were used to assess group differences on CRS subscale scores (inattention, hyperactivity, and executive functioning *T*-scores) and TOL scores (total correct moves, total number of moves, natural log-transformed initiation time, execution time, and total time scaled scores), given the medium to high inter-correlations among scores from each of these measures. For the remaining parent-report (BRIEF global executive composite *T*-scores) and behavioral measures (age-adjusted Flanker Test, DCCS, and List Sorting scaled scores; and IGT age- and demographic-adjusted *T*-scores), separate ANCOVAs, adjusting for WASI full scale IQ scores, were used to assess group differences. For significant main effects, post-hoc least squared difference tests were used to evaluate the significance of the specific group differences. Partial correlations adjusted for group were used to examine associations among Child EDE-reported number of LOC eating episodes in the 3 months prior to assessment, and executive functioning measures. Partial correlations were used so that associations reflected the overlap among executive functioning constructs of interest, independent of group status.

Results

Descriptive Characteristics

There were no group differences on the basis of age [$F(2,74)=2.20$; $p=.12$], gender [$\chi^2(2)=0.21$; $p=.90$], or race/ethnicity [$\chi^2(4)=4.81$; $p=.31$; see Table 1]. As expected, children in the OW-LOC (*M* BMI z-score=2.08±0.47) and OW-CON groups (*M* BMI z-score=2.02±0.47) had significantly higher z-BMIs than those in the NW-CON group [*M* BMI z-score=−0.18±0.71; $F(2, 74)=106.29$; $p<.001$). OW-LOC and OW-CON also had significantly lower WASI scores than NW-CON [$F(2,74)=4.24$; $p<.02$].

Executive Functioning Measures

The MANCOVA for parent-reported CRS subscales was non-significant [$F(3,68)=0.73$; $p=.54$; partial eta^2=.03], as was the ANCOVA for BRIEF GEC scores [$F(2,70)=0.81$; $p=.45$; partial eta^2=.02]. The MANCOVA for TOL scores was significant [$F(5,65)=3.52$; $p=.007$; partial eta^2=.21], with significant group differences on TOL total correct moves [$F(2,68)=4.04$; $p=.02$; partial eta^2=.11] and total moves [$F(2,68)=6.32$; $p=.003$; partial eta^2=.16]. Post-hoc tests revealed that NW-CON had significantly more correct moves than either the OW-CON (p=.01) or OW-LOC (p=.02) groups; OW-CON and OW-LOC did not significantly differ from one another (p=.92). The NW-CON group also demonstrated more total moves than the OW-CON (p=.001) and OW-LOC (p=.003) groups on the TOL; again, the latter two groups did not differ from one another (p=.91).The ANCOVA for List Sorting score was also significant [$F(2,71)=6.45$; p=.003; partial eta^2=.15]. OW-LOC showed significantly worse performance on the List Sorting task relative to both OW-CON (p=.02) and NW-CON (p=.003) groups, who did not differ from one another (p=.17). None of the other behavioral executive functioning measures differed by group (all p>.05).

The 3-month frequency of LOC eating episodes (square-root transformed) was not associated with any executive functioning measures after statistically adjusting for group status (Partial r range for LOC eating frequency=−.13 to .23; all p>.05; see Table 2).

Discussion

The current study was the first, to our knowledge, to assess a range of executive functioning constructs in children with concomitant overweight and LOC eating relative to their overweight and normal-weight peers without LOC eating. In partial support of our hypotheses, we found that youth with overweight, irrespective of LOC eating status, differed from normal-weight controls in their performance on the Tower of London task, a behavioral measure of planning, with relative decrements reflecting accuracy in planning rather than performance time. Moreover, youth with both overweight and LOC eating showed poorer performance on the List Sorting task, a measure of working memory, than both overweight and normal-weight controls. One unanticipated finding was that youth with overweight, irrespective of LOC eating, had lower general IQ than their normal-weight peers. However, these differences appear to be accounted for by higher intellectual functioning in normal-weight controls (M=107.7±22.4) relative to youth with overweight (M=95.9±11.8) and are unlikely to be clinically significant given that all participants scored in the average range, regardless of weight status. Overall, results suggest that overweight with or without concomitant LOC eating in children may be characterized by a unique pattern of executive dysfunction that could have clinical implications for both eating- and weight-related problems.

