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Parent-Reported Symptoms of Sleep-Disordered Breathing Are Associated With Increased Behavioral Problems at 2 Years of Age: The Canadian Healthy Infant Longitudinal Development Birth Cohort Study FREE

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Abstract

Study Objectives

To examine the association between the age of onset and duration of parent-reported symptoms of sleep-disordered breathing (SDB) and behavioral problems at age 2.

Methods

Parent-reported SDB symptoms were assessed quarterly between 3 months and 2 years among 583 Canadian Healthy Infant Longitudinal Development Edmonton-site participants. Parent-reported SDB symptoms were clustered into phenotypes using group-based trajectory analysis based on age of onset and duration of symptoms. Home-based polysomnography (PSG) was completed at 1 year. The Child Behavior Checklist preschool-version (Mean *T*-score 50, standard deviation 10 points) assessed total, externalizing (attention), and internalizing (anxiety, depression) behaviors at 2 years.

Results

Four phenotypes were identified: no SDB (64.7%), early-onset SDB (15.7%, peak symptoms at 9 months), late-onset (14.2%, peak symptoms at 18 months), and persistent SDB symptoms (5.3%, peak symptoms from 3 through 24 months). Persistent SDB (9.5 points, 95% CI 1.7, 17.2; $p = .02$) predicted the greatest magnitude of effect of total behavior problems, compared with children without SDB. Children with early-onset SDB (3.5 points, 95% CI 1.6, 5.4; $p \leq .001$) and late-onset SDB (6.1 points 95% CI 4.0, 8.3; $p \leq .001$) had increased total behavioral problems than children without SDB to 2 years. Additional analyses showed that the SDB phenotypes' trajectories were important for internalizing but not for externalizing behavior problems. There were no significant associations between home-PSG and parent-reported behavior problems.

Conclusions

Findings suggest that the age of onset and duration of parent-reported SDB symptoms prior to age 2 have adverse consequences for overall behavior problems.

sleep-disordered breathing, sleep apnea, behavior, infants, epidemiology, population-based birth cohort

Statement of Significance

Sleep-disordered breathing (SDB) has adverse effects on behavior among school-aged children. It is unknown whether the age of onset and duration of SDB symptoms affect behavior in young children. Previous studies have generally assessed SDB symptoms annually using parent-reported measurements. We examined associations between SDB phenotypes assessed as a trajectory of symptoms from 3 to 24 months using parent-reported 22-item sleep-related breathing disorder scale. Home polysomnography was also completed at 12 months. We found that age of onset and duration of parent-reported SDB symptoms adversely affect behavioral development by 2 years of age. Our study supports early screening and intervention among young children with SDB to treat current behavioral problems and prevent behavioral morbidity in later childhood.

INTRODUCTION

Sleep-disordered breathing (SDB), from habitual snoring to obstructive sleep apnea, affects up to 10% of children with a peak prevalence between 2 and 8 years of age.[1–3] Neurobehavioral sequelae associated with SDB in school-aged children include poor learning, adverse executive functioning, and externalizing behavior problems such as attention deficit or hyperactivity disorder (ADHD) symptoms.[4,5] Less is known about the development of internalizing behavior problems such as anxiety and depression among children with SDB. The negative consequences of SDB may be irreversible; tonsil and adenoidectomy (T&A) for SDB in school-aged children produced no significant change on executive function[6,7] and only temporarily improved behavior.[8,9] T&A in preschool children has had more success, although results are mixed.[10–18] Determining the relationship between preschool SDB and subsequent neurobehavioral function has important implications for screening children and triaging limited pediatric surgical resources.

The spectrum of SDB during childhood may encompass overlapping phenotypes associated with a child's facial morphology, tonsil and adenoid growth, body habitus, and rhinitis symptoms.[19] The different SDB phenotypes, distinguished by age of onset and duration of symptoms, may be associated with different neurobehavioral consequences. The UK Avon Longitudinal Study of Parents and Children (ALSPAC) birth cohort showed that SDB prior to age 2 predicts ADHD symptoms at 7 years even after the resolution of SDB symptoms.[20] However, the ALSPAC cohort cannot determine preschool SDB phenotypes as they assessed SDB annually, did not use validated SDB questionnaires, and did not use objective measures of sleep or SDB.

