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Socioecological factors linked to co-occurring early childhood sleep health disparities and developmental outcomes: protocol for the sleep in preschoolers cross-sectional study

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ABSTRACT

Introduction Sleep deficiencies, such as sleep disordered breathing (SDB) and insufficient sleep, are linked to adverse health outcomes. These sleep deficiencies are more common in racial and ethnic minoritised children and have significant negative impacts on neurobehavioural and social-emotional development. Non-Latine Black/African American children are 4–6 times more likely than non-Latine White children to experience both SDB and short sleep duration. Although SDB and insufficient sleep often co-occur in young children, there is a paucity of research considering the potential unique and additive impacts of SDB and insufficient sleep on child outcomes, as well as racial disparities in these outcomes, thus hindering comprehensive interventions. Our study objectives are to (1) examine racial disparities in the neurobehavioural and social-emotional impacts of early childhood SDB and/or insufficient sleep and (2) identify proximal and distal socioecological factors linked to these sleep disparities and outcomes.

Methods and analysis A cross-sectional observational study comparing neurobehavioural (executive functioning, attention, vigilance) and social-emotional functioning (social skills, emotion regulation) in 400 dyads consisting of caregivers and their otherwise healthy Black and White 3–5 year-old children and divided into four groups: (A) preschoolers with SDB; (B) preschoolers with insufficient sleep; (C) preschoolers with both SDB and insufficient sleep and (D) matched controls. Child SDB, insufficient sleep, neurobehavioural skills and social-emotional functioning are measured using validated objective and subjective assessment tools, with a subset of caregivers completing qualitative interviews. Primary outcomes include individual differences in neurobehavioural and social-emotional functioning in these groups of Black and White preschoolers, and multilevel socioecological factors associated with variation in outcomes. Quantitative data will be analysed using descriptive analyses, linear regression and comparison of model coefficients. Qualitative data will be coded using thematic analysis and a joint display to stratify qualitative themes by child race and sleep deficiencies.

Ethics and dissemination The study protocol has been approved by the institutional review board of the Children's Hospital of Philadelphia and the University of Oregon. Results will be disseminated through peer-reviewed publications and conferences.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study uses a multimethod, multi-informant approach incorporating caregiver and teacher reports, observational tasks and qualitative methods to identify socioecological factors linked to co-occurring sleep health disparities and developmental outcomes in preschool-aged children.
⇒ The impact of racism will be examined across socioecological levels, including caregivers' experiences of personally mediated racism, preschoolers' internalised racism, teachers' racial bias and structural racism.
⇒ As this is a cross-sectional study design, causality cannot be tested; future longitudinal and interventional studies are needed to understand the mechanisms of sleep health disparities.

INTRODUCTION

Sleep disordered breathing (SDB) and insufficient sleep are prevalent sleep deficiencies among paediatric populations, with persistent racial disparities and adverse developmental impacts. SDB affects up to 17% of children, with higher prevalence among non-Latine Black/African American (hereafter referred to as 'Black') children across various SDB severities, ranging from mild snoring to severe obstructive sleep apnoea (OSA).[1–3] Compared with non-Latine White (hereafter referred to as 'White') children, Black children are 4–6 times more likely to snore and 2–4 times more likely to develop OSA.[3–5]

Furthermore, studies show that Black children exhibit more severe OSA on polysomnogram (PSG) compared with their White and other racial and ethnic counterparts and demonstrate less OSA resolution following adenotonsillectomy—the gold standard treatment.[6–8] Across severities, SDB poses a significant risk to the health and well-being of all children. Snoring and OSA are associated with obesity, hypertension, poor asthma control and neurobehavioural deficits in attention and executive functioning.[9–16] Moreover, greater SDB symptoms have been linked to thinner cortical grey matter in the frontal lobes, further impacting neurobehavioural function.[17] The racial disparities observed in SDB are also seen in insufficient sleep,[2 18 19] or sleeping less than age-based recommendations.[20] Racial disparities in total (24 hours) sleep duration have been observed as early as age 6 months, with research across ages showing that Black children obtain less sleep than White children, from infancy through adolescence.[18 21–23] Similar to SDB, insufficient sleep in children has been linked to worse cardiometabolic health and diminished neurobehavioural functioning.[24–29] Research shows that 30–60 min of restricted nighttime sleep negatively impacts children's daytime behaviour and executive functioning.[30–33] As with SDB, insufficient sleep is thought to impact the frontal lobes, leading to these neurobehavioural deficits.[34]

Early childhood sleep health disparities and development

Rapid neurobehavioural and social-emotional development, with gains in executive functioning and social skills instrumental for school success, occurs in children between the ages of 3 and 5 years.[35–37] Thus, the preschool years represent a sensitive period for intervening on common sleep deficiencies that impair neurobehavioural and social-emotional skills, specifically, SDB and insufficient sleep. SDB symptoms in the first 5 years of life are associated with greater odds of inattention and emotional problems at age 7, even after controlling for family income and other factors.[13] Relevant for school transitions, early childhood SDB is linked to greater special education needs at age 8.[38] Insufficient sleep in young children is also concurrently and longitudinally linked to worse emotion regulation and executive functioning, thereby impacting school readiness.[29 39]

Despite their high prevalence, observed racial disparities and similar adverse outcomes, prior research has not considered the potential unique and additive impacts of SDB and insufficient sleep on child outcomes. Studies show that medical and behavioural sleep disorders such as SDB and insufficient sleep frequently co-occur in paediatric populations.[40 41] In a secondary analysis of data from the Childhood Adenotonsillectomy Trial, we found that ~19% of 5–9 year-olds diagnosed with OSA obtained insufficient sleep, with Black children sleeping an average of 25 min less overnight compared with Wite children.[42] Importantly, our pilot data (figure 1) demonstrate that ~42% of 2–5 year-olds with caregiver-reported snoring ≥3 nights/week also obtain insufficient sleep, with Black children significantly more likely to exhibit these co-occurring sleep concerns compared with children of White or other racial and ethnic backgrounds.[43] While our prior study was not designed to examine these racial disparities and co-occurring concerns, we also found that preschoolers with both SDB and insufficient sleep had significantly worse caregiver-rated child executive functioning, attention and emotional reactivity compared with those without SDB and insufficient sleep, covarying for race and ethnicity.[44] These findings highlight the need to further evaluate the potential disparities in and developmental outcomes of co-occurring SDB and insufficient sleep. Objective tasks and teacher ratings of child outcomes are also needed to complement caregiver reports.

