Cognitive Disengagement Syndrome But Not ADHD Symptoms Predict Child Body Mass Index: Examination in a Sample of Clinically Referred Youth

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Research Article

Keywords: Cognitive Disengagement Syndrome, Attention-Deficit Hyperactivity Disorder, body mass index, childhood obesity

Posted Date: March 13th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2661740/v1

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Abstract

Given the substantial increase in pediatric obesity rates in recent decades, its long-term stability, and its pervasive negative outcomes, continuous efforts to identify factors that may place children at increased risk for overweight or obesity (OW/OB) are essential. As such, the primary aim of the present investigation was to examine the extent to which symptoms of Cognitive Disengagement Syndrome (CDS; i.e., Sluggish Cognitive Tempo) predict child body mass index (BMI) independent of Attention-Deficit/Hyperactivity Disorder (ADHD). The study is the first to examine whether CDS subdomains of slowed thinking, hypoarousal, and daydreamy predict BMI. Analyses included data from 72 clinically-referred children (46 males, 26 females) aged 4 to 12 years old (M = 8.41, SD = 2.48). CDS and ADHD were assessed using standardized parent-report rating scales, and children's BMI was collected at the time of encounter. Bayesian hierarchical regression models revealed no evidence that overall CDS symptoms or ADHD symptoms (overall and subdomain) predicted child BMI. However, models did provide moderate evidence that hypoarousal and daydream subdomains jointly predicted BMI independent of ADHD (BF<sub>10</sub> = 19.28–21.87). The present study suggests that CDS is a risk factor of obesity in young children and future research is needed to inform clinical interventions and to provide further understanding of the relatively nuanced association between CDS symptoms and obesity.

Introduction

Cognitive Disengagement Syndrome (CDS), a newly proposed moniker to replace the construct of Sluggish Cognitive Tempo (SCT; Becker et al., 2022), is a set of symptoms characterized by hypoactivity, excessive daydreaming, and slowed behavior and thinking (Becker, 2021). CDS often correlates with Attention Deficit Hyperactivity Disorder (ADHD), particularly inattention symptoms (Barkley, 2013a). However, CDS is dissociable from ADHD (Becker et al, 2016) and shows a different developmental trajectory than ADHD (Dvorsky et al., 2021). Moreover, CDS either differently (Barkley, 2013b) or independently (Willcutt et al., 2014) predicts multiple important child health outcomes such as social, educational, and health outcomes.

While comparatively greater attention has been placed on the association between CDS and social or academic outcomes (Becker et al., 2016), much less focus has been placed on health outcomes, in particular obesity. This is surprising as pediatric obesity poses a major public health issue, with approximately 20% of children in the United States (Stierman et al., 2021) and 23% children worldwide (GBD 2015 Risk Factors Collaborators, 2016) considered either overweight or obese (OW/OB). Defined by body mass index [BMI] ≥ the 85th percentile for age and sex, childhood obesity is associated with a multitude of negative outcomes, including peer victimization (Gray et al., 2009) and poor self-esteem (BeLue et al., 2009), and often predicts long-term consequences, such as increased risk for psychopathology (e.g., depression, anxiety; Pervanidou et al., 2013), physical complications (e.g., type 2 diabetes, cardiovascular disease; Global BMI Mortality Collaboration, 2016), lower cognitive functioning (Fang et al., 2019), and impaired social relationships (Washington, 2011). Given the substantial increase in pediatric obesity rates in recent decades, its long-term stability (GBD 2015 Risk Factors Collaborators,
2016), and its pervasive negative outcomes, continuous efforts to identify factors that may place children at increased risk for OW/OB are essential. As such, the primary aim of the present investigation is to examine the extent to which symptoms of CDS predict child BMI, and independent from ADHD.

A growing body of research suggests an association between ADHD and OW/OB status in children and adults (Cortese, 2019; Merrill et al., 2021), and that both inattentive and hyperactive/impulsive ADHD symptoms may contribute to increased BMI (Cortese et al., 2016; Graziano et al., 2010). Proposed plausible explanations for their association include genetic factors (Chen et al., 2019), abnormal eating patterns (Egbert et al., 2018), executive function deficits (Fang et al., 2019), and alterations in sleep patterns (Türkoğlu & Çetin, 2019). For instance, impaired inhibitory control may increase abnormal eating behaviors (e.g., binging; Graziano et al., 2010), whereas inattention may decrease awareness of food intake in terms of quality (i.e., low nutrition, high caloric food) and quantity (i.e., over-eating; Cortese et al., 2016), each leading to heightened obesity risk. Therefore, overall ADHD symptoms, as well as presentation-related symptoms (i.e., inattentive and hyperactive/impulsive symptoms), were expected to significantly predict child BMI.