We present findings from a subcohort within the Canadian Healthy Infant Longitudinal Development (CHILD) study[21] in which we explored whether the age of onset and duration of parent-reported SDB (SDB phenotypes) were associated with behavioral problems at age 2. We also examined whether current parent-reported symptoms of SDB at age 2 were associated with increased behavioral problems. We hypothesized that children with earlier onset SDB would show increased behavioral problems compared with children without SDB.

METHODS

Study Population

CHILD is a multi-center population-based longitudinal birth cohort study initially designed to examine gene-environment influences on the development of atopy and asthma. CHILD families in Edmonton participated in a substudy examining the longitudinal relationship between sleep and neurodevelopment.[21,22] Pregnant mothers aged ≥18 were recruited in the second or third trimester, and children were seen at delivery, 3 months of age, and then annually. Parents completed questionnaires about family and child characteristics (i.e., socioeconomic status (SES), ethnicity, and child gender), maternal and infant nutrition, and maternal stress at recruitment and then regularly throughout the larger CHILD study. In addition, CHILD Edmonton families also completed questionnaires about their child's sleep and participated in a home-polysomnography (PSG) sleep study. CHILD Edmonton families also completed neurodevelopmental assessments and parent-reported behavioral questionnaires during 12-month and 24-month clinic visits. Informed consent was obtained from all mothers and consenting fathers. CHILD study ethics approval was obtained from the University of Alberta Health Ethics Research Office (Pro00002099).

Study Variables

SDB (Primary Exposure Variable)

SDB was assessed quarterly from 3 months by parent-report using the 22-item sleep-related breathing disorder (SRBD) scale,[23] based on the pediatric sleep questionnaire (PSQ). The SRBD scale[23] uses 22 yes or no items, which includes snoring, excessive daytime sleepiness, and ADHD symptoms.[24] The SRBD ratio was determined by dividing the sum of all "yes" responses by the total number of nonmissing items (yes or no). At each quarter, children were classified as having SDB if they had a SRBD ratio ≥ 0.33. SDB was objectively assessed for one night at the 1-year study visit (mean age of 13.2 months (95% CI: 9.5, 22.2) using portable level three home PSG (NOX-T3 portable sleep monitor). Home PSG was not undertaken at any other time point. The NOX-T3 PSG recorded pulse oximetry, real-time audio, and chest/abdominal respiratory inductance plethysmography.[25] NOX-T3 scoring was completed by sleep strategies using a scoring rubric based on the American Academy of Sleep Medicine (AASM) paediatric scoring guidelines[26] modified to reflect the channels available. Measures of apneas, hypopneas, apnea–hypopnea index (AHI), sleep duration, and total time in bed were obtained from the PSG.

Behavior Problems

Parents completed the Child Behavior Checklist (CBCL) 1½–5 preschool version[27] at 2 years. The CBCL is a standardized measure of childhood mental health and has good internal reliability and validity in a number of population settings.[28,29] The CBCL yields a *T*-score (adjusted for age) for total problems, internalizing problems, and externalizing problems composite scales.[27,29] The total behavior problems *T*-score (primary outcome) is the sum of internalizing and externalizing composite scales, the sleep issues scale, perceived stress scale, and other problems not classified under the prior groups. The externalizing behavior problems *T*-score (secondary outcome) is the sum of inattention and aggressiveness subscales. The internalizing behaviors problems *T*-score incorporates the withdrawal, somatic, and anxious or depressed subscales. The CBCL normative mean is 50 and higher scores indicate increased behavior problems. *T*-scores of >65 suggest clinical behavioral problems. As recommended by the CBCL manual, 10 points (1 standard deviation) change in a T-score greater than the normative mean of 50 is indicative of problematic behaviors in comparison to a nonclinical sample.[27]

Covariates

Covariates associated with SDB or childhood behavior were assessed longitudinally (see Supplementary Methods section for a more complete treatment of the covariates assessed).

Sleep Times and Duration

Sleep duration and sleep times were determined using the parent-reported Brief Infant Sleep Questionnaire[30] (BISQ) administered quarterly from 3 months of age. Total sleep time was the sum of daytime and nighttime sleep (hours and minutes). Trajectory patterns of sleep duration throughout the first 2 years of life are described in Supplementary Figures S2 and S3. Sleep duration was objectively assessed at 12 months of age by PSG.