The tendencies of youth with overweight, regardless of LOC eating, to be less accurate in planning (as measured by the TOL), yet similarly prompt in developing and executing their plans (as reflected in equivalent initiation and execution times) compared to their normal-weight peers, suggests that they may have more difficulties following the most efficient path to a future, desired outcome. These findings are consistent with previous research demonstrating that poorer planning (as measured by the Mazes subtest of the Wechsler Intelligence Scale for Children) was predictive of excess weight gain (but not LOC eating) in girls (Goldschmidt, Hipwell, et al., 2015), and may generalize to difficulties carrying out a successful weight control plan. Indeed, structured interventions in which youth develop weight loss plans in conjunction with healthcare providers and their families are recommended as a first-line treatment for pediatric obesity (Coppock, Ridolfi, Hayes, St Paul, & Wilfley, 2014), but maintenance of weight loss is currently one of the major challenges plaguing the field (Epstein & Wrotniak, 2010). Taken together, the weight regain that frequently occurs following the withdrawal of treatment may be related to children's relative deficiencies in executing healthy weight control plans without the intensive assistance from family members and providers that is present during treatment. Therefore, effective weight control interventions need to account for the relative difficulties youth with overweight may have in carrying out effective meal and activity plans during and after treatment. Importantly, the impact of global planning abilities should be studied in relation to weight control treatment outcome in youth.

In addition to planning difficulties that were general to youth with overweight, those with both overweight and LOC eating demonstrated poorer working memory, as measured by the List Sorting task, relative to overweight and normal-weight controls. Working memory generally refers to the ability to retain and manipulate information; for youth with overweight and LOC eating, diminished working memory, combined with relatively poor planning abilities, may manifest in dysregulated eating via difficulties generating alternative plans for eating when faced with distractions or other barriers to implementing a previously established plan (e.g., choosing to eat a different food when the expected food is unavailable). The combination of relatively poor planning and working memory also has important implications for treatment. Thus far, interventions for LOC eating in youth have exclusively focused on adolescents, and have primarily targeted dietary restraint and/or negative affect as antecedents to LOC eating (Jones et al., 2008; Mazzeo et al., 2013; Tanofsky-Kraff et al., 2014). Novel interventions targeting younger children may need to incorporate a focus on their relative executive functioning deficiencies as well. Based on their difficulties with planning and working memory, children with comorbid overweight and LOC eating may benefit from interventions that help them anticipate and overcome barriers to successful control of eating and weight, and practice recalling/manipulating plans to enhance success. In particular, executive control training, particularly in conjunction with traditional interventions targeting LOC eating, might be beneficial for improving both cognitive and eating-related difficulties in these children. Examples of strategies that may be helpful include flexibly planning ahead for meals and snacks; generating alternatives when planned meals and snacks are not available; adhering to a routine eating schedule; utilizing reminders to engage in an eating plan (e.g., notes, rehearsal); and limiting access to foods that present a high risk for LOC eating. Parents are likely to play a critical role in helping their children generate and utilize these strategies in treatment, for example, by limiting opportunities to deviate from meal plans and structuring the home environment to support abstinence from LOC eating (e.g., avoiding purchasing foods that tend to be consumed during LOC eating episodes). However, a better understanding of how parents can best assist their children is needed as executive functioning is heritable (Barnes, Dean, Nandam, O'Connell, & Bellgrove, 2011), and thus the parents of youth with LOC eating and overweight may struggle with their own planning and working memory abilities as well.

The current study had multiple strengths, including the racially diverse, community-based sample which represented children across both the weight and LOC eating spectrums; the inclusion of both parent-report and behavioral measures of executive functioning; and the use of a well-validated, semi-structured interview to assess LOC eating. However, there were also several limitations which should be addressed in future studies. These included the cross-sectional study design, which precludes speculation about causality, and the use of generalized, non-food-specific measures of executive functioning constructs, which may have limited the relevance of our tasks to this subset of the pediatric population and contributed to some of the null findings. Finally, because power calculations were based on expected differences between children with overweight with or without LOC eating, the study may have been under-powered to detect significant differences between children of overweight and normal-weight status.