Similarly, previous research has identified an association between CDS and characteristic behavioral patterns of obesity, including daytime sleepiness (Becker et al., 2016; Willcutt et al., 2014) and hypoactivity (McBurnett et al., 2014). Despite these findings, only one study to date has directly examined the relationship between obesity and CDS symptoms. In a recent examination of only 35 children with obesity aged 10 to 17 years old, Öğütlü and colleagues (Öğütlü et al., 2022) observed that 29% of children experienced elevated CDS, and that CDS was associated with several factors related to obesity, including emotional over-eating, food enjoyment, daytime sleepiness, and the diagnosis of ADHD predominantly inattentive type. Surprisingly, there was no significant association between CDS, and BMI examined continuously or among those with versus without elevated CDS symptoms. This unexpected finding, however, may be explained by the inclusion of only children with obesity, which limits our understanding of the association between CDS and individual differences in BMI more broadly. Further, although the study was the first to examine CDS and obesity in children—though predominantly adolescents—findings were limited to overall symptoms of CDS and did not examine potential CDS subdomains, which ignores the multidimensionality of CDS (Barkley, 2013b; McBurnett et al., 2014). Acknowledging this multidimensionality is crucial given that subdomains may relate to distinct outcomes, imply different risk factors, or indicate different treatment strategies. Additional examination of overall and subdomain symptoms of CDS and their relations with obesity is imperative for our understanding of CDS-related outcomes.

The present study examines the relation between CDS symptoms and BMI in a sample of children with a range of BMI, including those with and without obesity. Based on previous empirical support for a three-factor model of CDS (McBurnett et al., 2014), the current study also examines the extent to which CDS domains of slowed thinking, hypoarousal, and daydreamy predict BMI. The present study is the first to examine the relation between CDS symptoms both overall and multidimensionally, and differs from the only other study of CDS and obesity (Öğütlü et al., 2022) in focusing on non-adolescent youth given the
critical importance of understanding early risk factors. Given that previous research has identified an association between CDS and characteristic behavioral patterns of obesity (Becker et al., 2016; Willcutt et al., 2014), it was expected that each of the three subdomains of CDS, in addition to overall symptoms of CDS, would significantly predict BMI. Moreover, it was predicted that CDS would significantly predict BMI independent of ADHD.

Method

Participants and Procedure

Participant characteristics are shown in Table 1. Participants were 93 children consecutively referred to an outpatient developmental-behavioral specialty clinic in the deep Southern U.S. for evaluations concerning suspected ADHD, learning, or behavioral problems. Written consent for services was provided by caregivers, and a retrospective chart review of data was approved by the university's institutional review board (protocol # redacted for anonymity). The sample was referred by primary care physicians or via internal referrals from medical providers within the clinic. Data were obtained between January 2016 and October 2018, and are openly available at http://bit.ly/3y1ESjw to facilitate peer review.
# Table 1
Sample Descriptive and Correlation Among Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Pearson’s &lt;i&gt;r&lt;/i&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>BF&lt;sub&gt;01&lt;/sub&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2. Sex&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Pearson’s &lt;i&gt;r&lt;/i&gt;</td>
<td>0.04</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>BF&lt;sub&gt;01&lt;/sub&gt;</td>
<td>6.49*</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(-0.19, 0.26)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3. SES&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Pearson’s &lt;i&gt;r&lt;/i&gt;</td>
<td>0.20</td>
<td>0.10</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>BF&lt;sub&gt;01&lt;/sub&gt;</td>
<td>1.83</td>
<td>4.89*</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(-0.04, 0.41)</td>
<td>(-0.14, 0.32)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4. Medication status&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Pearson’s &lt;i&gt;r&lt;/i&gt;</td>
<td>0.01</td>
<td>0.17</td>
<td>0.07</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>BF&lt;sub&gt;01&lt;/sub&gt;</td>
<td>6.79*</td>
<td>2.59*</td>
<td>5.68*</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(-0.22, 0.23)</td>
<td>(-0.07, 0.38)</td>
<td>(-0.16, 0.30)</td>
<td>–</td>
</tr>
<tr>
<td>5. Child BMI&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Pearson’s &lt;i&gt;r&lt;/i&gt;</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.10</td>
<td>-0.11</td>
</tr>
<tr>
<td></td>
<td>BF&lt;sub&gt;01&lt;/sub&gt;</td>
<td>6.25*</td>
<td>6.58*</td>
<td>5.00*</td>
<td>4.63*</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(-0.27, 0.18)</td>
<td>(-0.26, 0.20)</td>
<td>(-0.31, 0.14)</td>
<td>(-0.32, 0.13)</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>8.41 (2.47)</td>
<td>34.18 (13.89)</td>
<td>0.71 (1.13)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Percentage&lt;sup&gt;f&lt;/sup&gt;</td>
<td>36</td>
<td>76</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Note. SES = socioeconomic status; BMI = body mass index; CI = confidence interval. <sup>a</sup> Age is calculated in years. <sup>b</sup> For sex, female = 0, male = 1. <sup>c</sup> SES reflects parents’ mean Hollingshead score. <sup>d</sup> Currently on medication = 0, <sup>e</sup> BMI score reflects Z-score, <sup>f</sup> Percentage of reference group coded 0.

