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Executive function phenotypes in pediatric obesity

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Abstract

Objective: To comprehensively examine the behavioral phenotypes of children with and without executive function (EF) impairments in a clinical sample of youth with obesity.

Methods: Youth aged 8 to 17 years (Mean age = 12.97) attending a medical clinic for obesity and their caregivers (N = 195 dyads) completed a battery of behavioral questionnaires. Caregiver-proxy report of EF was assessed using the Behavior Rating Inventory of Executive Function. Latent Class Analysis was conducted to identify EF groupings. Analysis of variance and chi-square tests were conducted to examine associations between EF groups and behavioral phenotypes.

Results: Four latent classes of EF impairment were identified (No/Low Impairment; Behavioral Regulation Impairment; Metacognition Impairment; Global Impairment). There was an overall positive pattern of associations between these EF groups and behavioral/emotional symptoms, such that behavioral/emotional symptoms tended to increase with EF impairment.

Conclusions: Children with obesity and EF impairment demonstrate a dysregulated behavioral phenotype ranging from internalizing to externalizing behavioral and weight-related symptoms. This phenotype framework may be clinically beneficial for utilizing screening/assessment results to develop, tailor, and/or match treatment approaches in pediatric obesity.

Keywords

adolescents; children; executive function; obesity; parents; phenotypes

1 | INTRODUCTION

Over the past decade, there has been an increased focus on executive functions (EF) and their role in the development, maintenance, and treatment of pediatric overweight/obesity. Indeed, a growing literature supports the association between obesity and poorer EF.¹⁻⁴ While longitudinal studies are limited, existing literature suggests that a bidirectional

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DISCLOSURE OF INTERESTS

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relationship exists between EF and obesity.⁵ Namely, EF problems early in childhood increase the likelihood of obesity development in pre-adolescence⁶; alternatively, preexisting EF impairments seem to be compounded by obesity or excess weight.⁷ Thus, there is an established and complex association between EF and obesity/weight management.

However, there is variability in the behavioral and emotional presentation of these EF problems within children with obesity—as well as other pediatric populations such as children with ADHD and epilepsy.^{8,9} In obesity, while all children may have medical diagnostic criteria in common (ie, 95th percentile for body mass index; BMI), there is diversity in their behavioral/emotional presentations, which may be related to varying degrees and types of underlying EF impairments. There are several types (ie, domains) of EF, such as inhibitory control, working memory, cognitive flexibility/shifting, planning, organization, and self-monitoring. Some children with obesity present with EF deficits in behavioral regulation (eg, inhibitory control, emotional control), while others present with deficits in metacognition (eg, planning, organization, self-monitoring) or even global deficits (ie, across most/all EF domains).¹⁰

Potential behavioral mechanisms have been identified that may explain the relationship between EF and obesity, such as emotion dysregulation, disinhibited and disordered eating behavior, low levels of physical activity, high levels of sedentary time, and poor sleep.^{7,11} For example, a child with poorer inhibitory control may have difficulty resisting the temptation to consume sweets or high-density foods that are likely to cause excess weight gain over time. Similarly, a child who has problems with cognitive flexibility may struggle to navigate unexpected barriers to their typical physical activity of playing outside when there is bad weather. Recent evidence also suggests that there are biological pathways (eg, chronic inflammation, appetite hormone dysregulation, poor glycemic control) that also likely contribute to the obesity-EF relationship.^{12,13}

Moreover, EF and self-regulatory behavioral/emotional concerns including impulsivity, loss of control, and binge eating have been associated with poorer weight outcomes in pediatric obesity treatment.^{14,15} Yet, there is currently no systematic way of identifying EF impairments and how they may translate into behavioral/emotional obstacles that could act as barriers to treatment in children with obesity. However, a systematic method of identifying such underlying EF impairments and the behavioral/emotional concerns associated with them might help to develop more precise, optimized healthy lifestyle treatments.

Thus, the objective of this study was to identify unique behavioral phenotypes of EF in a sample of children with obesity. Specifically, our aim was to determine whether there were subgroups of children with specific types of EF impairments that were associated with specific types of behavioral/emotional symptoms. It was hypothesized that high, mid, and low EF impairment groups would be identified, and that the degree and type(s) of behavioral and emotional symptoms would correspond to the level of EF impairment (eg, high EF impairment would be associated with high behavioral/emotional problems).