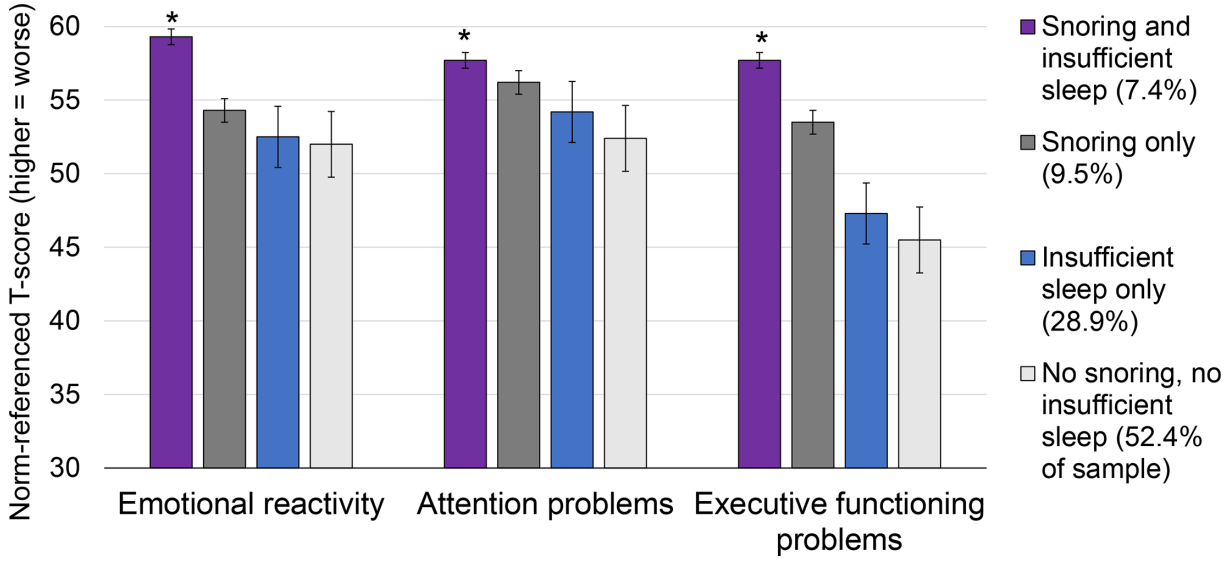

Figure 1 Pilot data: preschooler neurobehaviour and social-emotional outcomes by sleep deficiency group, covarying for child race/ethnicity (n=205).[43] *p<0.05 for snoring and insufficient sleep versus no snoring, no insufficient sleep.

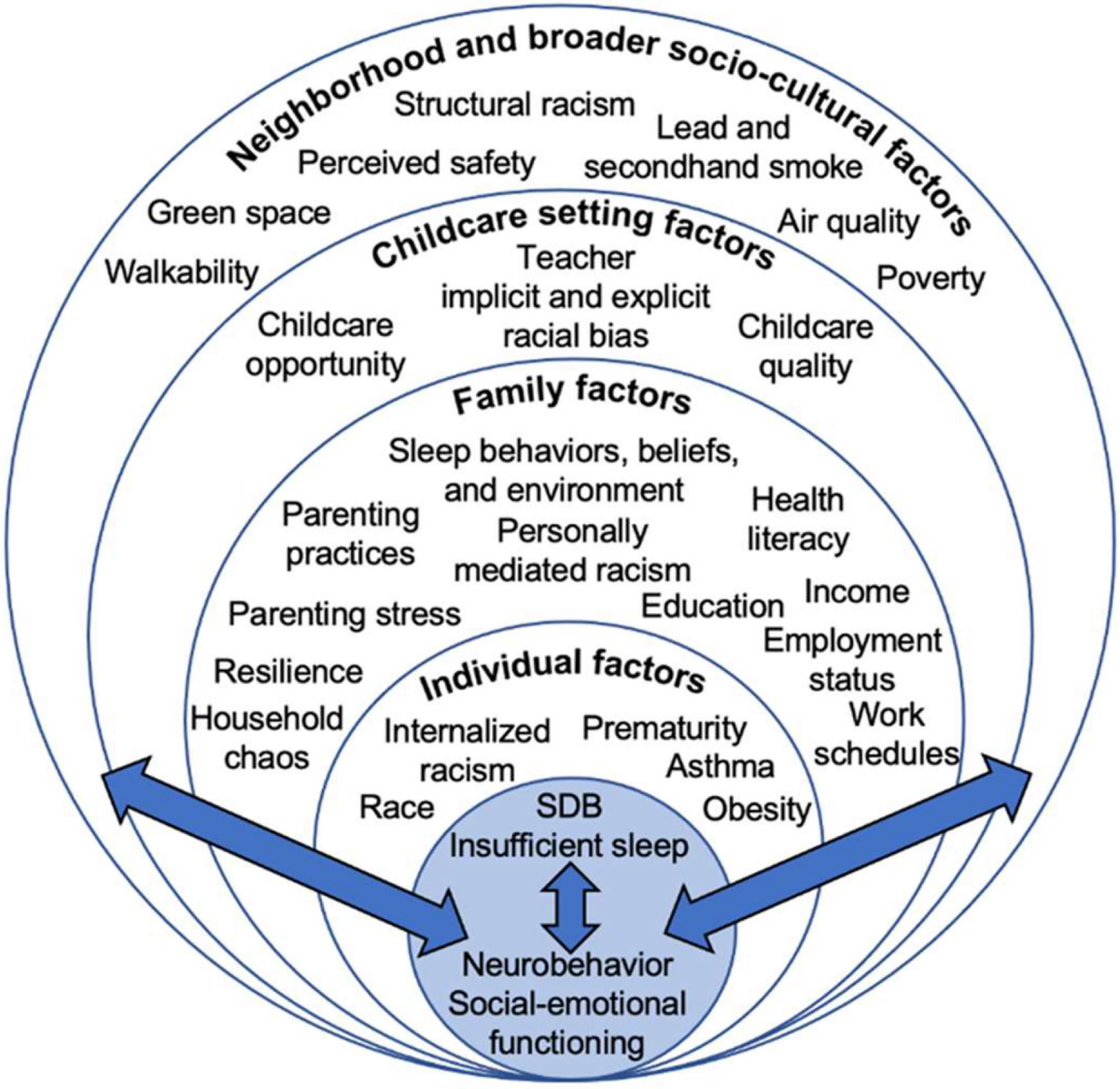

Figure 2 Putative socioecological factors contributing to racial disparities in comorbid sleep deficiencies and outcomes in early childhood (adapted from Billings *et al*[49] with permission). SDB, sleep disordered breathing.

Socioecological framework and sleep health disparities

There is a notable lack of research on co-occurring sleep deficiencies and modifiable family, childcare and neighbourhood factors that either contribute to or buffer against sleep health disparities. Also, the developmental impacts of these factors in the context of SDB and insufficient sleep health disparities are poorly understood. Racial disparities in sleep health are due to differential exposure to adverse social and environmental factors, rather than biological or genetic differences.[45–48] Thus, we will apply a socioecological framework drawn from prior sleep health disparities research to identify and explore potential modifiable factors driving these disparities in sleep health and related outcomes (figure 2).[49 50] This framework recognises the complex interplay between proximal and distal factors at various levels, including individual, family, childcare neighbourhood and broader sociocultural factors, all of which influence child development and sleep. For instance, there are well-documented socioeconomic disparities in SDB[51–54] and insufficient sleep,[18 55] but related family factors, including parenting stress,[44 56] health literacy[57] and work schedules,[58 59] are rarely considered in this research. Few studies have examined how other modifiable family factors, such as bedtime routines,[60] bedtime electronics[61] and parenting practices,[62] may also contribute to or buffer against disparities in the prevalence and sequelae of SDB and insufficient sleep. Furthermore, ongoing personally mediated and structural racism faced by Black families[45–48 63] can directly impact parenting stress, which is linked to parenting practices that impact child neurobehavioural and social-emotional development.[63–66] Teachers' racial bias[67–69] as well as childcare quality[70] and neighbourhood characteristics (safety, environmental toxins)[49 71] are also likely

contributors[72] to child neurobehavioural and social-emotional development, but are understudied in paediatric sleep research.