Social–Emotional Development and Language

Social–emotional (caregiver questionnaire) and language development (objectively evaluated by trained research assistants) were assessed using the Bayley Scale of Infant Development Third Edition (BSID-III)[31] at the age of 12 and 24 months. The BSID-III composite score (mean 100, $SD = 15$) for the social–emotional development scale and the language scale was included as potential confounders.

Statistical Analysis

We used STATA Traj[32,33] (December 2016 Version), to identify and assign SDB phenotypes to each child based on age of onset and duration of parent-reported SDB symptoms between 3 and 24 months, consistent with prior research.[34–37] We describe the SDB trajectories in detail separately.[38] A similar analysis was completed to determine sleep duration trajectories based on the BISQ.[39] Analyses of the behavior data were conducted using the CBCL total behavior problem, externalizing behavior problems, and internalizing behavior problem composite scales. The CBCL total behavior problem *T*-score was rescored to exclude the sleep problem questions to avoid misinterpretation of the study findings. Univariate regression analysis was used to independently examine the association among SDB, sleep duration, environmental, and child and family characteristics associated with total behavior problems (primary outcome), externalizing behavior (secondary outcome), and internalizing behavior (secondary outcome) *T*-scores (continuous) at 2 years of age.

Separate multivariate regression analyses were used to model the relationship between total behavioral problems: (1) current parent-reported SDB symptoms at age 2 (SDB as a dichotomous predictor) and (2) SDB phenotypes based on parent-report up to 2 years using trajectory analysis while controlling for sleep duration and other factors previously associated with SDB or behavior. Multivariate analyses included an adjustment for reported versus actual sleep duration using the ratio of 12 months parent-reported nighttime sleep duration to nighttime sleep duration measured at 12 months of age by home PSG. Results for both models (current SDB and SDB phenotypes) are presented with lower Bayesian Information Criteria (BIC) indicating better model fit. Data were analyzed using Stata 14 (STATA Corp.).

RESULTS

Of the 822 CHILD Edmonton participants originally consented, 712 (87%) were still enrolled at 2 years of age, of whom 583 (81%; Table 1) had CBCL data at 24 months. Those with CBCL data had higher family income, less divorce or separation, were more often Caucasian, and somewhat older mothers (see Table 1). There were no significant differences between participants with and without CBCL data in the proportion of children with parent-reported SDB at 2 years of age (6.8% vs. 7.4%; $p \geq .05$) or parent-reported sleep duration time at age 2 (mean 12.6 hours; 95% CI 12.2, 12.9 vs. 12.6 hours; 95% CI 12.5, 12.7, $p > .05$). Among our sample of children with behavior data, only one participant was missing sleep data.

Table 1

Demographic Characteristics for Children With and Without CBCL Data at Age 2.

Categorical	Data absent % (behavior/total)	Data present % (behavior/total)	*p*
Male	50.7% (117/231)	50.9% (297/583)	.97
Child ethnicity: Caucasian	52.4% (121/231)	69.5% (405/583)	.01
Birth order: Second born	54.1% (125/231)	56.4% (329/583)	.64
Late preterm: born between 34–37 weeks	4.4% (10/228)	5.5% (32/583)	.52
Higher income > $60,000	54.0% (138/231)	86.3% (503/583)	<.001
Marital divorce or separation	9.5% (22/231)	5.3% (31/583)	.02
Attend daycare at age 2: yes[a]	57.1% (32/56)	50.9% (262/515)	.37
Current SDB symptoms at age 2[a]	7.4% (4/54)	6.8% (35/512)	.88
Continuous	Data absent *mean* (95% CI)	Data present mean (95% CI)	
Maternal age at time of child's birth	29.9 (29.3, 30.6)	31.8 (31.5, 32.1)	<.001
Maternal depression at 1 year	8.9 (7.0, 10.8)	7.6 (7.0, 8.3)	.14
BIDS-III social–emotional development at age 1	10.7 (10.2, 11.1)	10.5 (10.3, 10.8)	.65
BISQ parent-reported total sleep duration at age 2 in hours	12.6 (12.2, 12.9)	12.6 (12.5, 12.7)	.81

BIDS-III = Bayley Infant Development Scale—Third Edition; BISQ = Brief Infant Sleep Questionnaire; SDB = Sleep-disordered breathing—parent-reported symptoms.