2 | METHODS

2.1 | Participants

Participants were 195 youth ages 8 to 17 years old attending a regularly scheduled medical appointment at a primary care (22%; $n = 43$) or specialty lipid clinic (78%; $n = 152$) and their accompanying legal guardians. All youth had overweight or obesity, defined by Centers for Disease Control (CDC) guidelines in the United States as a BMI ≥ 85 th percentile for age and sex norms.¹⁶ Exclusion criteria included children diagnosed with intellectual disability, psychotic disorder, or short stature, and children or caregivers who did not speak and read English. Eligible families were approached in a private exam room by a trained member of the research team to determine study interest and conduct written informed consent and assent procedures. Youth and caregivers independently completed questionnaires during the visit and were compensated for their time and participation. The study was approved by the governing IRB.

2.2 | Measures

2.2.1 | Demographic information—Caregivers completed a demographic questionnaire to report child age, sex, and race/ethnicity, as well as caregiver age, sex, height, weight, and family income.

2.2.2 | Anthropometric data—Youth height and weight were measured by trained medical staff at the clinic visit and obtained from the medical chart. Standardized BMI scores (zBMI) and percentiles were derived from CDC norms adjusted for age and sex.¹⁶ Self-reported height and weight were used to calculate the BMI (kg/m^2) of caregivers.

2.2.3 | Executive function—The Behavior Rating Inventory of Executive Function (BRIEF)¹⁷ is an 86-item parent-report measure that assesses EF impairment in healthy and clinical pediatric populations.^{17,18} Caregivers/parents rate their child's behaviors over the past 6 months on a 3-point Likert scale (Never, Sometimes, Often). Scoring produces a Global Executive Composite (GEC), Behavioral Regulation Index (BRI), Metacognition Index (MI), and 8 clinical subscales of EF domains. The BRI is a composite of the Inhibit, Shift, and Emotional Control subscales, and the MI is a composite of the Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor subscales. T-scores based on age and sex are converted from raw scores, where higher scores indicate greater executive dysfunction. A t-score of ≥ 65 on any scale or index represents potential clinical impairment.¹⁷ Cronbach's alpha of the GEC is 0.98 in the current sample.

2.3 | Behavioral phenotype characteristics

2.3.1 | Child behavioral and emotional problems—The Pediatric Symptom Checklist (PSC-17)¹⁹ is a parent-proxy report measure of a child's overall psychosocial functioning. It produces a total score and 3 subscales consisting of 5 or 7 items of internalizing, attention, and externalizing problems. Parents are asked to rate each symptom with Never (0), Sometimes (1), and Often (2). Weighted scores for the 17 items are summed to produce a total score ranging from 0 to 34. Higher scores indicate greater risk. Total scores are recoded categorically, based on a validated cutoff score of ≥ 15 ^{20,21} on the

global scale to indicate overall psychological risk. Subscale total and categorical scores are calculated in the same manner. Scores of 7 indicate risk on the attention and externalizing subscales, and scores of 5 indicate risk on the internalizing subscale. Cronbach's alphas were 0.84, 0.86, and 0.84 for the Attention, Internalizing, and Externalizing Problems subscales, respectively, and $\alpha = 0.89$ for the PSC-17 Total Score in the current sample.

2.3.2 | Child dysregulated eating—The Questionnaire of Eating and Weight Patterns-Adolescent and- Parent (QEWP-A; QEWP-P) measures²² were used to assess youth dysregulated eating episodes over the past 6 months via youth and parent perspective, respectively. The QEWP is a valid and stable 12-item measure of eating and weight-related behavior.^{22,23} Item response options are either Yes/No format or rated on a frequency or intensity Likert scale. For the current study, responses were classified using a scoring protocol^{10,24,25} as *no episode* of dysregulated eating, *episodic overeating* (ate an unusually large amount of food within short time period), *binge eating* (overeating + loss of control), or *bulimic behavior* (self-induced vomiting and laxative, diuretic, diet pill, or other supplement use to prevent weight gain after binge eating).