* BF<sub>01</sub> ≥ 3
Inclusion criteria for participants included all 93 children aged 4 to 15 years old. Participant were excluded if (a) data for symptoms of CDS ($n = 11$) or ADHD ($n = 1$) were not obtained, (b) intelligence testing indicated a full scale estimate below 70 ($n = 1$), (c) the child was over the age of 12 years old ($n = 6$), or the time between the date of the evaluation and the date the child’s BMI was collected was greater than 3 months ($n = 2$). The final analytic sample consisted of 72 children (46 males, 26 females) aged 4 to 12 years old ($M = 8.41$, $SD = 2.48$).

Caregivers completed a battery of intake measures prior to or during the evaluation. Evaluation procedures included completion of demographic and standardized questionnaires, brief intellectual, neurocognitive (e.g., continuous performance, digit span), and academic measures, as well as a clinical interview with caregiver and child using the Schedule for Affective Disorders and Schizophrenia for School Aged Children Present and Lifetime Version (KSADS-PL; Kaufman et al., 1997). Only data from mothers were used in this study given complete data from all mothers and only 22% ($n = 16$) of measures were completed by fathers. The final sample’s demographic characteristics closely represented that of the larger state community. Sixty-three percent ($n = 45$) of the sample met DSM-5 criteria for ADHD based on an independent clinical diagnosis by a licensed clinical psychologist (DES) using the K-SADS diagnostic interview and parent and/or teacher ratings. Other psychological disorders in the sample included specific learning disorder (32%), anxiety disorders (13%), oppositional defiant disorder (8%), post-traumatic stress disorder (7%), depression (6%), generalized anxiety disorder (4%), separation anxiety (4%), or autism spectrum disorder (1%). Eighteen children (25%) were taking stimulant medication at the time of the evaluation. Of these 18 children, seven (39%) children were rated off medication by their parent with regard to CDS and ADHD symptoms.

**Measures**

**Demographics.** Parents completed a demographics form providing information on the child’s age, sex, ethnicity, and medication status. Information on parental occupation and family income was also collected, which was used to calculate socioeconomic status (Hollingshead, 1975).

**Body Mass Index.** Children’s height and weight were collected at the evaluation encounter by nursing staff and converted to BMI according to child age and sex. Twenty-seven (38%) of children did not have BMI collected at the encounter, and the nearest BMI contained in the medical record within +/- 3 months was used. The average elapsed time between the evaluation and the date of BMI collection was 13 days ($SD = 22.43$).

**CDS Symptoms.** The Child and Adolescent Behavior Inventory (CABI; Cianchetti et al., 2017) examines child performance over 10 different domains, using a 6-point Likert scale response ($0 = almost never$ to $5 = almost always$). For the present study, only the 16 items from the CDS module were totaled and used for analyses. The CABI has good psychometric qualities and was designed to allow examination of all domains both individually and collectively (Cianchetti et al., 2020). Internal reliability in the sample was strong ($\omega = 0.94$).
ADHD Symptoms. The National Initiative for Children's Healthcare Quality (NICHQ) Vanderbilt ADHD Diagnostic Parent Rating Scale: Second Edition (VADPRS-2; Wolraich et al., 2004), is a 64-item screening instrument assessing the 18 DSM-5 symptoms of ADHD as well as other commonly related conditions and impairment. Items are rated on a 4-point Likert scale (0 = never to 3 = very often). Dimensional scores were totaled for overall ADHD, inattention, and hyperactivity-impulsivity severity. Internal reliability for overall ADHD symptoms in the sample was strong (ω = 0.94).