[a]Data on daycare attendance at age 2 were missing for 175 at age 2, and current SDB symptoms, reported on the Pediatric Sleep Questionnaire at age 2, were missing for 177 participants.

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Severe behavioral problems (mean CBCL total behavior *T*-score above 65) were present in 44 of 583 children (7.5%) with 38 children (6.5%) having significant externalizing concerns (*T*-score above the clinical cutoff of 65) and 31 children (5.3%) having a CBCL internalizing *T*-score above the

clinical cutoff of 65. Boys exhibited significantly higher CBCL externalizing behavior *T*-scores (mean = 46.9, *SD* = 9.54) than girls (mean = 44.96, *SD* = 9.04, $p \leq .01$). There was no difference by gender for internalizing problems.

SDB Trajectories

We describe the results for the development of the SDB trajectories groups in detail elsewhere.[38] Trajectory analysis yielded four independent phenotypes with participants assigned to only one group (Supplementary Figure S1). Children with no SDB (64.7%) had a mean SRBD ratio of 0.10 (*SD* = 0) at 12 months and 0.14 (*SD* = 0.11) at 24 months. Children identified as developing SDB included three phenotypic groups: early-onset SDB symptom (15.7%), with a peak of SDB symptoms at 9 months (mean SRBD = 0.29, *SD* 0.12), late-onset SDB symptoms (14.2%) with a peak of SDB symptoms at 18 months (mean SRBD = 0.34, *SD* 0.09), and persistent SDB (5.3%) with peak symptoms from 3 months of age (mean SRBD = 0.32, *SD* 0.16) through 24 months of age with a mean SRBD of 0.43 (*SD* 0.14). Children classed in the early-onset SDB group had a positive SRBD ratio at one time point from 3 months to 24 months.

Univariate Results

Children with current parent-reported SDB symptoms and children in each of the three SDB phenotypes, derived from parent-report, showed increased behavioral morbidity compared with children with no SDB symptoms (refer to Supplementary Table S4). Home-PSG derived measures of AHI, desaturation index, and sleep efficiency, assessed approximately 1 year of age, were not significantly associated with increased behavioral problems (refer to Supplementary Table S3).

Multivariate Results

Based on our univariate results, we examined the influence of parent-reported symptoms of SDB on behavioral morbidity in adjusted multivariate analysis.

CBCL Primary Outcome Variable

Total Behavior Problems Composite *T*-Score

Two multivariate analyses were conducted using current SDB symptoms at age 2 (Table 2; model 1) and SDB phenotypes identified using trajectory analysis (model 2) as predictors of total behavioral morbidity. The lower BIC for model 2 (BIC = 4153.2 vs. 4172.6) suggests that the duration and pattern of SDB phenotypes had a greater explanatory impact on total behavior problems at age 2 than analyzing for current SDB symptoms alone.

Table 2

Multivariate Analysis Examining Associations Between Parent-Reported Symptoms of SDB and Total Behavior Problems at Age 2 (*n* = 582).