Nevertheless, as the first study to investigate executive functioning in youth with concomitant overweight and LOC eating, this study marks an important contribution to the literature. Results were somewhat at odds with the adult literature, which has more consistently reported executive functioning deficits among those with binge eating problems (Voon, 2015), and may reflect developmental shifts in cognition and eating-related pathology. Future research should investigate whether and how results generalize to real-world processes and related neural functioning patterns, as well as whether executive functioning difficulties predate pathological eating in order to optimally inform early identification and prevention efforts.

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Abbreviations

OW-LOC	overweight with loss of control
OW-CON	overweight control
NW-CON	normal-weight control
ANOVA	analysis of covariance
MANCOVA	multivariate analysis of covariance
LOC	loss of control
BMI	body mass index
CDC	Centers for Disease Control and Prevention
BED	binge eating disorder
ADHD	attention deficit hyperactivity disorder
EDE	Eating Disorders Examination
CRS	Conners Rating Scale
BRIEF	Behavior Rating Inventory of Executive Function

DCCS	Dimensional Change Card Sort
IGT	Iowa Gambling Task
TOL	Tower of London
WASI	Wechsler Abbreviated Scale of Intelligence

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Table 1

Participant characteristics, *M*±*S.D.*

Variable		Full sample (*n*=75)	NW-CON (*n*=15)	OW-CON (*n*=34)	OW-LOC (*n*=26)	Test statistics	Effect size
Demographic variables							
Age, y		10.5±1.1	10.4±1.1	10.8±1.1	10.2±0.9	$F(2,74)=2.20$; $p=.12$	Partial $\eta^2=.06$
Gender, % female (*n*)		58.7 (44)	60.0 (9)	55.9 (19)	61.5 (16)	$\chi^2(2)=0.21$; $p=.90$	Φ=.05
	African-American	81.3 (61)	73.3 (11)	82.4 (28)	84.6 (22)	$\chi^2(4)=4.81$; $p=.31$	
Race, % (*n*)	White	12.0 (9)	26.7 (4)	8.8 (3)	7.7 (2)		Φ=.31
	Other	6.7 (5)	0.0 (0)	8.8 (3)	7.7 (2)		
BMI z-score		**1.61±1.04**	**-0.18±0.71[a]**	**2.02±0.47[b]**	**2.08±0.47[b]**	$\boldsymbol{F(2,74)=106.29;\ p<.001}$	Partial $\eta^2=.75$
Neuropsychological variables							
	Inattention	55.2±14.3	53.4±13.7	54.1±12.2	57.5±17.1	$F(2,73)=0.30$; $p=.75^{*}$	Partial $\eta^2=.01$
CRS *T*-score	Hyperactivity	56.2±12.4	56.9±10.7	54.7±10.9	57.7±15.0	$F(2,73)=0.58$; $p=.56^{*}$	Partial $\eta^2=.02$
	Executive function	55.6±13.6	52.1±9.9	55.6±13.4	57.6±15.6	$F(2,73)=0.23$; $p=.80^{*}$	Partial $\eta^2=.01$
BRIEF GEC *T*-score		51.7±11.6	47.3±10.9	52.9±10.4	52.7±13.2	$F(2,70)=0.81$; $p=.45^{*}$	Partial $\eta^2=.02$
TOL scaled score	Total correct moves	**94.6±13.5**	**105.6±14.3[a]**	**92.1±10.4[b]**	**91.5±13.8[b]**	$\boldsymbol{F(2,72)=4.04;\ p=.02}^{*}$	Partial $\eta^2=$**.11**
	Total moves	**91.7±16.6**	**107.1±11.1[a]**	**88.1±15.9[b]**	**87.5±15.1[b]**	$\boldsymbol{F(2,72)=6.32;\ p=.003}^{*}$	Partial $\eta^2=$**.16**
	Initiation time	101.8±12.6	111.9±20.4	100.0±10.3	99.1±7.2	$F(2,72)=2.22$; $p=.12^{*,**}$	Partial $\eta^2=.06$
	Total execution time	88.0±14.4	96.0±9.5	86.9±15.0	85.4±14.7	$F(2,72)=1.82$; $p=.17^{*}$	Partial $\eta^2=.05$
	Total time	87.6±14.7	91.6±11.7	87.3±15.8	85.9±14.8	$F(2,72)=0.85$; $p=.43^{*}$	Partial $\eta^2=.02$
Flanker Test scaled score		91.9±13.2	94.3±11.7	92.0±12.7	90.5±14.9	$F(2,71)=0.04$; $p=.96^{*}$	Partial $\eta^2=.00$
DCCS task scaled score		96.1±9.7	97.2±11.0	96.7±9.7	94.6±9.0	$F(2,71)=0.27$; $p=.77^{*}$	Partial $\eta^2=.01$
List Sorting task scaled score		**101.5±13.0**	**110.6±10.3[a]**	**102.8±12.7[a]**	**94.6±11.3[b]**	$\boldsymbol{F(2,71)=6.45;\ p=.003}^{*}$	Partial $\eta^2=$**.15**
IGT *T*-score		44.8±6.7	45.8±9.6	44.8±6.5	44.2±5.1	$F(2,71)=0.14$; $p=.87^{*}$	Partial $\eta^2=.00$
WASI scaled score		**98.2±15.1**	**107.7±22.4[a]**	**96.9±12.3[b]**	**94.5±11.2[b]**	$\boldsymbol{F(2,74)=4.24;\ p=.02}$	Partial $\eta^2=.11$