Intelligence. Full-scale estimates were obtained from the Kaufman Brief Intelligence Test, Second edition (KBIT-2; Kaufman & Kaufman, 2004).

Data Analytic Plan. To identify CDS symptom subdomains, principal axis factoring (PAF) with varimax rotation was conducted on CDS symptoms. The determinant of the correlation matrix, Bartlett's test of sphericity, and the Kaiser-Meyer-Olkin (KMO) measure were used to validate the appropriateness of using an exploratory factor analysis (Pett et al., 2003). CDS symptom subdomains were computed by summing the items that corresponded with each factor, based on results of the PAF analysis.

Bayesian methods offer several well documented benefits over null hypothesis significance testing (NHST; Rouder & Morey, 2012; Wagenmakers et al., 2018). Bayesian analyses were selected as they permit stronger conclusions than NHST by quantifying the magnitude of relative support for both the alternative and null hypotheses given the data observed (Wagenmakers et al., 2018). This in turn allows inferences regarding associations to be confirmed, which is not permitted in frequentist NHST (Kelter, 2020). This is particularly beneficial with smaller sample sizes to allow potential conclusions regarding the absence of a statistical effect when concerns regarding the presence of Type-II error in NHST may otherwise arise (Kruschke, 2010). Bayesian linear regressions with JZS default prior scales (Morey et al., 2015; Rouder et al., 2012) were conducted using JASP 0.16 (JASP Team, 2021). Instead of a p-value, Bayesian analyses provide BF\textsubscript{10}, which is the Bayes Factor of the alternative hypothesis (H1) against the null hypothesis (H0). BF\textsubscript{10} is an odds ratio, where values above 3.0 are considered moderate evidence supporting the alternative hypothesis (conceptual equivalent of p < .05). BF\textsubscript{10} values below 3.0 are considered anecdotal, whereas BF\textsubscript{10} above 10.0 are considered strong (≥ 30 = very strong, ≥ 100 = decisive/extreme support; Kelter, 2020). Conversely, BF\textsubscript{01} is the Bayes Factor of the null hypothesis (H0) against the alternative hypothesis (H1). BF\textsubscript{01} is the inverse of BF\textsubscript{10} (i.e., BF\textsubscript{01} = 1/BF\textsubscript{10}), and is reported when the evidence indicates a lack of an effect (favors the null hypothesis, i.e., when BF\textsubscript{10}.

We initially used Bayesian correlations to detect evidence for associations/ equivalence in each potential demographic covariate. Those variables demonstrating associations with BMI favoring the null (BF\textsubscript{01} ≥ 3) were removed prior the primary regression analyses; those with positive or equivocal evidence were retained. Next, a one-sample t-test examined BMI of the sample relative to normative BMI (Z-score) to characterize the overall sample with regards to OW/OB status. For primary analyses, a Bayesian hierarchical linear regression was conducted to investigate the unique contribution of overall CDS symptoms and ADHD symptoms to child BMI (Aim 1), and repeated with CDS subdomains rather than overall CDS symptoms (Aim 2). In the first step, demographic covariates were included in the model. The
second step added ADHD symptoms and the final step added CDS symptoms. In each step, the best fitting model was selected (criteria: combination of predictors with highest $BF_{10} \geq 3$), and each additional predictor was tested relative to this best-fitting model (Rouder et al., 2012). Regression models were then repeated separately for inattention and hyperactivity-impulsivity. Credible intervals of 95%, which are interpreted as the probability that the corresponding interval contains the true parameter, were used. We supplemented the Bayesian methods by including NHST significance levels $p < .05$ for completeness as recommended (Rouder et al., 2012; Wagenmakers et al., 2018). Tests supportive of an association are also supplemented with $\beta$-weights to inform effect magnitude and directionality.