		Model 1: Current SDB BIC: 4172.6		Model 2: SDB Phenotypes BIC: 4153.2	
	Factor	Coefficient 95% CI	*p*	Coefficient 95% CI	*p*
	SDB symptoms at age 2: yes	6.2 (4.1, 8.2)	<.001	—	—
SDB symptoms	Late onset	—	—	6.1 (4.0, 8.3)	<.001
	Early onset	—	—	3.5 (1.6, 5.4)	<.001
	Persistent	—	—	9.5 (1.7, 17.2)	.02
Total sleep duration	Short sleepers	2.0 (0.1, 3.9)	.04	2.3 (0.4, 4.1)	.02
	Decline to short sleep	0.1 (−1.7, 1.9)	.92	0.2 (−1.6, 2.0)	.80
	Long sleepers	−1.2 (−2.9, 0.5)	.16	−0.7 (−2.4, 0.9)	.40
	Gestational age at delivery	−0.5 (−1.0, 0.9×10^{-2})	.06	−0.5 (−0.9, 0.2×10^{-1})	.07
	Maternal nutritional status during pregnancy using the HEI-2010	−0.1 (−0.2, 0.4×10^{-1})	<.001	−0.1 (−0.2, −0.1)	<.001
	Gestational age at time of food frequency questionnaire completion	0.1 (0.1×10^{-1}, 0.2)	.03	—	—
	Household smoke at 1 year: yes	2.2 (0.2 4.3)	.03	2.3 (0.3, 4.4)	.02
	BSID-III social emotional development at age 1 year	-0.1×10^{-1} (−0.1, 0.2)	<.001	−0.1 (−0.1, -0.3×10^{-1})	<.001
	Parenting stress at 2 years using the PSI-SF Scale	0.2 (0.1, 0.3)	<.001	0.2 (0.1, 0.3)	<.001
	BSID-III language at age 2	−0.1 (−0.2, −0.1)	<.001	−0.1 (−0.2, −0.1)	<.001
	Maternal body mass index at 1 year	0.1 (0.1, 0.3×10^{-1})	.03	—	—
	Constant	73.6 (43.6, 103.5)	<.001	84.0 (59.9, 108.2)	<.001

BSID-III = Bayley Scale of Infant Development Third Edition, lower scaled score represents delayed development; HEI-2010 = Healthy Eating Index 2010, higher score represents better diet quality; PSI-SF = Parenting Stress Index–Self-Report, higher score presents increased levels of parenting stress; SDB = sleep-disordered breathing.

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Children with persistent SDB had a 9.5-point increase in CBCL total behavior *T*-score (95% CI 1.7, 17.2, $p < .05$; Table 2, model 2), compared with children without SDB symptoms. The influence of persistent SDB symptoms on total behavioral scores indicates a clinically significant change in behavior problems (clinical cut-point defined as a 10-point change [one standard deviation][27]). Although children with late-onset SDB had a 6.1-point increase (95% CI 4.0, 8.3, $p \leq .001$), those with early-onset SDB had a 3.5-point increase (95% CI 1.6, 5.4, $p \leq .001$), compared with children without SDB. Each of the three SDB groups was still significantly associated ($p < .05$) with increased total behavioral morbidity in a sensitivity analysis when both SDB phenotypes and current SDB at age 2 were included in the same regression (see Supplementary Table S1 for details). The impact of SDB phenotypes remained significant even after adjusting for sleep duration trajectories, maternal stress at 24 months, social–emotional difficulties at age 12 months, and language difficulties at age 24 months.

Short total sleep duration trajectories were significantly associated with increased total behavioral problems, with a 2.3-point increase in CBCL total behavior *T*-score (95% CI 0.4, 4.1, $p = .02$) compared with intermediate sleepers (reference). Decline to short sleepers (0.2 points, 95% CI −1.6, 2.0,

$p > .05$) and long sleepers (−0.7 points, 95% CI −2.4, 0.9, $p > .05$) showed no significant effect on their CBCL total behavior *T*-score compared with intermediate sleepers.

CBCL Secondary Outcome Variables

Externalizing Behavior Problems Composite *T*-Score

The lower BIC for the current SDB model suggests that having current symptoms at age 2 had slightly greater explanatory capacity for externalizing behavior problems by age 2 than the trajectory of SDB phenotypes based on age of onset and duration of SDB symptoms (BIC = 4199.6 vs 4204.3). Children with current SDB symptoms at 2 years had a 5.8-point increase in externalizing behavior *T*-score (95% CI 3.7, 8.0, $p \leq 0.001$; Table 3, model 1) compared with children without current SDB symptoms at that age. The magnitude of effect of current SDB at 2 years on externalizing behavior was greater than all other significant factors in multivariate analysis. Only daytime sleep duration trajectories were significantly associated with increased externalizing behavior problems (Table 3).

Table 3

Multivariate Analysis Examining Associations Between Parent-Reported Symptoms of SDB and Externalizing Behavior Problems at Age 2 (n = 582).

