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Polysomnographic versus parent-reported predictors of executive function in children with sleep disordered breathing

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1. Introduction

Sleep-disordered breathing (SDB) affects up to 10% of children and is characterized by habitual snoring, sleep fragmentation, and intermittent hypoxia [1,2]. Untreated pediatric SDB is linked to daytime sleepiness [3], behavioral problems [4], decreased academic performance [5], and lower quality of life [6]. Many of these negative outcomes are believed to result from SDB's impact on the structure and function of the prefrontal cortex (PFC), which plays a key role in attention and executive functioning in children [7].

The first line of management of SDB is adenotonsillectomy (AT), which improves symptoms in most children and remains one of the most common pediatric surgical procedures [8]. However, because SDB can also resolve spontaneously, "watchful waiting" with supportive care is a viable alternative [9,10]. Currently, there are no validated tools to predict which children will benefit most from surgery versus conservative management, leading to heterogeneity in clinical practice, including *small area variation*, which refers to the differences in surgical rates and treatment patterns observed across regions that cannot be explained by patient-level factors alone [11,12].

Polysomnography (PSG) is considered the gold standard for diagnosing and assessing the severity of OSA [13]. However, its usefulness in assisting with surgical decision-making is limited [14]. PSG may not accurately represent a child's typical sleep environment, and it is expensive, requires significant resources, and is often hard to access. Importantly, PSG-derived measures such as the apnea-hypopnea index (AHI) are weakly correlated with behavioral, cognitive, and quality-of-life outcomes in children [15]. Conversely, the subjective nature of parent-reported questionnaires like the Pediatric Sleep Questionnaire (PSQ) and the Obstructive Sleep Apnea-18 (OSA-18) confines their use mainly to research settings [16,17].

Recent research has identified biological factors that link SDB to neurobehavioral problems [18]. In particular, functional neuroimaging studies show that reduced activation of the prefrontal cortex (PFC) correlates with parent-reported problem behaviors in children with SDB, indicating that executive dysfunction could serve as an clinical marker of SDB [19]. However, it remains unclear whether PSG parameters or parent-reported measures better detect executive dysfunction related to SDB. Therefore, we hypothesized that although both measures provide overlapping information, parent-reported symptom burden would more closely align with PFC-related executive function. Our study aims to address this critical knowledge gap and move toward identifying

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accessible biomarkers to help guide surgical decisions in pediatric SDB.

2. Methods

2.1. Study design and participants

Between January 2025 to August 2025, we conducted a prospective observational study of children aged 5-11 years referred for definitive management of SDB at the University of Maryland Medical Center (Baltimore, MD) and the University of Texas Southwestern (Dallas, TX). Children were excluded if they had uncorrected congenital heart disease, significant neurologic or psychiatric disorders, prior upper airway surgery or treatment with continuous positive airway pressure, sickle cell disease, stimulant medication use, autism spectrum disorder, or other developmental delays. Demographic and socioeconomic information, including age, sex, race, insurance type, and caregiver income, was collected through caregiver questionnaires and electronic medical records. Body mass index (BMI) percentile was calculated using age- and sex-specific growth charts from the US Centers for Disease Control and Prevention [20]. The study protocol (HP-00102524) was reviewed and approved by the institutional review boards of the University of Maryland, Baltimore, MD, and University of Texas Southwestern Medical Center, Dallas, TX. Participants received financial compensation for completion of the research visit. All polysomnography studies were ordered via standardized clinical pathways (e.g., by any member of the treatment team including the primary care provider).

2.2. Clinical predictors

All participants underwent an overnight PSG and scored in accordance with the American Academy of Sleep Medicine pediatric guidelines [21,22]. From each PSG report, we extracted the total AHI, obstructive AHI (oAHI), rapid eye movement (REM) latency, wake after sleep onset (WASO), percentage of REM sleep, total sleep time (TST), arousal index, sleep efficiency, and oxygen saturation (SpO_2) nadir. AHI was defined as the sum of all obstructive and mixed apneas, with hypopneas associated with a 50% decrease in airflow and either a greater than 3% desaturation or electroencephalographic arousal, divided by the total sleep time in hours. oAHI was defined as the averaged total number of obstructive apneas and hypopneas per hour of sleep. REM latency was defined as the time in minutes it took for participants to enter stage REM of sleep after sleep onset, and WASO was measured as the number of minutes participants were awake following initial onset of sleep. Percentage REM sleep was the proportion of REM sleep that a patient experienced out of total sleep time (TST). TST was the total duration of time spent in any stage of sleep, including Stages N1, N2, N3, and REM sleep. Arousal Index was measured from the change in state from sleeping to wakefulness per hour of sleep. Sleep efficiency refers to the percentage of total time in bed that a patient spends in sleep. These variables were chosen because they represent the primary domains of SDB pathology, including airway obstruction, sleep fragmentation, and hypoxemia.