Objectives

The overall objectives of the 'Sleep in Preschoolers' Study (SIPS) are to (1) examine racial disparities in the developmental impacts of SDB and/or insufficient sleep in Black and White preschoolers and (2) identify proximal and distal socioecological factors linked to these racial disparities in sleep-related outcomes. We are using a multimethod and multi-informant approach to assess neurobehavioural and social-emotional functioning, as well as racial disparities in these outcomes, across groups of preschoolers with (A) SDB only, (B) insufficient sleep only, (C) comorbid SDB and insufficient sleep and (D) controls without SDB and insufficient sleep. We will focus on modifiable socioecological factors beyond individual level differences to inform the development of feasible, effective and equitable interventions at multiple levels, including the family, childcare settings and policy domains. This study has the following specific aims and hypotheses.

Our first study aim is to compare neurobehavioural (executive functioning, attention and vigilance) and social-emotional functioning (social skills and emotion regulation) in groups A, B, C and D, above. Hypothesis 1a is that Black preschoolers with SDB only (group A) or insufficient sleep only (group B) will show more neurobehavioural and social-emotional impairments compared with White preschoolers in these groups and to Black and White controls (group D). Hypothesis 1b is that Black preschoolers with both SDB and insufficient sleep (group C) will have the greatest neurobehavioural and social-emotional impairments.

Our second aim is to identify modifiable family factors that contribute to sleep-related racial disparities in the neurobehavioural and social-emotional outcomes of Black and White preschoolers in groups A, B, C and D (above). Hypothesis 2 is that the following socioecological factors contribute to sleep-related racial disparities: family sleep health behaviours, beliefs and environment (light, noise); parenting stress; parenting practices; household chaos; caregiver experiences of personally mediated racism; child internalised racism; caregiver resilience; caregiver health literacy and family income, education, employment status and work schedules.

Our third and final aim is to identify proximal and distal childcare and neighbourhood factors that contribute to sleep-related racial disparities in the neurobehavioural and social-emotional outcomes of Black and White preschoolers in groups A, B, C and D (above). Hypothesis 3 is that the following socioecological factors contribute to sleep-related racial disparities: childcare quality and opportunity; teachers' implicit and explicit racial bias; child exposure to lead and secondhand smoke; caregiver-perceived neighbourhood safety; structural racism and neighbourhood environment characteristics (walkability, green space, toxins, poverty).

METHODS AND ANALYSIS

Study design

SIPS is a cross-sectional study with planned recruitment of 400 dyads of Black and White preschoolers and their caregivers and teachers of participating children. The study involves a multimethod and multi-informant approach. Data are collected at four time points (figure 3) through completion of validated questionnaires, standardised behavioural testing—observational and computer tasks—actigraphy, PSG, semistructured qualitative interviews and systemic biomarkers. Duration of study participation for caregiver-child dyads is approximately 20 days, but may range up to 60 days. Enrolment started in November 2022 and is anticipated to end in 2027.

Sample and recruitment

The study is being conducted at two sites: Children's Hospital of Philadelphia (CHOP) and University of Oregon. All recruitment and data collection procedures occur at CHOP, with data management, analysis and interpretation occurring at the University of Oregon. 400 caregiver-child dyads consisting of caregivers and their otherwise healthy Black and White preschoolers

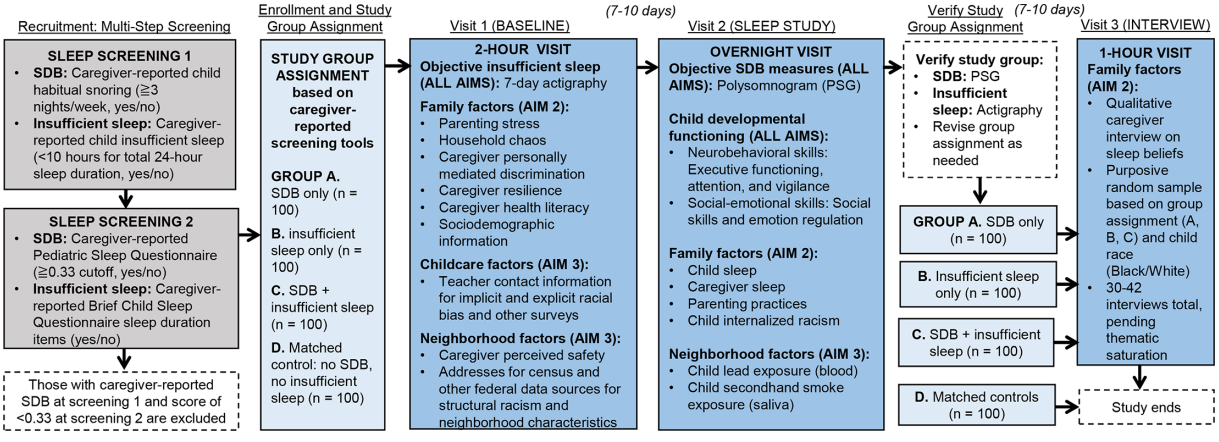

Figure 3 Overview of study design and procedures. SDB, sleep disordered breathing.

with and without SDB and/or insufficient sleep are being recruited primarily from CHOP primary care clinics. Preschool teachers of participating children are also being recruited. The study sample of 400 dyads is divided into four groups of 100 dyads, with 50 Black children and 50 White children in each group: (A) preschoolers with SDB and their caregivers; (B) preschoolers with insufficient sleep and their caregivers; (C) preschoolers with both SDB and insufficient sleep and their caregivers and (D) age-matched, race-matched, sex-matched and body mass index (BMI)-matched healthy controls and their caregivers. The eligibility criteria include child age 3–5 years of age, no previous diagnosis of OSA, no diagnosed neurodevelopmental, genetic or medical condition that could impact sleep, attending childcare outside the family's home with a non-relative provider for at least 1 day per week and caregiver aged 18 years or older. Box 1 provides a detailed description of inclusion and exclusion criteria.