Results

Preliminary Analyses

All variables were screened for univariate and multivariate outliers and tested against $p < 0.001$ and no univariate or multivariate outliers were identified. Skewness and kurtosis values were within acceptable limits ranging from $-0.42$ to $1.32$ (skewness) and $-1.50$ to $1.37$ (kurtosis). Children in the sample had excessive BMI relative to age norms, ($BF_{10} = 16.8 \times 10^3; p < .001$). Initial bivariate correlations were conducted to determine the pattern of relationships among CDS and ADHD symptoms and to establish which demographic and symptom variables were related to child BMI. Results provided moderate support against including any covariate in models. Specifically age ($r = -.05, BF_{01} = 6.25 [-.27 - .18], p = .66$), sex ($r = -.03, BF_{01} = 6.58 [-.26 - .19], p = .80$), SES ($r = -.10, BF_{01} = 5.0 [-.32 - .14], p = .43$), and medication status ($r = -.11, BF_{01} = 4.63 [-.32 - .13], p = .38$) failed to exhibit adequate levels of support with an association to BMI and were therefore not included in subsequent regression models. Descriptive statistics and correlations are provided in Table 1.

The exploratory factor analysis indicated that a three-factor model accounted for 65.79% of the item variance in CDS symptoms. The first factor accounted for 26.35% of the item variance. Six items loaded on the first factor and reflected *slowed thinking*. The second factor accounted for 19.77% of the item variance. Four items loaded on the second factor and reflected *hypoarousal*. Finally, the third factor accounted for 19.68% of the item variance. Five items loaded on the third factor and reflected *daydreamy*. Notably, one item ("gets lost in own thoughts") loaded onto both the first and third factors (i.e., factor loading of 0.53 and 0.54 on the first and third factor, respectively). However, based on the quantitative (i.e., magnitude of factor loading) and qualitative (i.e., interpretation of the component) results, the item was determined to load onto the third component. Factor loadings, communalities, and the amount of variance accounted for by each factor are displayed in Table 2.
### Table 2
Results from Factor Analysis of the Child and Adolescent Behavior Inventory (CABI)

<table>
<thead>
<tr>
<th>CABI Item</th>
<th>Factor Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Factor 1: Slowed Thinking</strong></td>
<td></td>
</tr>
<tr>
<td>6. Lose train of thought</td>
<td>0.84</td>
</tr>
<tr>
<td>14. Gets mixed up</td>
<td>0.82</td>
</tr>
<tr>
<td>11. Easily confused</td>
<td>0.72</td>
</tr>
<tr>
<td>16. Difficulty expressing thoughts (e.g., gets tongue-tied)</td>
<td>0.72</td>
</tr>
<tr>
<td>12. Lacks motivation to complete simple tasks (e.g., apathetic)</td>
<td>0.71</td>
</tr>
<tr>
<td>10. Forgets what was going to say</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Factor 2: Hypoarousal</strong></td>
<td></td>
</tr>
<tr>
<td>9. Easily tired or fatigue</td>
<td>0.09</td>
</tr>
<tr>
<td>7. Low level of activity</td>
<td>0.15</td>
</tr>
<tr>
<td>1. Behavior is slow (sluggish)</td>
<td>0.20</td>
</tr>
<tr>
<td>4. Drowsy or sleepy (yawns) during the day</td>
<td>0.20</td>
</tr>
<tr>
<td>15. Thinking is slow</td>
<td><strong>0.56</strong></td>
</tr>
<tr>
<td><strong>Factor 3: Daydreamy</strong></td>
<td></td>
</tr>
<tr>
<td>3. Stares blankly into space</td>
<td>0.25</td>
</tr>
<tr>
<td>5. Daydreams</td>
<td>0.19</td>
</tr>
<tr>
<td>13. Spaces or zones out</td>
<td><strong>0.44</strong></td>
</tr>
<tr>
<td>2. Lost in a fog</td>
<td>0.27</td>
</tr>
<tr>
<td>8. Gets lost in own thoughts</td>
<td><strong>0.54</strong></td>
</tr>
</tbody>
</table>

*Note. N = 307. The extraction method was principal axis factoring with an oblique (Varimax with Kaiser Normalization) rotation. Factor loadings above .30 are in bold.*

### Primary Analyses

A series of six hierarchical linear regression models were conducted to characterize the additive predictive relationship among CDS (overall CDS symptoms, slowed thinking, hypoarousal, daydreamy dimensions) and ADHD (overall ADHD symptoms, inattention, hyperactivity/impulsivity) symptoms in predicting child BMI. ADHD symptoms were entered in the first step and Bayesian linear regressions with default prior
scales provided moderate evidence that ADHD was unrelated to BMI in any model. Overall ADHD symptoms accounted for 0.9% of the variance in BMI ($BF_{01} = 3.16$ [95% credible interval: 0.44–0.98], $p = .44$), inattention accounted for 0.4% of the variance ($BF_{01} = 3.61$ [0.45–0.98], $p = .58$), and hyperactivity/impulsivity accounted for 0.8% of the variance ($BF_{01} = 3.22$ [0.44–0.98], $p = .45$).