Caregivers also completed two validated screening questionnaires during the study visit. The OSA-18 is an 18-item tool that measures OSA-specific quality of life across four domains: sleep disturbance, physical suffering, emotional distress, and caregiver concern [16]. Higher scores reflect greater symptom burden, with values above 80 indicating severe impact. The Pediatric Sleep Questionnaire, Sleep-Related Breathing Disorder scale (PSQ-SRBD), is a 22-item measure addressing snoring, sleepiness, and inattention or hyperactivity [17]. Responses are coded as "yes," "no," or "don't know," and a composite score of 0.33 or higher identifies children at high risk for clinically significant SDB.

2.3. Executive function outcomes

Children's executive function was assessed using both objective and subjective (parent-reported) measures. For the objective assessment, children completed a custom computerized Go/No-Go (GNG) task [23] created in PsychoPy (https://www.psychopy.org). GNG is a widely validated paradigm for quantifying inhibitory control and attentional regulation, and is also used in SDB research given the importance of measuring inhibition [24]. It is developmentally appropriate for children aged 5-11 years and does not require reading skills. In this task, stimuli were presented sequentially on a computer screen for 1.5 s each, separated by a 0.5-s inter-stimulus interval (Fig. 1a). The task design alternated between two block types: pure "Go" blocks, in which all stimuli required a button press, and mixed blocks, which contained equal proportions of Go (target) and No-Go (non-target) trials. During mixed blocks, participants were instructed to respond quickly to Go stimuli while withholding responses to No-Go stimuli, thereby engaging inhibitory control processes. The block design of the task is summarized in Fig. 1b and highlights the simple and visually salient images used. Task instructions were delivered verbally using standardized, age-appropriate language.

Task performance was quantified using d-prime (d′) sensitivity, a signal detection measure that accounts for both correct responses and errors [25]. Specifically, d′ was calculated as the difference between the z-transformed hit rate (proportion of correct Go responses) and the z-transformed false alarm rate (proportion of incorrect responses to No-Go trials). Higher d′ values indicate greater ability to discriminate targets from non-targets, reflecting stronger inhibitory control and attentional regulation. This approach minimizes the influence of age-related response bias and provides a robust, psychometrically validated index of executive function in children.

The parent-reported assessment was obtained using the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2), which captures day-to-day executive functioning across home and school contexts [26]. Parents rated their child's behavior across nine domains that aggregate into three indices (Behavioral Regulation, Emotional Regulation, and Cognitive Regulation). These indices are combined into the Global Executive Composite (GEC) score, which was the primary parent-reported outcome. Raw scores were converted to age- and sex-adjusted t-scores, with higher scores indicating greater executive dysfunction.

2.4. Statistical analysis

Continuous variables were summarized as means with 95% confidence intervals, and categorical variables as counts with percentages. The normality of the distributions was evaluated using Shapiro-Wilk tests and visual inspection of histograms. Associations between PSG indices, questionnaire scores, and executive function outcomes were analyzed using Spearman's rank correlation coefficients. Effect sizes were interpreted as weak ($\rho < 0.3$), moderate ($\rho = 0.3$-0.5), or strong ($\rho > 0.50$). All associations were adjusted for demographic covariates.

Missing data were addressed with multiple imputation by chained equations, which preserves variability and accounts for the uncertainty of imputed values. Imputation models included demographic, PSG, and questionnaire variables to maximize accuracy.

The target sample size was determined based on the detection of correlations between clinical predictors and executive outcomes. Using Fisher's z transformation for a two-tailed α of 0.05, a sample of 80 participants provides 80% power to detect at least a moderate correlation. While the study may be underpowered to identify smaller effects, the sample size is adequate for identifying moderate associations and prioritizing candidate predictors for larger confirmatory studies. All analyses were conducted using R (version 4.3, https://cran.r-project.org), and statistical significance was defined as $P < 0.05$.