Study procedures

Data collection for the caregiver-child dyads procedures is occurring on-site at the CHOP Research Institute and Sleep Laboratory in private rooms. For teachers of participating children, all study procedures and measures are completed electronically via Research Electronic Data Capture (REDCap).[73 74]

Participant screening and consent (visit 0)

A multistep screening is used to identify study groups. First, caregiver-child dyads are recruited based on a brief sleep screener integrated into the electronic health record and deployed at all well child visits in the 31-practice CHOP primary care network. The sleep screener includes items identifying (1) caregiver-reported habitual child snoring, defined as three or more nights per week according to American Academy of Pediatrics guidelines[8] and (2) insufficient total (24 hours) child sleep duration, based on American Academy of Sleep Medicine guidelines. Caregivers of children with reported sleep concerns receive a recruitment email with study information. Interested caregivers with a potentially eligible child who contact the study team undergo a secondary screening using the reliable and validated Pediatric Sleep Questionnaire Sleep-Related Breathing Disorders (PSQ-SRBD) scale[75 76] to further assess SDB and the Brief Child Sleep Questionnaire (BCSQ) items to reconfirm caregiver-reported child sleep duration.[77 78] Based on the screening results, we initially assign eligible families to groups A, B, C and D using the PSQ-SRBD-derived clinical cut-off for potential OSA and the age-based sleep duration guidance, as shown in box 1. We have approval from the CHOP institutional review board (IRB) to obtain verbal Health Insurance Portability and Accountability Act (HIPAA) authorisation from families to conduct the secondary screening before the consent procedure. Written consent is obtained from parents or legal guardians for themselves and their child's participation before the baseline visit. In addition, children in the 3–5 year-old age group who have been

Box 1 Eligibility criteria

Child inclusion criteria

For all groups (A, B, C, D)

⇒ Child 3–5 years of age.
⇒ Attending childcare outside the family's home with a non-relative provider for at least 1 day/week.

Group A (SDB only)

⇒ Child PSQ ≥0.33.
⇒ Child presence of snoring or other symptoms of SDB.
⇒ Child Obstructive Apnoea Hypopnoea Index (OAHI) >1.5 events per hour (determined by polysomnography).
⇒ Child total (24-hour; nighttime sleep+naps) sleep duration of 10 hours or more, on average (initially determined by caregiver report; confirmed via 7-day day actigraphy).

Group B (insufficient sleep only)

⇒ Child PSQ <0.33.
⇒ Absence of snoring and other symptoms of SDB.
⇒ Child OAHI <1.5 events per hour (determined by polysomnography).
⇒ Total (24-hour; nighttime sleep+naps) sleep duration of less than 10 hours, on average (initially determined by caregiver report; confirmed via 7-day day actigraphy).

Group C (SDB and insufficient sleep)

⇒ Child PSQ ≥0.33.
⇒ Child presence of snoring or other symptoms of SDB.
⇒ Child OAHI >1.5 events per hour (determined by polysomnography).
⇒ Total (24-hour; nighttime sleep+naps) sleep duration of less than 10 hours, on average (initially determined by caregiver report; confirmed via 7-day day actigraphy).

Group D (controls)

⇒ Child PSQ <0.33.
⇒ Absence of snoring and other symptoms of SDB.
⇒ Child OAHI <1.5 events per hour (determined by polysomnography as part of research procedures).
⇒ Total (24-hour; nighttime sleep+naps) sleep duration of 10 hours or more, on average (initially determined by caregiver report; confirmed via 7-day day actigraphy).

Child exclusion criteria for all groups (A, B, C and D, above)

⇒ Previous adenotonsillectomy.
⇒ Previous diagnosis of OSA.
⇒ A diagnosed neurodevelopmental (eg, Autism), genetic or medical condition that could impact sleep, including poorly controlled asthma or eczema.
⇒ Limited English proficiency that may result in misunderstanding of questionnaires and neurobehavioural testing.
⇒ Family identifies child as non-Black/African American or non-White race, mixed race or Hispanic/Latine.
⇒ Attends childcare with relative provider and/or less than 1 day/week, or does not attend childcare.

Caregiver inclusion criteria

⇒ Parent/guardian providing informed consent or accompanying the child on the study visits.
⇒ English proficient as questionnaires will be conducted in English.
⇒ Caregiver ≥18 years of age.

Caregiver exclusion criteria

⇒ Not proficient in English.
⇒ OSA, obstructive sleep apnoea; PSQ, Paediatric Sleep Questionnaire; SDB, sleep disordered breathing.

clinically referred for a PSG at CHOP are contacted by the study team to identify whether they would be interested in and eligible for study participation, using the same screening methods.

Baseline (visit 1)

The baseline visit is approximately 2 hours and includes caregiver completion of sociodemographic and other surveys assessing family and neighbourhood factors. Children also complete developmental tasks, and dyads engage in video-recorded caregiver-child interaction tasks during this visit. Participants are randomised into four groups for the task-based procedures: (1) caregiver-child interaction tasks first, followed by child-only tasks (Puzzle task first, followed by the Clark Doll task, see below), (2) caregiver-child tasks first, followed by child-only tasks (Clark Doll task first, followed by the puzzle task), (3) child-only tasks first (Puzzle task first, followed by the Clark Doll task), followed by caregiver-child tasks and (4) child-only tasks first (Clark Doll task first, followed by the puzzle task), followed by caregiver-child tasks. An actigraph is issued at the end of the study visit. Children wear the actigraph for seven consecutive nights to objectively identify insufficient sleep, followed by an overnight PSG. We also obtain contact information for the child's preschool teacher during the baseline visit and contact the teachers; those interested in participating complete the consent form and online questionnaires via REDCap.[73 74]

Overnight PSG (visit 2)

Before the PSG set up, caregivers complete additional sleep and child neurobehavioural and social-emotional surveys, and children complete the Go-No-Go computer task. Staff measure the child's height, weight and blood pressure. The CHOP nursing staff collect biological samples in the morning after the PSG. PSG results and scored actigraphy are used to confirm the child's final group assignment (box 1).

Qualitative interview (visit 3)

After the second study visit and final group assignment confirmation, we randomly invite caregivers in groups A, B and C (approximately 5–7 Black-identifying and 5–7 White-identifying per group, total n=30–42, pending thematic saturation) to participate in semistructured interviews on sleep beliefs and socioecological factors. An experienced qualitative researcher conducts the interviews either by phone or video call. The interviews are audiorecorded and transcribed for coding and data analysis.

Family advisory board input

Throughout this project, we will meet with an existing sleep-focused family advisory board, with the support of the CHOP research family partners programme.[79] Family partners are caregivers with a child who has received care at CHOP and collaborate with investigators on community-engaged research.[80] The CHOP research family partners programme provides training and onboarding for family partners and helps study teams recruit family partners. The sleep-focused family advisory board consists of caregivers living in the Philadelphia area who have collaborated with AAW on prior early childhood sleep research.[81] Family partners are compensated for their time and their expert input on study procedures (eg, recruitment, enrolment, measurement approach, data collection methods), materials (eg, study flyers) and eventual interpretation of findings. Family partner meetings occur at least two times per year and initially focused on study procedures, then moved into updates on study progress and problem-solving for any recruitment or procedural challenges.

Measures

Table 1 provides a summary of measures, including construct and methods, completed throughout the study.