Note: NW-CON=normal-weight control; OW-CON=overweight control; OW-LOC=overweight with loss of control eating; BMI=body mass index (kg/m^2); CRS=Conners Rating Scale; BRIEF GEC=Behavior Rating Inventory of Executive Function Global Executive Composite; TOL=Tower of London; DCCS=Dimensional Change Card Sort; IGT=Iowa Gambling Task; WASI=Wechsler Abbreviated Scale of Intelligence. Bold font denotes significant test results, while differing superscript letters indicate where significant differences lie.

*Analyses adjusted for WASI full scale IQ.

**Analyses involved natural log-transformed values; pre-transformation scores are presented for ease of interpretation

Table 2

Partial correlations among eating-related and neuropsychological variables, adjusted for group

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.LOC eating frequency[a]	---	.10	.11	−.10	.06	.24	.14	.20	.00	−.03	.03	.21	−.11	−.07	.00
2.CRS inattention	---	---	.67***	.78***	.78***	.09	.08	−.04	.02	.05	−.06	−.08	−.08	.08	−.16
3.CRS hyperactivity	---	---	---	.53***	.64***	.10	.20	−.04	.18	.18	−.06	.01	−.02	−.03	−.14
4.CRS executive function	---	---	---	---	.68***	.04	.07	−.09	.11	.13	−.09	−.18	.01	.05	−.17
5.BRIEF GEC	---	---	---	---	---	.14	.04	−.09	.06	.09	−.08	−.02	.05	.06	−.09
6.TOL total correct moves	---	---	---	---	---	---	.67***	.15	.44***	.36**	.08	.25*	.01	.02	.37**
7.TOL total moves	---	---	---	---	---	---	---	.14	.70***	.61***	.10	.26*	.01	.21	.34**
8.TOL initiation time[b]	---	---	---	---	---	---	---	---	−.29*	−.46***	.28*	.28*	.16	−.02	.25*
9. TOL total execution time	---	---	---	---	---	---	---	---	---	.97***	.10	.10	−.03	.21	.18
10. TOL total time	---	---	---	---	---	---	---	---	---	---	.03	.03	−.08	.20	.09
11. Flanker Test	---	---	---	---	---	---	---	---	---	---	---	.30*	.05	−.04	.27*
12. DCCS	---	---	---	---	---	---	---	---	---	---	---	---	.31**	.09	.35**
13. List Sorting task	---	---	---	---	---	---	---	---	---	---	---	---	---	.15	.27*
14. IGT	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.10
15. WASI	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

[a]Analyses involved square-root transformed values

[b]Analyses involved log-transformed values

*$p<.05$;

**$p\leq.01$;

***$p\leq.001$

Note: LOC=loss of control; CRS=Conners Rating Scale’ BRIEF GEC=Behavior Rating Inventory of Executive Functioning Global Executive Composite; TOL=Tower of London; DCCS=Dimensional Change Card Sort; IGT=Iowa Gambling Task; WASI=Wechsler Abbreviated Scale of Intelligence