2.3.3 | Child health-related quality of life—The Pediatric Quality of Life Inventory (PedsQL)²⁶ is a reliable and valid generic Child health-related quality of life (HRQoL) questionnaire with similar self- and parent-proxy report versions for use in healthy and chronically ill pediatric populations.^{26,27} The parent-proxy report version was used for the current study, which consists of 23 items rated on a 5-point Likert scale. The PedsQL yields a global score and 4 subscale scores for physical, emotional, social, and school functioning. Standardized scale scores range from 0 to 100, with higher scores indicating better quality of life. Cronbach's alpha for the global score was 0.90 in the current sample.

2.4 | Statistical analysis

Measures of central tendency and dispersion were calculated for all variables. Categorical variables were summarized using sample proportions. To allow exploration of a possible latent class structure within the data, 8 dichotomous variables were created from the BRIEF subscales indicating clinically impaired (T -score ≥ 65) vs intact EF with regard to Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. Using the R Package poLCA,²⁸ Latent Class Analysis was conducted. To determine the number of EF groups associated with the best fitting model, Akaike's Information Criteria (AIC) and Bayes Information Criteria (BIC) were used as indicators of model fit, where smaller numbers indicate better model fit. AIC is typically better for describing heterogeneity in the sample, especially when class size is small; while BIC tends to be more parsimonious, identifying fewer and larger distinct classes.²⁹ Thus, they are commonly interpreted in combination to determine the best model fit depending on the study goals and class sizes. Analysis of Variance models were constructed to test for differences among EF groups means for continuous outcomes. Chi-square tests were used to test for association between categorical variables and latent classes. As the primary measure of EF provided age- and sex-corrected norms, these were not included as covariates. Only omnibus effects were tested and no post hoc probing was conducted, given limited power and variability within each behavioral/emotional variable. Thus, the P-values provided in the

text and figures refer to the omnibus tests. Due to the limited cell sizes of the dysregulated eating variables (no eating episode, binge eating, overeating, bulimic behavior) within each EF subgroup, a dichotomized dysregulated eating variable was created (presence vs absence of any eating episode across the EF groups) and used in chi-square tests. All analyses were conducted in SAS 9.4 or R 3.3.3.

3 | RESULTS

3.1 | Participants

Child and caregiver characteristics of the study sample are stratified by EF phenotype group and displayed in Table 1. The child sample was primarily adolescent females with obesity. Approximately half were non-Hispanic Caucasian and one-third were non-Hispanic African-American. Most caregivers were female, in their 40s, had obesity, and reported family incomes less than \$40 000. No differences in the sample were identified by recruitment source which is likely attributable to the functioning of this specific primary care clinic which was commonly known to treat children with obesity and thus likely received more patients with obesity than a typical primary care clinic. The only statistically significant difference across the EF phenotypes was BMI percentile and z-score, such that the Metacognition Impairment group had significantly higher BMI percentiles and z-scores on average than the Low/No Impairment group.

3.2 | EF groups

Figure 1 displays the model fit by number of estimated latent groups based on AIC and BIC. Interpretation of the AIC trend across the latent group models suggests that the 4-group model is the best fit, whereas the BIC trend indicates the 3-group model. The 4-group model was ultimately chosen based on AIC typically being more appropriate for lower and variable class sizes ($n = 30$ for 3 classes and >100 for 1 class) than BIC, as well as the nature of the study goal was to identify maximal yet distinguishable heterogeneity in EF-associated concerns in the sample.²⁹

Based on the 4-group latent class analysis model, Figure 2 displays the proportions of participants whose EF was considered potentially clinically impaired for each of the 8 EF scales. The EF latent classes/groups were named similarly to the BRIEF Indices, as there were substantial similarities in the EF domains that were impaired in the groups we identified via latent class analysis in comparison to the indices from the BRIEF questionnaire (Global Executive Composite, Metacognition Index, Behavioral Regulation Index, or no impairment). The Global Impairment group ($n = 26$) had exceptionally high rates of EF impairment, with 80–100% of this group meeting clinically significant impairment on every BRIEF subscale, with the exception of Organization of Materials which had a 65% impairment rate. The Metacognition Impairment group ($n = 27$) had high rates of EF impairment on the subdomains of the BRIEF's Metacognition Index, including the areas of Working Memory (82%), Planning/Organization (78%), Organization of Materials (70%), Initiation (63%), and Monitoring (48%), while relatively lower rates of impairment (33%) were reported on the subdomains included in the BRIEF's Behavioral Regulation Index. Alternatively, the Behavioral Regulation Impairment group ($n = 30$)