Child insufficient sleep measures

Brief Child Sleep Questionnaire

BCSQ items related to daytime and nighttime sleep[77 78] are used during screening to identify whether the child appears to obtain insufficient total (24 hours) sleep. Items include caregiver-reported child bedtime and waketime, child total sleep time during the night and child total sleep time during the day. Total sleep time is calculated based on caregiver-reported nighttime and daytime sleep, as in prior research.[44]

Actigraphy

Sleep duration in the natural home environment is assessed using a wrist actigraph (Actiwatch 2, Philips Respironics, Murrysville, Pennsylvania, USA). Child participants wear the device on their nondominant wrist for seven consecutive days starting at baseline. Caregivers are also instructed to complete a daily sleep diary consisting of BCSQ items to report on the child's bedtime, wake time, naps, any device removal, sleep location and perceived sleep quality. The sleep diary is sent electronically via HIPAA-secured REDCap text messages and email and takes approximately 3 min to complete. The sleep diary is used to aid actigraphy scoring, consistent with prior research.[82–84] Actigraphy is a well-validated method to estimate sleep-wake parameters in children, has a high accuracy (84%–97%) for identifying the sleep period when compared with PSG and can reliably assess within-individual change in sleep duration and timing.[78 82 83] Actigraphy data are scored and analysed in line with previous early childhood studies.[82–84] Based on actigraphy data for average child sleep duration, we confirm final group assignments (box 1), with reassignment if needed. Average total (24 hours) actigraphy-derived sleep duration is defined as the number of minutes asleep between sleep onset and sleep offset minus any nocturnal wake time, plus minutes asleep during naps, averaged over all days/nights of measurement. An average total sleep duration of <10 hours is used to define insufficient sleep, based on guidelines for children ages 3–5 years.[20]

Table 1 Overview of study measures, including construct, method and variable type in planned analyses

Construct	Measure(s)	Method
Aim 1: compare neurobehavioural and social-emotional functioning across study groups		
Child SDB	PSQ-SRBD, polysomnogram	Caregiver; observed
Child insufficient sleep	BCSQ screening items Actigraphy (7-day average 24 hours sleep duration) and sleep diary	Observed; caregiver
Child neurobehavioural skills		
Executive functioning	BRIEF-P (global composite T-score)	Caregiver
Attention	CBCL/C-TRF (attention problem T-score)	Caregiver; teacher
Vigilance	Go-No-Go (D-prime)	Observed
Child socioemotional skills		
Social skills	ASQ:SE-2 (total score)	Caregiver
Emotion regulation	CBCL/C-TRF (emotional reactivity T-score) Puzzle task (negative emotional displays)	Caregiver; teacher; observed
Aim 2: identify modifiable family factors that contribute to sleep-related racial disparities in outcomes		
Child sleep health behaviours and environment	BCSQ and National Sleep Foundation items	Caregiver; teacher
Caregiver sleep health behaviours and environment	PSQI and Sleep Environment Inventory items	Caregiver
Caregiver sleep health beliefs	Qualitative interviews	Caregiver
Parenting stress	PSI-SF	Caregiver
Parenting practices (positive parenting, emotional scaffolding, harsh parenting)	Caregiver-child interaction tasks: building blocks, limit-setting, clean-up, story book	Caregiver; observed
Home chaos	CHAOS	Caregiver
Caregiver personally mediated racism	General Ethnic Discrimination Scale, Parent Ethnic-Racial Socialisation Behaviours measure	Caregiver
Child internalised racism	Clark doll task	Observed
Caregiver resilience	Risk and Resilience Battery	Caregiver
Caregiver health literacy	REALM-R	Caregiver
Family income, education, employment status and work schedules	Sociodemographic survey items and Standard Shiftwork index items	Caregiver
Aim 3: identify proximal and distal childcare and neighbourhood factors that contribute to sleep-related racial disparities in outcomes		
Child lead exposure	Blood toxicity	Observed
Child secondhand smoke exposure	Salivary cotinine	Observed
Childcare access and opportunity	COI 2.0 (education domain)	Observed
Teacher implicit racial bias	IAT, Adult and child pro-White bias	Teacher
Teacher explicit racial bias	Black/White temperature rating difference	Teacher
Perceived neighbourhood safety	Risk and Resilience Battery, Neighbourhood safety subscale	Caregiver
Structural racism	ICE- race+income	Observed
Neighbourhood environment (green space, walkability, toxins, poverty)	COI 2.0 (Health and environment domain and social and economic domain)	Observed

ASQ:SE-2, Ages and Stages Questionnaire: Social Emotional, second edition; BCSQ, Brief Child Sleep Questionnaire; BRIEF-P, Behaviour Rating Inventory of Executive Function—Preschool Version; CBCL/C-TRF, Child Behaviour Checklist/CBCL—Teacher Report Form; CHAOS, Confusion, Hubbub, and Order Scale; COI 2.0, Child Opportunity Index 2.0; IAT, Implicit Association Test; ICE- race+income, Index of Concentration at the Extremes for race+income; PSI-SF, Parenting Stress Index—Short Form; PSQI, Pittsburgh Sleep Quality Index; PSQ-SRBD, Paediatric Sleep Questionnaire—Sleep-Related Breathing Disorders Scale; REALM-R, Rapid Estimate of Adult Literacy in Medicine, Revised; SDB, sleep disordered breathing.

Child SDB measures

PSQ-SRBD Scale

As described above, the PSQ-SRBD is used during screening to detect SDB and inform initial study group assignment. The PSQ-SRBD is a 22-item questionnaire with scores ranging from 0 to 1. Higher scores indicate greater severity, and elevated scores are defined as 0.33 or greater. This measure has strong sensitivity (0.85) and specificity (0.87) for detecting SDB in children, including 3–5 year-olds.[75 76]

Polysomnography

Overnight PSG, a multiparametric tool used for monitoring and diagnosing sleep disorders, is used to confirm screening results and categorise SDB. PSG is done for all children including those in group D, to ensure that controls do not have any evidence of SDB and that all participants are assessed for SDB using the same gold standard assessment method. PSG is conducted and scored according to the American Academy of Sleep Medicine guidelines.[85] Children are re-classified into study groups (box 1) if the PSG and screening results differ.

Child neurobehavioural skills

Child neurobehavioural constructs and related measures were selected based on prior work showing that executive functioning, attention and vigilance are linked to SDB[14–16] and insufficient sleep.[28 29]

Executive functioning

Behaviour Rating Inventory of Executive Function—Preschool Version (BRIEF-P)

The BRIEF-P parent report form is used to capture a range of child's executive function behaviours in the home environment. BRIEF-P is a standardised questionnaire that measures executive functioning constructs, such as inhibitory control, attention, organisation and working memory, in preschool-aged children. This measure has a strong internal consistency and validity in clinical and non-clinical preschool samples, with established cut-offs for clinically significant executive functioning impairments.[86 87] The caregiver-reported Global Composite Executive Score T-score is used to index executive functioning impairments, with higher scores reflecting worse global executive functioning.

Attention

Child Behaviour Checklist (CBCL)

The CBCL is a reliable and validated caregiver-report measure that detects behavioural and emotional problems in children. The attention problems and emotional reactivity subscale T-scores are used to index attention and emotional regulation, with higher scores reflecting worse functioning.

The CBCL provides standardised, age-adjusted scores with clinical cut-offs to indicate behaviour concerns.[88] These ratings will complement the BRIEF-P.