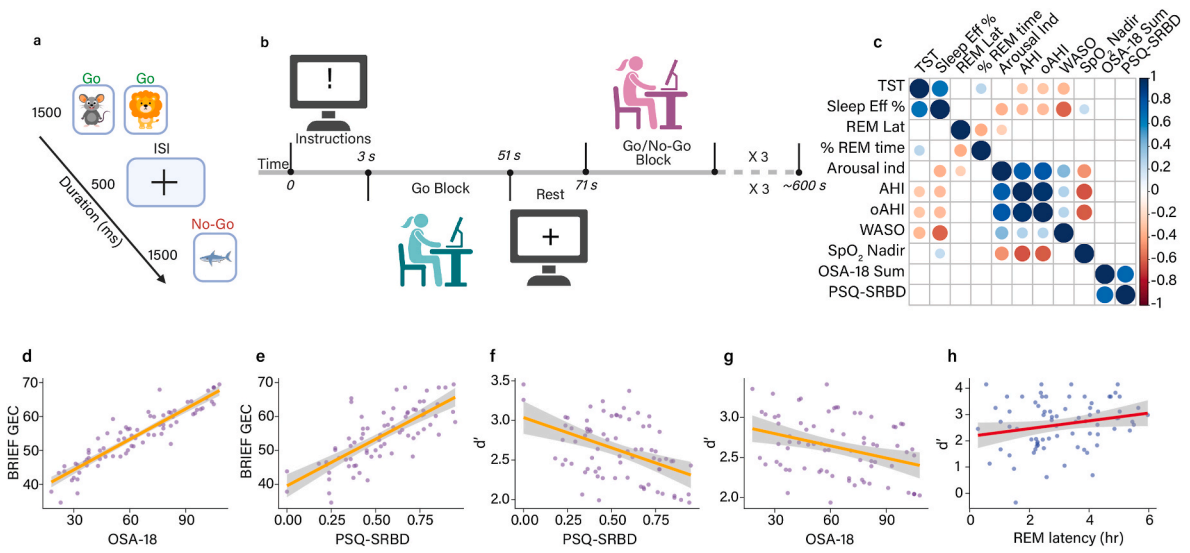

Fig. 1. Study paradigm and associations between polysomnographic (PSG) and questionnaire predictors with executive function outcomes. (a–b) Schematic of the computerized Go/No-Go (GNG) task used to assess inhibitory control. Each trial consisted of a 1500 ms stimulus presentation followed by a 500 ms interstimulus interval (ISI). Children completed alternating Go blocks (all "Go" trials) and mixed Go/No-Go blocks, each repeated three times. **(c)** Correlation matrix of PSG variables and questionnaire scores. **(d–e)** Higher scores on the Obstructive Sleep Apnea-18 (OSA-18) and Pediatric Sleep Questionnaire Sleep-Related Breathing Disorder scale (PSQ-SRBD) were significantly associated with greater parent-reported executive dysfunction on the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2) Global Executive Composite (GEC) (OSA-18 vs GEC: $\rho = 0.61$, $P < 0.001$; PSQ-SRBD vs GEC: $\rho = 0.62$, $P < 0.001$). **(f–g)** Questionnaire scores were not significantly correlated with inhibitory control as measured by GNG d′ (OSA-18: $\rho = -0.16$, $P = 0.18$; PSQ-SRBD: $\rho = -0.19$, $P = 0.10$). **(h)** PSG variable rapid eye movement (REM) latency showed a nonsignificant trend toward association with GNG d′ ($\rho = 0.21$, $P = 0.07$).

3. Results

3.1. Participant characteristics

Seventy-eight children with SDB were enrolled, with demographic and clinical characteristics summarized in Table 1. The mean age was 7.8 years (95% CI, 7.4-8.2), and 52.6% were male. More than half of the cohort identified as Black (56.4%), and 75.6% were non-Hispanic. Most participants were insured through public programs (78.2%), and one-third of families reported annual household incomes below $30,000. The mean body mass index percentile was 82.0 (95% CI, 75.8-88.3). Questionnaire scores indicated a substantial symptom burden. The mean OSA-18 total score was 63.2, consistent with moderate SDB impact on disease-specific quality of life, while 84.6% of children had PSQ-SRBD scores ≥0.33, placing them at high risk for clinically significant SDB.

3.2. Polysomnographic findings

Polysomnographic data are presented in Table 2. The mean AHI was 12.7 events/hour (95% CI, 9.3-16.1), and the mean obstructive AHI was 11.9 events/hour (95% CI, 8.6-15.3). The mean SpO_2 nadir was 86.6% (84.9-88.3). Sleep efficiency averaged 84.0% (82.0-86.1), with a mean REM latency of 182.1 min (163.1-201.0).