showed high rates of clinical impairment in the BRIEF's subdomains of the Behavioral Regulation Index, including Inhibition (63%), Shifting (60%), Emotional Control (50%). In addition to these impairments, there was also substantial impairment in Working Memory (50%) in the Behavioral Regulation Impairment group, whereas the other domains that correspond to the BRIEF's Metacognition Index had lower levels of impairment (20%) in this group. The Low/No Impairment Group ($n = 112$) comprised more than half of the sample, who demonstrated no or minimal EF impairment.

3.3 | Behavioral phenotypes

The level of severity of EF impairment generally matched the behavioral/emotional symptom presentation. The Low/No EF Impairment group had the fewest identified behavioral/emotional symptoms, whereas the Global EF Impairment group had the greatest. Behavioral Regulation and Metacognition Impairment groups were associated with moderate symptoms, although the type of concerns was different. Figures 3–5 display the descriptive statistics (frequencies, means) of the behavioral and emotional symptoms examined across EF groups for visual representation.

3.3.1 | Child behavioral and emotional problems—There were statistically significant main effects ($P < .001$) for all 4 ANOVAs examining the percentage of youth with clinically significant impairments in Global, Attention, Internalizing, and Externalizing Problems across the 4 EF groups. Figure 3 displays the rates of parent-reported clinically significant behavioral/emotional problems in the four domains for each EF group. The Global Impairment EF group had the highest rates of clinically significant impairment on all of these domains. Within the Global Impairment EF group, 50% to 85% of youth had parent-reported clinically impaired levels of Attention, Internalizing, Externalizing, or Global Problems. In the Behavioral Regulation Group, 17% to 37% had clinically significant parent-reported behavioral/emotional problems, followed by the Metacognition Group (11%–26%), and lastly the Low/No EF Impairment group (2%–11%).

3.3.2 | Child dysregulated eating—Presence/absence of dysregulated eating episodes differed across EF groups, per parent-report ($P = .0011$) and child self-report ($P = .0175$). The percentage of each group endorsing different eating episodes are displayed for illustrative purposes in Figure 4A,B. Per parent report, the visual trend demonstrates that the most severe and prevalent eating concerns were reported in the Global Impairment group, followed by the Metacognition group, and the Behavioral Regulation Group; whereas the Low/No Impairment Group had the highest reported absence of dysregulated eating (72% no episode). Children self-reported a similar trend as parent-proxy reports (although rates were different): highest absence of dysregulated eating (81%) in the Low/No Impairment group, which decreased (ie, dysregulated eating increased) in the Behavioral Regulation (67%) and Metacognition (52%) Impairment groups, but [absence of dysregulated eating] rose in the Global Impairment group (73%), suggesting divergence between parent- and child-reports in the Global Impairment group.

3.3.3 | Child HRQoL—ANOVA results indicated statistically significant differences in HRQoL domains (Physical: $P = .001$; Emotional: $P = .0268$; Social: $P = .0008$; School: P

= .0013) across EF Groups. Mean HRQoL level for each domain of functioning across EF groups is displayed in Figure 5A–D. The Low/No Impairment group consistently had the highest reported HRQoL in all domains, whereas the Global Impairment group tended to have the lowest HRQoL in all domains except School Functioning, which was lowest for the Metacognition Impairment group. Behavioral Regulation and Metacognition Impairment Groups had HRQoL levels of 61 to 78, which tended to fall below the Low/No Impairment group and above the Global Impairment group.