		Model 1: Current SDB BIC: 4199.6		Model 2: SDB phenotypes BIC: 4204.3	
	Factor	**Coefficient 95% CI**	***p***	**Coefficient 95% CI**	***p***
	SDB symptoms at age 2: yes	5.8 (3.7, 8.0)	<.001	—	—
SDB symptoms	Late onset	—	—	5.6 (3.3, 7.8)	<.001
	Early onset	—	—	2.8 (0.8, 4.8)	.01
	Persistent	—	—	5.8 (−2.4, 14.0)	.16
Daytime sleep Duration	Intermediate sleepers	−2.1 (−3.9, −0.2)	.03	−2.0 (−3.9, −0.1)	.04
	Short sleepers	−1.3 (−3.0, 0.4)	.13	−1.1 (−2.8, 0.6)	.19
	Decrease to intermediate	−1.8 (−4.1, 0.5)	.12	−1.7 (−4.0, 0.6)	.15
	HEI-2010 during pregnancy	-0.1 (-0.2, 0.0×10^{-2})	.03	-0.1 (-0.2, -0.1×10^{-1})	.03
	Household smoke at 3 months: yes	2.0 (0.1×10^{-2}, 4.0)	.05	2.0×10^{-1} (0.3, 4.0)	.05
	BSID-III language at age 2	-0.1 (-0.2, 0.4×10^{-1})	<.001	-0.1 (-0.2, 0.3×10^{-1})	<.001
	Maternal depression during pregnancy using the CES-D scale: yes	0.2 (0.1, 0.3)	<.001	0.2 (0.1, 0.3×10^{-1})	<.001
	Parent-child interaction at 2 years using the P-CDI scale	0.6 (0.4, 0.8)	<.001	0.6 (0.4, 0.8)	<.001
	Constant	49.0 (36.1, 61.8)	<.001	48.2 (36.8, 59.7)	<.001

BSID-III = Bayley Scale of Infant Development Third Edition, lower scaled score represents delayed development; CES-D = Centre for Epidemiological Studies-Depression, higher scores represent increased maternal symptoms of depression; P-CDI = Parent–Child Dysfunction Index, higher scores reflect increased perceived difficulties; SDB = sleep-disordered breathing.

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Internalizing Behavior Problems Composite *T*-Score

In contrast to externalizing behavior, SDB phenotypes had greater explanatory capacity for internalizing behavioral problems than current SDB symptoms alone (BIC = 4192.9 vs 4206.4) (Table 4). Children with early-onset SDB had a 3.8-point increase (95% CI 1.9, 5.8, $p \leq .001$), whereas those with late-onset SDB symptoms had a 3.5-point increase (95% CI 1.3, 5.7, $p \leq .001$), compared with children with no SDB symptoms. In a sensitivity analysis, only the early SDB trajectory group remained a significant predictor of internalizing morbidity at age 2 ($p < .001$) after controlling for current SDB symptoms) (see Supplementary Table S2 for details).

Table 4

Multivariate Analysis Examining Associations Between Parent-Reported Symptoms of SDB and Internalizing Behavior Problems at Age 2 (n = 582).

		Model 1: Current SDB BIC: 4206.4		Model 2: SDB phenotypes BIC: 4192.9	
	Factor	**Coefficient 95% CI**	***p***	**Coefficient 95% CI**	***p***
	SDB symptoms at age 2 years: Yes	2.4 (0.2, 4.6)	.03	—	—
SDB symptoms	Late onset	—	—	3.5 (1.3, 5.7)	<.001
	Early onset	—	—	3.8 (1.9, 5.8)	<.001
	Persistent	—	—	7.8 (−0.3, 15.8)	.06
Total sleep duration	Short sleepers	2.9 (1.0, 4.9)	<.001	2.9 (1.0, 4.8)	<.001
	Decline to short sleepers	0.7 (−1.1, 2.6)	.45	0.8 (−1.1, 2.6)	.41
	Long sleepers	0.3 (−1.4, 2.0)	.72	0.5 (−1.2, 2.2)	.53
	T3 sleep efficiency at age 1	0.1 (-0.1×10^{-1}, 0.3)	.07	0.1 (0.8×10^{-3}, 0.3)	.05
	Maternal nutritional status during pregnancy using the HEI-2010	−0.1 (−0.2, 0.8×10^{-3})	.05	−0.1 (−0.2, 0.3×10^{-2})	.04
	Household smoke at 1 year: yes	2.9 (0.8, 5.0)	.01	2.8 (0.7, 4.8)	.01
	BSID-III social–emotional development at age 1	−0.1 (−0.1, 0.1×10^{-1})	.05	−0.1 (−0.1, -0.2×10^{-1})	.01
	BSID-III language at age 2	−0.1 (−0.2, −0.1)	<.001	−0.1 (−0.2, −0.1)	<.001
	Maternal depression at age 1 using the CES-D scale	0.1 (0.3×10^{-1}, 0.3)	.01	0.1 (0.3×10^{-1}, 0.2)	.01
	Parent-child interaction at age 2 using the P-CDI scale	0.7 (0.5, 0.8)	<.001	0.6 (0.5, 0.8)	<.001
	Constant	48.1 (29.5, 66.6)	<.001	49.5 (32.0, 67.0)	<.001