CBCL—Teacher Report Form (C-TRF)

The C-TRF provides standardised, age-adjusted T-scores with clinical cut-offs to indicate behaviour concerns.[88] C-TRF attention problems and emotional reactivity subscale T-scores are used to index attention and emotional regulation.

Vigilance

Go-No-Go Continuous Performance Task (GNG CPT)

The GNG CPT is used to objectively measure vigilance. This measure is appropriate for 3–5 year-olds,[89] distinguishes those with and without neurodevelopmental conditions and has strong reliability and validity.[90 91] This computerised task shows children pictures of coloured fish and sharks and asks them to respond to only the fish using a button box. The outcome, D-prime, is the standardised difference between the hit rate and the false alarm rate.

Child socioemotional skills

Social skills

Ages and Stages Questionnaire: Social Emotional, second edition (ASQ:SE-2)

The ASQ:SE-2, completed by caregivers, is used to assess child social function. ASQ:SE-2 is a reliable and valid measure of social development in children up to age 5.5 years.[92] The measure assesses seven domains of social development: self-regulation, compliance, communication, adaptive functioning, autonomy, affect and social interactions. The ASQ:SE-2 has strong sensitivity (0.81) and specificity (0.83) in identifying children with social-emotional delays.[92 93] The total ASQ:SE-2 Score, which reflects all seven domains, is used to index social development.

Emotion regulation

Puzzle task

In addition to the emotional reactivity subscale scores from the CBCL and C-TRF described above, child emotion regulation is objectively assessed through a video-recorded challenge task that has been used in early childhood sleep restriction research.[94] First, the child is asked to complete a solvable, age-appropriate puzzle and given a sticker for task completion, to elicit positive emotions. The child is then asked to complete a puzzle designed to be unsolvable, as it contains an incorrect piece, to elicit negative emotions. As in previous research,[94] we are using validated child affect coding with 20% of tasks double-coded for reliability. The percentage of time spent in negative emotional states is used to index emotion regulation challenges.

Child sleep health behaviours and environment

BCSQ and National Sleep Foundation items

Studies show that poor sleep health behaviours, such as presence and use of electronic devices at

bedtime and overnight, caffeine consumption and inconsistent bedtime routines are more prevalent in children exposed to cumulative social and environmental risk factors.[44 95] We evaluate child sleep health behaviours and environment using the BCSQ[77] and National Sleep Foundation items.[96] The BCSQ items assess child bedtime, overnight electronics usage and bedtime routine consistency. This measure has good reliability and moderate correspondence with actigraphy in young children.[78 97] The BCSQ also provides environmental information about room-sharing/bed-sharing, which is important given racial and ethnic variation in sleep arrangements and the potential impacts of this arrangement on caregiver-rated child sleep.[98] Caregivers complete the full BCSQ measure, with teachers completing items related to child daytime sleep (naps) to assess nap frequency and duration. The National Sleep Foundation items are used to assess the presence and number of electronics in the child's bedroom and the daily frequency and type of caffeine consumption.

Caregiver sleep health behaviours, environment and beliefs

Pittsburgh Sleep Quality Index (PSQI) and Sleep Environment Inventory items

Caregiver sleep health behaviours and environment are assessed via the PSQI. The PSQI is a widely used measure of adult sleep with strong psychometric properties[99 100] and it includes seven scales: subjective sleep quality, sleep latency, habitual sleep efficiency, sleep duration, sleep disturbance, sleep medication use and daytime impairments. Caregiver sleep health is measured using the sleep duration and quality scores. The sleep disturbance scale is used to evaluate the sleep environment including bedroom temperature. We also use items from the Sleep Environment Inventory[101] that measure bedroom light and noise as sleep disruptors.

Qualitative interviews

Caregiver sleep health beliefs and contributing socioecological factors are examined through semistructured qualitative interviews in a purposive sample[102] of randomly selected Black and White caregivers in study groups A, B and C. Socioecological theory[103] and previous qualitative study of caregiver perspectives on barriers to and facilitators of healthy sleep habits in preschoolers[58] informed the basis of the interview guide. Interview questions focus on caregiver sleep beliefs and identify the impact of family, childcare, neighbourhood and broader sociocultural factors on these beliefs (see online supplemental appendix A for the interview guide).

Parenting stress

Parenting Stress Index—Short Form (PSI-SF)

Caregiver-rated PSI-SF[104 105] is being used to measure parenting stress. This tool detects difficulties in caregiver-child dyad interactions and shows strong psychometric properties across caregivers and children of different racial, ethnic and socioeconomic backgrounds.[104 106] Caregivers rate their level of agreement or disagreement with each item on a five-point Likert scale. Parenting stress is indexed by the total PSI-SF score which reflects parental distress, difficult child behaviour and dysfunction in parent-child interactions. Total scores of 17 or greater are considered clinically significant, in line with previous research using this measure.[104–106]

Parenting practices (positive parenting, emotional scaffolding, harsh parenting)

Caregiver-child interaction tasks: building blocks, limit-setting, clean-up, story book

Positive parenting and emotional scaffolding are implicated in the development of optimal child emotion regulation and social skills,[107–109] while harsh parenting is linked to child attention and executive functioning concerns.[110 111] Positive parenting is also associated with better sleep health in children.[62] Three parenting dimensions (positive parenting, emotional scaffolding and harsh parenting) are rated by trained observers during four well-established and widely used caregiver-child interaction tasks[112–114]: (1) building blocks task, during which the caregiver and child are asked to build increasingly complex structures with blocks, (2) limit-setting task, during which the caregiver is told to remove toys from a bag and prevent the child from touching or playing with them for 2 min, (3) clean-up task, during which the dyad is told they can play with a fun game for 5 min but are unexpectedly asked to stop and clean up after 2 min and (4) story book task, where the caregiver and child are asked to narrate a wordless book for 3 min. The caregiver-child interaction tasks are implemented by a trained study team member and coded using well-validated schemes, with 20% of tasks double coded for reliability purposes. Positive parenting is indexed by the Maternal Warmth and Coding Scale,[113] emotional scaffolding indexed by the Mental-state and Emotion Language Scales[112] and harsh parenting indexed by the System for Coding Interactions and Family Functioning.[114]

Home chaos

Confusion, Hubbub and Order Scale (CHAOS)

Household chaos is assessed using the caregiver-rated CHAOS. CHAOS is a 15-item caregiver report measure of the home environment with items rated on a four-point scale (1=very much like your own home to 4=not at all like your own home). The measure shows good reliability and validity in evaluating confusion and disorganisation in children's homes.[115] The total score will be used in analyses.

Caregiver personally mediated racism

General Ethnic Discrimination Scale

Caregiver personally mediated racism is assessed using the General Ethnic Discrimination Scale,[116] which asks

respondents to report on 20 discriminatory experiences (eg, being called a racist name) with regard to lifetime frequency (lifetime discrimination subscale), frequency in the last year (recent discrimination) and associated stress (appraised discrimination).[116] The overall score will be used in analyses.