In the second step, either overall CDS symptoms or CDS subdomains were entered. Results provided inclusive, anecdotal evidence concerning the relationship between overall CDS symptoms and BMI using Bayesian criteria, though NHST indicated non-significant associations while accounting for overall ADHD symptoms ($BF_{10} = 0.84$ [-0.02–0.13], $p = .15$), inattention ($BF_{10} = 0.96$ [-0.05–0.03], $p = .12$), and hyperactivity/impulsivity ($BF_{10} = 0.92$ [-0.04–0.02], $p = .13$). In contrast, we found the strongest support for models that included CDS subdomains when predicting BMI. With reference to these models, including both hypoarousal and daydreamy CDS symptoms exhibited strong evidence of their joint contribution to BMI independent of overall symptoms of ADHD ($BF_{10} = 19.28$, $p = .01$; $R^2 = 17\%$), inattention ($BF_{10} = 21.87$, $p = .01$; $R^2 = 17.5\%$), and hyperactivity/impulsivity ($BF_{10} = 19.57$, $p = .01$; $R^2 = 17\%$). Inspection of $\beta$-weights and posterior $BF_{10}$ coefficients indicated that hypoarousal ($BF_{10} = 5.40$ to 5.65 across models) and daydreamy ($BF_{10} = 7.95$ to 8.24 across models) contributed to BMI independent from overall ADHD symptoms, inattention, and hyperactivity/impulsivity, whereas there was only anecdotal evidence for the inclusion of slowed thinking ($BF_{10} = 1.39–1.47$). A diverging pattern of association was observed such that hypoarousal was positively associated with greater BMI ($\beta = 0.37$ all models) but daydreamy was negatively associated with greater BMI ($\beta = -0.39$ all models).

**Discussion**

Given the significant rates of pediatric obesity (Stierman et al., 2021), its long-term stability (GBD 2015 Risk Factors Collaborators, 2016), and its pervasive negative outcomes (BeLue et al., 2009; Fang et al., 2019; Gray et al., 2009; Pervanidou et al., 2013; Washington, 2011), identification of early factors that may place children at increased risk for OW/OB is crucial. As such, the present study is the first to examine the relation between BMI, CDS and ADHD symptoms, both overall and multidimensionally, and differs from the only other study of CDS and obesity (Öğütlü et al., 2022) by focusing on non-adolescent youth.

Surprisingly, overall ADHD symptoms, inattentive symptoms, and hyperactive/impulsive symptoms did not significantly predict child BMI. Despite previous research that suggests an association between ADHD and OW/OB status in children and adults (Cortese, 2019; Merrill et al., 2021), and that both inattentive and hyperactive/impulsive ADHD symptoms may contribute to increased BMI (Cortese et al., 2016; Graziano et al., 2010), the present study did not observe these findings. One potential explanation for our disparate findings involves our sample of predominantly male, pre-adolescent youth, such that other research has indicated no discernible association of ADHD with obesity in the pre-adolescent years, and that the association between ADHD and obesity is more reliable in females (Nigg et al., 2016) and may be specific to adolescent females among youth. A meta-analysis conducted by Cortese and colleagues (Cortese et
al., 2016), conversely, indicated that both age and gender did not significantly influence the association between ADHD and obesity. Therefore, a more parsimonious explanation for our equivocal findings is that previous reports of the ADHD-obesity relationship are better explained by the frequently co-occurring but dissociable symptoms of CDS.