BSID-III = Bayley Scale of Infant Development Third Edition, lower scaled score represents delayed development; CES-D = Centre for Epidemiological Studies-Depression, higher scores represent increased maternal symptoms of depression; HEI-2010 = Healthy Eating Index 2010, higher score represents better diet quality; P-CDI = Parent–Child Dysfunction Index, higher scores reflect increased perceived difficulties; SDB = sleep-disordered breathing.

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Short sleep duration trajectories were significantly associated with worse internalizing behavioral problems (2.9 points; 95% CI 1.0, 4.8, $p \leq .001$). Maternal depression, parenting dysfunction, social–emotional difficulties, and language difficulties at age 24 months had significant but minimal effects on increased internalizing behavior problems at 2 years of age in adjusted analysis (Table 4).

DISCUSSION

This analysis of data from a population-based birth cohort study showed that parent-reported SDB symptoms during the first 2 years of life are associated with overall increased behavior problems at 2 years of age. Specifically, we identified that children with current SDB symptoms exhibited greater externalizing behavior problems such as inattention by age 2. In contrast, using a trajectory analysis to identify SDB phenotypes, we showed differing impacts of early-onset, late-onset, and persistent SDB symptoms on increased internalizing behavior problems such as anxiety and depression by 2 years of age. The effects of parent-reported SDB on behavior exceeded those of any other potential covariates controlled for in our study, including sleep duration, maternal stress, maternal nutrition during pregnancy, and family SES. Similar to previous reports in younger children,[40] we found that adverse behavioral outcomes related more to parent-reported SDB symptoms than PSG derived parameters.

The finding that the onset and duration of parent-reported SDB symptoms, during an early critical period in development, affect early childhood total behavioral problems helps clarify the findings of previous studies. Our data suggest that children with persistent SDB to age 2 are at risk for developing clinically relevant behavior problems (10-point increase or one standard deviation change in score). Prior reports of SDB effects on early childhood behavior have generally been from cross-sectional studies or referred clinical samples with limited control for potential confounders.[40–42] In their population-based cross-sectional survey of a birth cohort, Gottlieb et al.[43] found increased behavior problems among preschool children with SDB compared with children without SDB even after adjusting for social factors. In contrast, a separate cross-sectional study[44] did not show increased behavior problems among preschoolers aged 3 to 4 years with current symptoms of snoring. However, ours is the first study to examine associations between both current SDB and trajectories of SDB symptoms determined using a gold standard parent measure, an objective assessment of SDB using PSG, and behavior problems in young children.

Our study further identified differences in the effects of SDB upon externalizing (e.g., ADHD symptoms) and internalizing behavior problems (e.g., anxiety or depression). Consistent with prior work, we found that current SDB symptoms at age 2 are associated with increased externalizing behavior problems. The ALSPAC study[20] found that children with either "early" SDB (SDB symptoms prior 18 months that then abated) or children with persistent SDB (symptoms that peak at 30 months and persist) both predicted ADHD symptoms at ages 4 to 7. In this cohort, our data suggest that children with SDB symptoms that peak at age 2 may be at risk for externalizing behavioral morbidity beginning in early childhood.