3.3. Associations between clinical predictors and executive function

Correlations between polysomnography (PSG) variables, parent-questionnaire scores, and GNG task results are shown in Fig. 1c. Both the OSA-18 questionnaire ($\rho = 0.61$, $P < 0.001$) and the PSQ-SRBD scale ($\rho = 0.62$, $P < 0.001$) were associated with Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2) Global Executive Composite (GEC) scores, indicating that higher symptom burden correlated with worse parent-reported executive dysfunction. In contrast, no PSG variable, including the AHI ($\rho = -0.05$, $P = 0.67$) or SpO_2 nadir ($\rho = 0.07$, $P = 0.55$), was significantly associated with BRIEF-2 outcomes. Questionnaire scores also did not correlate with inhibitory control as measured by GNG d′ (OSA-18: $\rho = -0.16$, $P = 0.18$; PSQ-SRBD: $\rho = -0.19$, $P = 0.10$). REM latency showed a nonsignificant trend toward association with d′ ($\rho = 0.21$, $P = 0.07$). These associations are summarized in the adjusted scatter plots in Fig. 1d–h.

4. Discussion

The present study compared the predictive value of PSG variables with parent-reported symptom burden on executive dysfunction in children with SDB. Our findings demonstrate that parent-reported measures, specifically the OSA-18 and PSQ-SRBD questionnaires, were the only consistent predictors of executive dysfunction as measured by the BRIEF-2 GEC. In contrast, PSG-derived variables, including indices of obstruction, oxygen desaturation, and sleep fragmentation, did not reliably predict executive dysfunction, except for a weak association between REM latency and performance on GNG task. Taken together, these results align with and extend prior work suggesting that parental symptom reports may capture the neurobehavioral morbidity of pediatric SDB more accurately than traditional PSG indices.

Our findings align with the previous analysis from the Childhood Adenotonsillectomy Trial (CHAT), the largest randomized trial to date comparing surgical and nonsurgical management of pediatric OSA. In that analysis, post-AT improvements were driven solely by changes in parent-reported symptom severity, with minimal contribution from PSG parameters [27]. Importantly, none of the PSG parameters, such as the AHI, SpO_2 nadir, or arousal index, were associated with assessments of behavior or cognition at baseline. Our current findings expand this understanding to quantitively assessed measures of response inhibition (GNG task), reinforced the consistent observation that caregiver-reported burden is a superior predictor of behavior in children with SDB than PSG-derived variables.

This apparent disconnect between PSG severity and neurobehavioral problems has been described previously in pediatric SDB research [14,28,29]. Some earlier studies suggested a dose-response link between AHI and cognition, but these links have been inconsistent and often weaken after adjusting for demographic and socioeconomic factors [30]. In contrast, caregiver reports of symptoms like snoring, restless sleep, and

Table 1
Demographic Characteristics of the study sample. The study sample included 78 participants. Continuous variables are presented as Mean (95% Confidence Intervals), while. categorical variables are shown as n (%). Sex is biological sex assigned at birth. Race was self-reported and categorized as White, Black, or Other (including Asian and Multiracial). Ethnicity was also self-reported. Body Mass Index (BMI) percentile scores were calculated per the Centers for Disease Control and Prevention BMI-for-age growth charts. The Sleep-Related Breathing Disorder (SRBD) scale from the Pediatric Sleep Questionnaire (PSQ) was categorized into high risk (SRBD ≥0.33) and low risk (SRBD <0.33) for clinically significant sleep-disordered breathing (SDB). The Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2) scores are age-adjusted t-scores, where higher scores indicate greater executive functioning difficulties. BRIEF-2 aggregate subscores are grouped into the Behavioral Regulation, Emotional Regulation, and Cognitive Regulation indices, along with the Global Executive Composite.