4 | DISCUSSION

The current study identified four EF phenotypes in youth with obesity. Over half of the sample was identified as the Low/No EF Impairment Phenotype (57%), while the rest of the sample was split almost equally into 3 other groups: Global EF Impairment (13%), Metacognition Impairment (14%), or Behavioral Regulation Impairment (15%). The overall pattern of these EF phenotypes demonstrates that behavioral/emotional symptoms tend to increase with EF impairment. In particular, youth with Global EF Impairments seemed to have widespread, impairing behavioral/emotional symptoms. The two moderately impaired EF phenotypes (Behavioral Regulation Impairment and Metacognition Impairment) had different types of presenting behavioral and emotional concerns but were similar in the amount/level of identified concerns (ie, moderate). For example, there were generally higher rates of internalizing, externalizing, and attention problems in the Behavioral Regulation Impairment group, whereas there were more binge eating and bulimic symptoms reported in the Metacognition Impairment group. Interestingly, there were more reported internalizing problems than externalizing problems in the Behavioral Regulation Impairment group, which may be due to the majority of the sample consisting of adolescent girls, who are more likely to demonstrate internalizing problems in relation to emotional control difficulties, as compared to boys who may be more likely to demonstrate externalizing problems.^{30,31} As expected, the Low/No EF Impairment Phenotype presented with substantially fewer behavioral and emotional concerns, although notable concerns were also evident in this group. This finding is consistent with our hypothesis that more EF problems would be associated with more behavioral/emotional problems, based on the theoretical rationale that problems with EF and self-regulation commonly underlie behavioral problems and disordered eating (eg, Baumeister's Self-Regulation Theory).^{32,33}

This is the first study to identify EF phenotypes in association with global behavioral/emotional problems in children with obesity. Extant literature supports associations between pediatric overweight/obesity, EF problems, obesity-related behaviors (eg, increased intake, decreased physical activity, and disinhibited eating), and behavioral/emotional concerns such as ADHD.^{34–36} Riggs et al¹¹ defined latent classes of obesity risk by identifying associations between general EF problems and patterns of obesity-related behaviors that involved “high sedentary behavior,” “high fat/high sugar snacks,” “weight conscious,” or “not weight conscious.” The current study was similar to Riggs et al¹¹ in its design by examining EF problems in association with patterns of behavior; however, we expanded the behavioral assessment battery beyond obesity-specific behavior to focus more globally on pediatric behavioral and emotional functioning including dysregulated eating, HRQoL, and externalizing, internalizing, and attention problems. Moreover, these comprehensive

assessments were then used with the benefit of clinical guidelines/cutoffs to inform, in a clinically interpretable way, how children with obesity with different types/levels of EF dysfunction present behaviorally and emotionally.

Working memory impairment was observed in all EF phenotypes except for the No/Low EF Impairment. Working memory deficits, in addition to inhibitory control problems, are among the most common types of EF deficits that co-occur with pediatric obesity.³⁷ As such, recent intervention approaches have targeted these EF domains together (ie, lifestyle intervention + computerized working memory/inhibition training).^{38,39} It has previously been demonstrated that working memory is intricately linked to inhibitory control, as inhibitory control is dependent on sufficient working memory capacity,⁴⁰ which may explain why working memory deficits were identified in all EF-impaired groups. Our findings are also consistent with recent findings of Modi et al⁸ identifying 4 identical latent classes of EF impairment, with working memory impairment across all groups, and similar patterns of behavioral/emotional concerns in pediatric epilepsy.

Thus, our findings are in line with previous literature that demonstrate associations between obesity and other pediatric health conditions, EF, and disease-specific emotional and behavioral concerns. Moreover, this study extends the literature by merging current and previous findings into interpretable behavioral profiles (ie, phenotypes) that may reflect different types of underlying EF deficits. As such, this EF phenotyping model could potentially be used for other health conditions and otherwise healthy youth. However, there are distinct behavioral/emotional concerns that children with obesity and health conditions are more likely to experience with impaired EF. Self-regulatory concerns in obesity have been associated with problems related to eating behavior, physical activity, sedentary behavior, and body image that place youth with obesity at even greater risk for increased weight gain, metabolic problems, psychological problems, and thus need special consideration for intervention. Notably, children in the Metacognition Impairment group had the highest BMI Z-scores, on average, of any group, though the differences were small. However, it is possible that even these small BMI differences could be clinically significant and could have attributed to the level of behavioral/emotional problems this group reported—or vice-versa. Moreover, these co-occurring behavioral/emotional problems may be substantially contributing to the EF impairments observed, perhaps even more than obesity-specific factors. Thus, it will be essential that future research examines the unique role of pediatric obesity, as well as the severity of obesity, in EF variability.