Increased internalizing behavior problems have been reported from clinical pediatric SDB cases.[40,45,46] We found that the SDB phenotypes (early- and late-onset) were significantly associated with increased internalizing behavior problems in adjusted analysis. Our findings suggest that the age of onset and duration of SDB symptoms are important determinants of internalizing behaviors. The ALSPAC study[20] only found that children with "later" SDB symptoms (symptoms that peak at 57 months) had the strongest effect on increased emotional difficulties at ages 4 to 7. In contrast to ALSPAC, we identified a third group of children with SDB (i.e., persistent SDB symptoms) and showed differential effects on behavior for all three SDB groups.

This is the first population-based study to examine associations between SDB and behavior in the first 2 years of life. There are several strengths associated with this present study including large sample size and repeated longitudinal data. Prior studies have lacked objective measures of sleep using PSG, sufficient frequency of data to examine associations between SDB phenotypes and behavior,[47–49] and measures of sleep duration. We examined the influence of SDB symptoms on behavior while controlling for several potential family and child, maternal, and environmental covariates previously shown to be associated with sleep or behavior. This included controlling for social–emotional difficulties identified at age 12 months and language difficulties at 24 months assessed using a standardized tool. Finally, behavioral problems identified in our unselected population-based sample are unlikely to reflect a referral bias and thereby strengthen the evidence from studies reporting on SDB adverse effects on behavior.

We are unable to determine whether sleep problems precede internalizing behavior problems.[50,51] Although we objectively assessed sleep duration using home-PSG, we acknowledge that assessing sleep time via a single night of PSG may not be representative of the child's actual sleep duration. Although we included a ratio of parent-reported to PSG-assessed sleep duration in the analysis, the majority of sleep assessments were measured using a validated parent-report which may underestimate sleep duration and over-report sleep problems in young children.[52] The child's environment and behavior were assessed by parent-report, which may be biased for social-desirability. Our study is unlikely to be sufficiently powered to investigate the effect of persistent SDB symptoms on behavior. Also, we only found small statistical differences between the effects of current SDB symptoms and age and duration of SDB symptoms, hence stressing the importance of current SDB symptoms on behavioral morbidity. However,

early-onset SDB and late-onset SDB groups were still significantly associated with increased behavioral morbidity in a sensitivity analysis when both SDB phenotypes and current SDB were included in the same regression. Our results may not be generalizable to the entire pediatric population as most of our sample had higher income, higher education, and Caucasian background. As a result, our findings need to be replicated in other populations.

Younger children with SDB may be at increased risk for long-term behavioral morbidity. Future research will examine trajectories of parent-reported SDB symptoms to determine their impact on long-term behavior. Future studies may also examine the role of genetics, physiological responses, cerebral insult, and craniofacial anatomy on the association between SDB phenotypes and associated neurobehavioral consequences. Surgery (T&A) may not reliably eliminate the associated behavior problems. The findings support the need for intervention studies to determine whether targeted early intervention of SDB among young children can help remediate early behavior problems.

CONCLUSION

SDB during the first two years of life is associated with detrimental effects on behavioral development in young children. Consistent with prior studies, current parent-reported SDB symptoms are strongly associated with increased externalizing behavior problems including ADHD like symptoms. Our findings extend these conclusions to younger children. Furthermore, we provide the first evidence to show that the age of onset or duration of parent-reported SDB symptoms may influence later internalizing behavioral deficits even after controlling for maternal and environmental factors. These findings highlight the need to screen young children with behavioral problems for potentially reversible sleep problems, such as SDB, to reduce later mental health problems.

Supplementary Material

Supplementary material is available at *SLEEP* online.

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Author Contributions

P.M. conceived the study, obtained funding for the study, and helped with statistical analysis and manuscript development. S.T. drafted the first version of the manuscript, completed the statistical analysis, and drafted the final version of the manuscript. L.S. helped draft the manuscript and contributed to statistical analysis. A.L. helped with data collection and statistical analysis. J.M. helped with designing and executing the CHILD neurodevelopmental testing and data collection. J.P. and R.Y. helped with designing and executing the CHILD neurodevelopmental testing. J.C. and D.L. helped with data collection and drafting the manuscript. M.R.S., A.B.B., P.S., and, S.E.T. helped obtain funding, advised on the CHILD study design, and participated in data collection. All authors provided critical comments on the manuscript content and approved the final version of the manuscript.

Work Performed

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Disclosure Statement

None declared.

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Author notes

A complete list of active investigators in the CHILD study is provided in Supplementary Material.

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