Variable	Value
Age in years	7.7 (7.4-8.2)
Sex	
Male	41 (52.6%)
Female	37 (47.4%)
Race	
Black	44 (56.4%)
White	19 (24.4%)
Other	15 (19.2%)
Ethnicity	
Non-Hispanic	59 (75.6%)
Hispanic	19 (24.4%)
Insurance Type	
Public	61 (78.2%)
Private	17 (21.8%)
Mean BMI percentile	82.04 (75.80-88.30)
Primary Caregiver Annual Pre-Tax Income	
< $30,000	25 (33.3%)
$30,000 - $50,000	29 (38.7%)
> $50,000	21 (28.0%)
Pediatric Sleep Questionnaire- SRBD scale	
High SDB Risk (≥0.33)	66 (84.6%)
Low SDB Risk (≤0.33)	12 (15.4%)
BRIEF®2 Mean age adjusted t-scores	
Behavioral Regulation Index	52.49 (49.80-55.20)
Inhibit	53.36 (50.67-56.06)
Self-Monitor	50.18 (47.70-52.60)
Emotional Regulation Index	54.15 (51.40-56.90)
Shift	53.72 (50.85-56.59)
Emotional Control	53.69 (51.00-56.40)
Cognitive Regulation Index	51.54 (49.10-54.00)
Initiate	51.59 (49.10-54.10)
Working Memory	53.85 (51.20-56.50)
Plan/Organize	49.59 (47.30-51.80)
Task Monitoring	50.06 (47.80-52.30)
Organization of Materials	52.06 (49.80-54.40)
Global Executive Composite	53.81 (51.00-56.70)

Table 2
Summary of polysomnographic outcomes in children with sleep disordered breathing. Polysomnographic data was collected for each of the 78 participants. Overnight polysomnography was conducted at an established sleep center and graded based on the American Academy of Sleep Medicine pediatric guidelines. Each participant had a scored report from the sleep laboratory that followed American Academy of Sleep Medicine pediatric scoring criteria. From these reports, seven primary response variables were recorded: (i) Apnea-Hypopnea Index (AHI), (ii) Obstructive Apnea-Hypopnea Index (oAHI), (iii) Rapid Eye Movement (REM) Latency, (iv) Wake After Sleep Onset (WASO), (v) % REM sleep, (vi) Total Sleep Time (TST), (vii) Arousal Index, and (viii) Sleep Efficiency.

PSG Variable	Mean (n = 78)
TST (min)	389.00 (378.89-399.10)
Sleep efficiency (%)	84.03 (82.00-86.05)
REM latency (min)	182.1 (163.13-200.96)
REM %	14.02 (12.15-15.88)
Arousal Index (events/hour)	9.22 (7.63-10.81)
AHI (events/hour)	12.66 (9.27-16.06)
oAHI (events/hour)	11.94 (8.57-15.31)
WASO (min)	36.50 (27.98-45.01)
SpO_2 Nadir (%)	86.58 (84.88-88.28)

daytime inattention are associated with problem behaviors. Smith et al., for example, found that parental reports of habitual snoring were stronger predictors of attention and behavior problems than PSG measures, similar to our findings [31]. This agreement across multiple independent samples increases confidence in the reliability of parent-reported measures as meaningful clinical indicators.

The reasons why PSG variables are weak predictors of neurobehavioral morbidity are multifactorial. First, PSG offers only a single-night snapshot of sleep physiology in a laboratory setting. Children's sleep varies greatly from night to night, and laboratory-based PSG might not reflect typical patterns, especially if anxiety, discomfort, or unfamiliar environments impact sleep quality [32]. Second, traditional PSG indices such as AHI quantify specific respiratory events but may not fully account for the overall physiological burden of ongoing sleep disruption [33]. For example, intermittent hypoxemia might affect neuronal integrity and synaptic plasticity in ways that are not directly related to desaturation frequency or lowest values [4,34,35]. Likewise, arousal indices may not capture more subtle but persistent sleep fragmentation that interferes with PFC-dependent processes [36].

In contrast, parent-reported questionnaires combine observations over multiple nights and settings, capturing both nocturnal symptoms (such as snoring, apneas, and restless sleep) and daytime effects (like sleepiness, hyperactivity, and inattention). These cumulative impressions may better represent the child's actual experience and the lasting impact of SDB on neurobehavioral functioning. From a neurobiological standpoint, impaired PFC function is believed to mediate the relationship between SDB and executive dysfunction [7]. Recent studies using functional neuroimaging have shown decreased PFC activity in children with SDB, which correlates with parent-reported behaviors [19,37]. This indicates that caregiver reports might serve as indirect indicators of underlying cortical dysfunction that PSG measures cannot fully capture.

The practical implications of these findings are significant. Despite being considered the gold standard, PSG is expensive, resource-intensive, and often inaccessible. Fewer than 10% of children undergoing AT in the United States undergo preoperative PSG [38]. Access is further limited in underserved communities and low-resource settings, where pediatric sleep laboratories and certified sleep specialists are scarce [39]. By contrast, validated questionnaires such as the OSA-18 and PSQ-SRBD are inexpensive, non-invasive, and scalable. Our data suggest that these instruments can provide meaningful insights into which children are at risk of neurobehavioral morbidity and may thus be prioritized for intervention.