Parent ethnic-racial socialisation

Parent ethnic-racial socialisation is assessed through the 25-item Parent Ethnic-Racial Socialisation Behaviours measure.[117] The questionnaire contains four subscales: Egalitarianism ('People are equal, regardless of their race or ethnic background'), History of Other Groups ('About important people in the history of other racial or ethnic groups'), Discrimination Against Other Groups ('About the discrimination people from other racial or ethnic groups have experienced in the past') and Preparation for Bias ('About the possibility that some people might treat him/her badly or unfairly because of our race or ethnicity'). The total score will be used in analyses.

Child internalised racism

Clark doll task

The Clark doll task is used to evaluate child internalised racism.[118] The task has been updated since its initial creation and used in samples that include preschoolers.[119 120] The updated version of this task uses cartoon images of children with a range of six skin tones, from White-appearing to Black-appearing, instead of physical dolls that are White or Black. We iteratively refined the cartoon images shown in figure 4 based on prior research, expert collaborator (TJJ and WFMN) input, and our desire to isolate skin tone rather than other phenotypic characteristics related to race. Girls are shown images of girls and boys are shown images of boys. Children are asked to respond to a series of 10 modified questions (eg, 'Which is the mean child?'; 'Which child do you want to play with?') and self-concept questions (eg, 'Which is the White child?'; 'Which is the Black child?'; 'Which looks most like you?') by pointing at one of six cartoon images.[119] There is one caregiver-directed item ('Which looks most like your child?'). A study team member records participant responses and makes notes of any observations, including child and/or caregiver questions and requests to select more than one image. The proportion of responses to skin tone questions that indicate a preference for, or positive attributes of, White children is the task outcome.

Caregiver resilience

Risk and resilience battery

Caregiver resilience is measured using a 21-item risk and resilience battery that assesses five domains: self-reliance, emotion regulation, supportive close relationships, non-hostile close relationships and perceived neighbourhood safety. This questionnaire has strong internal consistency (0.70–0.91 across domains) and evidence of validity.[121–123] Caregiver resilience is indexed using all subscales except for perceived neighbourhood safety, which is used to reflect neighbourhood-level factors (see below).

Caregiver health literacy

Rapid Estimate of Adult Literacy in Medicine, Revised (REALM-R)

Caregiver health literacy is indexed by the REALM-R, an eight-item word recognition test with strong validity.[124]

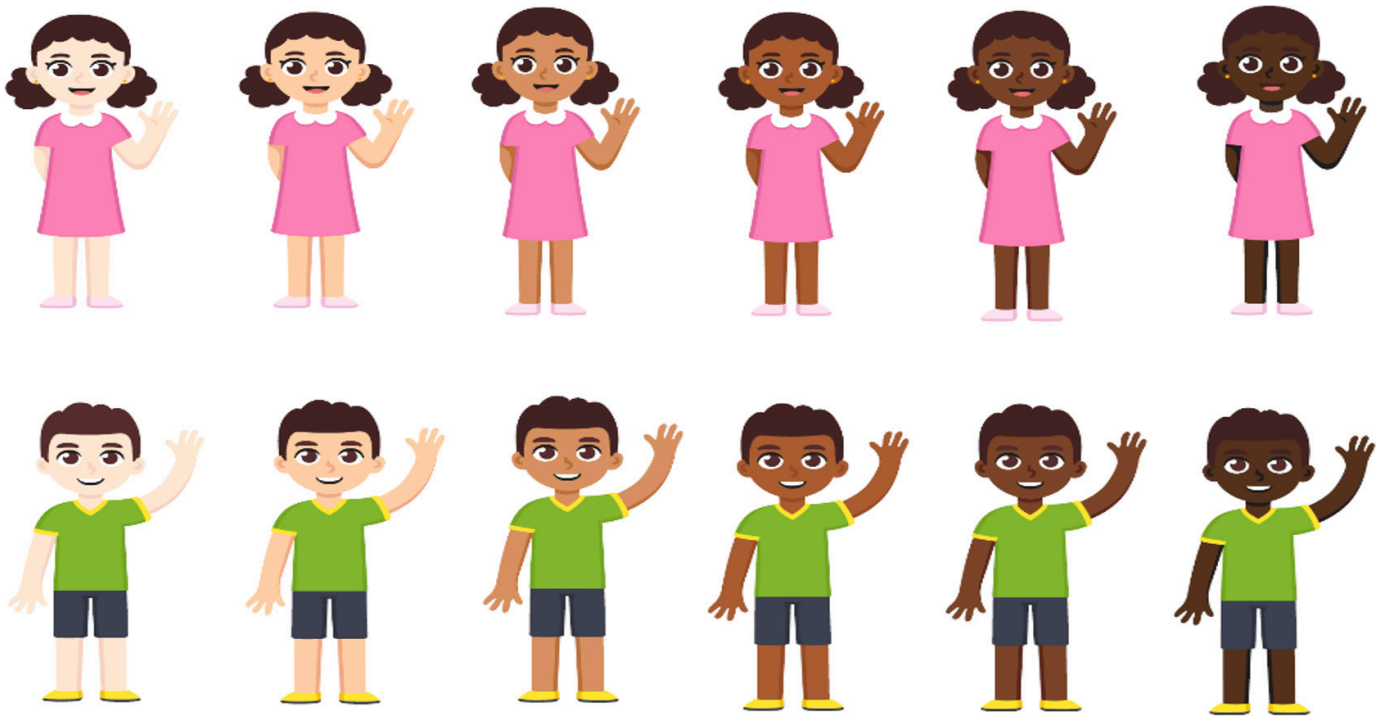

Figure 4 Cartoon images for the Clark doll task.

Family income, education, employment status and work schedules

Sociodemographic survey items and Standard Shiftwork Index items

Caregivers report on their education, employment status (unemployed, employed full-time or part-time, stay-at-home caregiver, etc) and income via a sociodemographic questionnaire used in prior research.[44] Caregivers also report the number of people at home to identify the family's poverty level according to US guidelines using both income and number of people in the home. Caregiver work schedules are thought to contribute to child sleep health,[58] but are understudied, so we are assessing caregiver work schedules and shift work (schedule outside 09:00 to 17:00)[125] via Standard Shiftwork Index items.[126]

Childcare access and opportunity

Child Opportunity Index (COI) 2.0 (education domain)

Childcare access and opportunity is indexed by the education domain score of the COI 2.0.[127] The COI 2.0 standardises and combines census, state and federal data based on residential address to yield comprehensive neighbourhood information, based on participants' residential addresses. The education domain score includes the number of early childhood education centres within a 5-mile radius; number of nationally accredited centres within a 5-mile radius; percent of 3–4 year-olds enrolled in childcare; local public school third grade reading and math proficiency; high school graduation rate, advanced placement and college enrolment; per cent of students receiving free and reduced lunch; per cent of public school teachers in their first and second year and per cent of adults with a college degree or higher.