The main clinical utility of these findings is increased awareness of the link between different types of EF impairments and behavioral health risk, which can inform screening procedures and treatment recommendations. While it is recommended that all children with overweight/obesity be screened for psychosocial functioning and quality of life, the current findings suggest that EF deficits are also prevalent in this population and associated with increased likelihood and severity of behavioral/emotional problems. There are few known quick and no-cost EF screeners, but a fast (fee-based) screener such as the BRIEF2 Screener might be used to screen for potential EF impairment in a clinical setting. If results of screening suggest potential impairment, further questionnaires (eg, BRIEF2), neuropsychological testing, or interviewing can be done to fully ascertain the

level and type of impairment and its impact on psychological and academic functioning, chronic illness, and treatment regimen. Notably, parent–child disagreement on psychological questionnaires can be common. The current findings, taken together with those of Modi et al,⁸ have identified inconsistencies in parent–child reports on emotional, behavioral, and cognitive questionnaires - particularly in groups including children with global EF impairment compared to those without impairment. Thus, multi-informant and multi-method reports may be crucial for an accurate picture of functioning when youth EF impairment is identified.

The following limitations of the study should be taken into consideration when interpreting these findings and their generalizability. First, this was a cross-sectional study and thus it cannot be assumed that EF deficits caused impairments in any of the behavioral/emotional domains but rather that they co-occur. Second, self-report or parent-proxy report was used for EF and all behavioral/emotional domains measured, which is subject to inherent reporting bias. Third, an obesity-specific QoL measure may have been able to discern nuances across the EF groups better than a generic HRQoL measure. There were also several strengths to support the study's findings: a comprehensive assessment of behavioral/emotional functioning with evidence-based measures, a diverse sample, and a unique approach to characterizing and understanding different EF phenotypes in pediatric obesity.

Based on these findings, there are several areas of future research that have potential clinical implications. First, it would be useful to determine whether the prevalence of clinically significant EF impairment reported in the sample (42%) as well as the EF phenotypes identified in this study (a) can be replicated in other samples with obesity and other diseases affected by EF impairment and (b) can explain individual variability in relevant treatment outcomes such as adherence. Second, it will be imperative that future studies not only assess behavioral/emotional symptoms but also co-occurring psychological disorders, which could be driving observed EF impairments and potentially alter the treatment strategy. Third, based on the current study's findings, development and evaluation of treatments targeting EF impairment may be warranted. Existing obesity interventions may demand a higher level of EF skills than some children with obesity possess, creating a mismatch in their abilities and what is being asked of them (eg, choosing fruit instead of a cookie when behavioral regulation is impaired; starting a new exercise routine when metacognitive skills such as initiation and planning are impaired). By knowing a child's specific EF deficits, intervention strategies can be better tailored to the needs of the child. Fourth, with further research and replication, EF phenotyping could be applied in a precision medicine model, where an individual's EF phenotype could help healthcare providers select tailored prevention and treatment recommendations.

4.1 | Conclusions

There were 4 unique behavioral phenotypes of EF identified in children with overweight/obesity. Overall severity of comorbid behavioral and emotional symptoms progressed across the 4 profiles, from No/Low EF impairment with fewest, least severe symptoms to Global EF impairment with most, and clinically significant symptoms. Furthermore, the different EF phenotypes demonstrated unique behavioral and emotional symptoms, particularly in

internalizing and externalizing problems, HRQoL, and binge eating. Ultimately, this EF phenotyping approach modeling the interplay between levels of executive dysfunction and behavioral/emotional symptoms is translatable to other pediatric conditions.⁸ This framework of EF as a potential contributor to behavioral and emotional factors, and vice versa, may be an important piece to understanding long-term health conditions and behaviors. Looking forward, this framework needs integration with other internal (eg, biological/medical, psychological) and external (eg, social, environmental) contributors to obesity and other health conditions.

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FIGURE 1. Comparison of AIC and BIC model fit by number of groups. AIC, Akaike information criterion; BIC, Bayes information criterion

FIGURE 2.