Incorporating standardized symptom questionnaires into surgical candidacy assessments could reduce reliance on PSG, streamline referrals, and promote more equitable care. Moreover, symptom-driven approaches may help reduce unwarranted practice variation, whereby children in regions with limited PSG access are either denied surgery or undergo surgery based on subjective impressions alone. Codifying the use of validated instruments, especially when PSG is not readily available, could help otolaryngologists standardize care and allocate resources to those most likely to benefit.

Another important implication is the alignment of outcome measures with patient-centered concerns. Families are most often motivated to seek treatment not because of PSG-based parameters, but because of the impact of SDB on daytime behavior, school performance, and quality of life. By centering decision-making on validated assessments of these domains, clinicians may better meet family expectations and optimize shared decision-making.

Traditional models of SDB morbidity have emphasized hypoxemia and sleep fragmentation as primary drivers of cognitive and behavioral deficits. Our findings suggest that while these physiological disruptions are necessary for diagnosis, they may not be sufficient markers of

downstream dysfunction. A refined conceptual model may posit that PSG indices capture the *proximal* physiology of airway obstruction, whereas parent-reported symptoms reflect the *distal* neurobehavioral consequences mediated by PFC vulnerability. This layered model reconciles the discrepancy between PSG severity and behavior: a child with modest AHI may still experience substantial neurobehavioral impairment if chronic sleep disruption disproportionately affects cortical maturation, while another child with higher AHI but preserved sleep quality may exhibit fewer daytime symptoms.

Several limitations deserve discussion. First, our sample size, although sufficient for correlation analyses, restricts the ability to detect more subtle associations between PSG variables and executive function. Larger cohorts or more detailed PSG metrics (such as respiratory event duration, arousal subtypes, or spectral EEG measures) might reveal connections not seen here. Second, despite using rigorous statistical methods, the cross-sectional design prevents us from making causal conclusions. Longitudinal studies are necessary to determine if improvements in parent-reported symptoms after adenotonsillectomy or other treatments lead to measurable gains in executive function. Third, parent-reported questionnaires, while ecologically valid, are vulnerable to bias, including expectancy effects and different thresholds of concern. In our study, the correlation between parent-reported outcomes and objective GNG performance was modest, emphasizing the need for multi-modal assessment.

Future work should focus on developing predictive models that combine the strengths of multiple modalities. For example, integrating validated questionnaires with digital home-based sleep monitoring methods such as actigraphy, wearable oximetry, or acoustic sensors may produce richer longitudinal datasets at a lower cost than PSG. Neuroimaging techniques can offer mechanistic insights into cortical function and development, potentially acting as intermediate biomarkers that connect SDB severity to executive function outcomes. Advances in machine learning could facilitate the combination of diverse data streams such as clinical, behavioral, physiological, and imaging, into comprehensive risk scores that more precisely identify children at risk for ongoing health issues [40]. Additionally, treatment stratification should consider sociodemographic factors, since evidence shows that race, socioeconomic status, and access to healthcare influence both the prevalence of SDB and its impacts. In our cohort, most participants came from socioeconomically disadvantaged backgrounds, highlighting the need for predictive tools that are equitable, scalable, and practical across diverse populations.

5. Conclusions

In summary, parent-reported questionnaires, rather than PSG-based indices, show stronger correlation with executive dysfunction in children referred for SDB treatment. These findings align with previous large-scale studies showing that behavioral improvements after adenotonsillectomy are driven by symptom reduction rather than polysomnographic resolution. Clinically, these results encourage wider use of validated questionnaires to guide surgical decisions, especially when PSG is not readily available. Future research should focus on multimodal, long-term studies to improve predictive models and better outcomes for children with SDB.

CRediT authorship contribution statement

Sabrina Nusraty: Writing – original draft, Validation, Methodology, Investigation, Data curation. **Nithya Navarathna:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Sergio Novi:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation. **Heather Bortfeld:** Writing – review & editing, Validation, Methodology, Conceptualization. **Ron B. Mitchell:** Validation, Resources, Project administration, Methodology. **Amal Isaiah:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization.

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Declaration of competing interest

Amal Isaiah receives patent-related royalties from University of Maryland for inventions related sleep apnea diagnostics. These technologies are not described in the manuscript. All other authors have no conflicts of interest.

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