Given that previous research has identified an association between CDS and characteristic behavioral patterns of obesity (Becker et al., 2016; Willcutt et al., 2014), it was expected that CDS would significantly predict BMI. Unexpectedly, our findings indicated only anecdotal evidence for overall CDS symptoms’ association with BMI. While at first glance this finding, in conjunction with the non-significant difference between CDS symptoms and BMI found by Öğütü and colleagues (2022), may suggest CDS does not pose as a significant risk-factor for obesity, our investigation of CDS subdomains indicates a more nuanced relation between CDS and BMI. The most unique contribution of the present study was its examination of multidimensional symptoms of CDS and their relation to child BMI. Based on previous empirical support for a three-factor model of CDS (McBurnett et al., 2014), which our study also closely observed, the current study examined the extent to which CDS domains of slowed thinking, hypoarousal, and daydreamy predicted BMI. Our data provided strong evidence consistent with hypoarousal and daydreamy predicting BMI, but not slowed thinking. The divergent direction of association of hypoarousal and daydreamy symptoms with BMI (each of similar magnitude), along with the equivocal slowed thinking and BMI relation, would also seem to account for anecdotal evidence between overall CDS symptoms and BMI and prior nonsignificant associations with overall CDS symptoms reported previously (Öğütü et al., 2022). Thus, it will be critical for future research to report both overall and domain-specific CDS symptoms when investigating OW/OB risk.

Consistent with expectations and previous research (McBurnett et al., 2014), we observed evidence for hypoarousal’s association with higher BMI. This finding provides additional support for sedentary behavior as a risk factor for OW/OB and suggests that low energy expenditure throughout the day puts a child at increased risk for obesity, and that this may in part be captured by CDS hypoarousal symptoms. This supports efforts to reduce hypoarousal and sedentary behavior to protect against excessive BMI risk. In contrast, our data was also consistent with daydreamy CDS symptoms predicting lower BMI. Although some research suggests that inattention or distractibility may increase the likelihood to develop OW/OB through a decreased awareness of food intake (i.e., over-eating; Cortese et al., 2016), our finding seems to suggest that daydreamy behavior actually serves as a protective factor for obesity, perhaps also through eating behavior. The current study’s seemingly paradoxical finding may be explained by eating behavior during bouts of daydreaming, such that a child may “zone out” and eat more slowly, which can lead to quicker satiety, thus resulting in less caloric intake (Liguori et al., 2020). Taken together, our examination of symptom domains of CDS provides a more comprehensive understanding of the relation between CDS and BMI, and provides clarity for potential behavioral mechanisms involved in increased risk for pediatric obesity.

The current study is the first to examine the extent to which symptoms of CDS and predict child BMI beyond ADHD in a sample of non-adolescent youth. Consequently, the present study serves as an
important step toward a better understanding of early risk factors for pediatric obesity. Nevertheless, the current study is not without limitations. The relatively small sample size and restricted use of clinically referred youth, for example, reduces the generalizability of findings. Future studies that include a more representative sample are therefore needed to determine if the effects reported in this study generalize to the broader population of children. Although the present study is the first to examine CDS and BMI in a sample of pre-adolescent youth which serves as an important contribution to our understanding of early risk factors in obesity, another limitation is the inclusion of children across a relatively wide range of ages (e.g., 4 to 12 years old). Despite the association between ADHD and obesity becoming more robust with increased age (Nigg et al., 2016), however, age was not a significant covariate in the current sample. A final limitation is that the cross-sectional nature of the data precludes an examination of the directionality of the relationship between CDS, ADHD, and BMI. Therefore, future research should leverage the use of a longitudinal design to better understand causal inferences regarding the risk of obesity in ADHD and CDS.

Collectively, our findings provide evidence that CDS significantly predicts child BMI and does so independently of ADHD. Most notable is our finding that subdomains of CDS symptoms—specifically hypoarousal and daydreamy symptoms—indeed and differentially predict greater BMI in children. Together this finding provides support for the positive energy balance theory of obesity in CDS, such that obesity occurs when the amount of energy accumulated in the body (e.g., overeating) is higher than the amount of energy that is expended (e.g., low levels of physical activity; Cortese, 2019). Overall, the present study suggests that CDS is a risk factor of obesity in young children and, given the pervasive negative outcomes associated with obesity, future research is needed to inform clinical interventions and to provide further understanding of the relatively nuanced association between CDS symptoms and obesity.

Declarations

Ethical approval

Approval was obtained from the ethics committee of University of Mississippi Medical Center. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Competing interests

(always applicable and includes interests of a financial or personal nature)

Authors' contributions
Delanie K. Roberts: Conceptualization, Formal analysis, Data curation, Writing – Original draft preparation. Dustin E. Sarver: Conceptualization, Methodology, Writing – Original draft preparation, Supervision. Domynic D. Elder: Conceptualization, Validation, Writing – Review and editing

Funding

No funding was received to assist with the preparation of this manuscript.

Availability of data and materials


Author Note

We have no known conflict of interest to disclose.

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