Latent class analysis model: 4-Group (N = 195). BRIEF, behavior rating inventory of executive function

FIGURE 3.

Child behavioral and emotional problems, parent-proxy report. PSC-17, Pediatric Symptom Checklist 17

FIGURE 4.

A, Dysregulated eating episodes, parent-proxy report. B, Dysregulated eating episodes, child self-report. Dysregulated eating episodes assessed with the questionnaire of eating and weight patterns-adolescent and -parent

FIGURE 5.

A, Physical HRQoL; B, Emotional HRQoL; C, Social HRQoL; D, School HRQoL. HRQoL, Health-related quality of life

TABLE 1

Participant characteristics stratified by EF phenotype group (N = 195)

Child characteristics	Mean ± Standard deviation or % (n)					P-value*	Total sample (N = 195)
	Low/no imp. (n = 112)	Behavioral regulation imp. (n = 30)	Meta-cognition imp. (n = 27)	Global imp. (n = 26)			
Age	12.66 ± 2.52	12.87 ± 2.01	14.00 ± 2.32	13.35 ± 2.70		.07	12.97 ± 2.47
Sex (% female)	57.14% (n = 64)	56.67% (n = 17)	70.37% (n = 19)	65.38% (n = 17)		.56	60.00% (n = 117)
Body mass index/BMI percentile	97.35 ± 3.07	97.97 ± 2.22	99.09 ± 0.54	98.27 ± 1.72		.01	97.82 ± 2.63
Body mass index/BMI Z-score	2.18 ± 0.48	2.25 ± 0.43	2.46 ± 0.31	2.23 ± 0.34		.03	2.23 ± 0.44
Race/ethnicity (%)	—	—	—	—		.87	—
Non-Hispanic Caucasian	47.32% (n = 53)	53.33% (n = 16)	48.15% (n = 13)	46.15% (n = 12)		—	48.21% (n = 94)
Non-Hispanic African-American	37.50% (n = 42)	30.00% (n = 9)	29.62% (n = 8)	26.92% (n = 7)		—	33.85% (n = 66)
Hispanic	8.04% (n = 9)	6.67% (n = 2)	7.41% (n = 2)	15.38% (n = 4)		—	8.72% (n = 17)
Mixed-race	5.36% (n = 6)	10.00% (n = 3)	14.81% (n = 4)	7.69% (n = 2)		—	7.69% (n = 15)
Asian, Asian-American, other	1.78% (n = 2)	0	0	3.85% (n = 1)		—	1.54% (n = 3)
Caregiver characteristics							M ± SD % (n)
Age	40.45 ± 8.64	41.67 ± 10.46	44.89 ± 7.93	43.92 ± 10.11		.07	41.80 ± 9.20
Sex (% female)	95.54% (n = 107)	90.00% (n = 27)	96.30% (n = 26)	88.46% (n = 23)		.41	93.85% (n = 183)
Body mass index/BMI	34.14 ± 8.53	35.03 ± 6.81	35.85 ± 7.06	33.04 ± 6.71		.57	34.37 ± 7.85
Family income (%)	—	—	—	—		.84	—
Below \$20,000	33.92% (n = 38)	43.33% (n = 13)	37.04% (n = 10)	46.15% (n = 12)		—	37.44% (n = 73)
\$20–39,999	28.57% (n = 32)	33.33% (n = 10)	29.63% (n = 8)	34.62% (n = 9)		—	30.26% (n = 59)
\$40–59,999	16.96% (n = 19)	10.0% (n = 3)	18.52% (n = 5)	7.69% (n = 2)		—	14.87% (n = 29)
\$60–79,999	7.14% (n = 8)	0	11.11% (n = 3)	3.85% (n = 1)		—	6.15% (n = 12)
Over \$80,000	13.39% (n = 15)	13.33% (n = 4)	3.70% (n = 1)	7.69% (n = 2)		—	11.28% (n = 22)

Note:

* Bonferroni-corrected *P*-value from chi-squared or ANOVA test results; significant omnibus effects were followed up with post-hoc analyses, which consistently identified differences between the low/no impairment group and the metacognition group.