Neighbourhood environment (green space, walkability, toxins, poverty)

COI 2.0 (health and environment domain and social and economic domain)

Neighbourhood environment is assessed through two COI 2.0 domain scores.[127] (1) The Health and Environment domain which standardises and combines nine indicators of environmental health (access to healthy food, access to green space, walkability, housing vacancy rate) and toxins (hazardous waste dump sites, industrial pollutants, airborne microparticles, ozone concentration, extreme heat) and (2) The Social and Economic domain, a standardised composite of the neighbourhood employment rate, poverty rate, public assistance rate, home ownership rate, median household income, percentage of single-headed households, percentage of workers commuting >1 hour to work and percentage of workers in high-skill jobs (eg, management, business, etc).

Structural racism

Index of Concentration at the Extremes (ICE) for race and income

Structural racism is assessed via the ICE-race+income, which quantifies economic and social spatial polarisation based on US census data. The ICE for race+income measures the degree of neighbourhood racialised economic segregation as a proxy for structural racism.[128–130] The ICE calculation generates a continuous score ranging from −1, representing the highest neighbourhood concentration of non-Latine Black residents making <$25 000 annually, to 1, representing the highest concentration of non-Latine White residents making >$100 000 annually. The ICE for race+income is linked to racial disparities in birth outcomes and mortality.[128–130] The continuous score will be used in analyses.

Perceived neighbourhood safety

Risk and Resilience Battery, Neighbourhood Safety Subscale

Caregivers' perceived neighbourhood safety is assessed through the 4-item perceived neighbourhood safety scale from the caregiver resilience measure.[121 122] This subscale assesses neighbourhood safety and trust in neighbours. Items are drawn from previous research and have been linked to adult sleep.[131–134] A total score will be used in analyses.

Teacher-completed measures

In addition to the BCSQ and CBCL teacher-completed measures noted above, teachers complete a brief sociodemographic questionnaire to report their gender, age, race, ethnicity, highest educational degree and years working in childcare. Teacher implicit and explicit racial bias are also assessed.

Teacher implicit racial bias: Implicit Association Test (IAT), adult and child pro-Wite bias

Implicit racial bias is measured with the adult race and child race IAT. The IAT assesses the strength of an association using response latency and the frequency of errors as participants pair words with faces. The adult race IAT asks participants to categorise pictures of Black and White adult faces with words that represent good and bad, with randomised trial blocks. The child race IAT replaces adult facial images with images of children and follows all other standard IAT procedures[135] and has been used previously to examine implicit racial bias towards Black children.[136] IATs are scored such that participants who categorise White faces with good words more quickly and with fewer errors compared with bad words have an implicit pro-White bias. The IAT score ranges from −2 to +2, with <0.15 indicating no racial bias; 0.16–0.35, slight pro-White bias; 0.36–0.65, moderate pro-White bias; >0.65, strong pro-White bias and negative scores indicating implicit pro-Black bias.[137]

Teacher explicit racial bias: Black/White temperature rating difference

Explicit racial bias is assessed using 11-point temperature scales (0=coldest feelings, 5=neutral, 10=warmest feelings)[138–140] that ask teachers to rate their feelings towards Black and White adults and children. Teachers are also asked to rate their Black versus White racial preferences with 11-point response scales. The outcome of Black/White temperature difference is calculated by subtracting the Black temperature score from the White temperature

score. A positive value indicates explicit pro-White/anti-Black bias; a negative value indicates explicit pro-Black/anti-White bias.

Family and child covariates

Covariates, including caregiver and child age, gender, religion, languages used at home, caregiver marital status and family composition, are collected using a sociodemographic questionnaire.[44] Atopy, asthma and prematurity have been linked to SDB[5 6 12]; data on these covariates are obtained through the caregiver-completed International Study of Asthma and Allergies in Childhood survey[141] and via electronic health record review. In addition, atopy is assessed via serum immunoglobulin E (IgE) levels (Immulite 1000 system, Siemens Healthcare Solutions, USA). Per NIH guidelines, atopy is defined as serum total IgE >150 IU/m.[142] At visit 2, we measure height and weight to define obesity via BMI z-scores.

Child lead exposure and secondhand smoke exposure

Environmental toxins, such as lead in poor-quality housing, are especially deleterious for the developing brain, resulting in significant neurobehavioural and social-emotional impairments. However, lead exposure is rarely studied in research on paediatric sleep disparities and their outcomes.[143–145] Studies also show links between secondhand smoke exposure and SDB.[146] Thus, we are assessing these and other biomarkers in this study.

Blood sample collection and systemic biomarkers

We collect approximately 7.5 mL of blood sample from child participants during study visit 2. The serum immunoglobulin E, interleukin-6, haemoglobin A1C, cortisol and high sensitivity C-reactive protein are analysed at the CHOP laboratory. In addition, blood testing for lead exposure is performed.

Saliva sample collection and systemic biomarkers

Secondhand smoke exposure is objectively assessed via salivary cotinine (1 ng/mL).[147 148] Approximately, 1 mL of saliva sample is collected from child participants during visit 2. Samples are collected either through passive drool or oral swabs.

Data analysis

Quantitative data

All statistical analyses will be conducted with Stata V.17MP, StataCorp, College Station, Texas, USA, with two-sided tests of hypotheses and p values of <0.05 as the criterion for statistical significance. Descriptive analyses will include computation of means (with 95% CIs), SD, medians and IQRs of continuous variables and tabulation of categorical variables. Tests of normal distribution will be performed to determine the extent of skewness, and transformation methods (eg, logarithmic) may be used to normalise seriously skewed variables. Frequency counts and percentages will be used for categorical variables. We will examine graphical displays to explore relationships and distributional assumptions. We will also explore any reasons for missing values and any patterns of missingness. If extreme outliers are identified, we will use robust linear regression rather than standard linear regression. Multiple imputation using chained equations in Stata V.17MP will be used to evaluate the sensitivity of conclusions based on final models fitted to observed versus imputed data.

Aim 1: neurobehavioural and social-emotional functioning

The primary endpoint (Aim 1) is the differences in neurobehavioural and social-emotional functioning in Black and White preschoolers with and without SDB and/or insufficient sleep. Primary analysis will include all subjects meeting all inclusion and exclusion criteria and completing study visits.

Linear regression will be used for Aim 1 models, as it can adjust coefficient estimates in the case of potential extreme outliers that significantly skew the estimates. A three-way interaction between SDB, insufficient sleep and race will be used to represent groups A, B, C and D, and will serve as the only fixed effect in regression models. We will conduct a univariate analysis for each outcome to assure that there is no significant confounding in our dataset. For all univariate analysis, if multiple confounders show a statistical trend for an association (p>0.2) with a given outcome, a purposeful backwards and forwards stepwise analysis will be conducted to identify a subset of confounders that show significant associations with the outcomes. Each final linear regression model will include the significant confounders. Post-hoc identification of marginal means and differences will be conducted to test Hypothesis 1a, which is that Black children with SDB only (group A) or insufficient sleep only (group B) will show more neurobehavioural and social-emotional impairments compared with White children in these groups and to Black and White controls (group D). This approach will also be used to test Hypothesis 1b, which is that Black children with both SDB and insufficient sleep (group C) will have the most impairments. A least significant differences method will be used to adjust the p values for all multiple comparison tests. All marginal means and differences will be reported with their respective 95% CIs.

Aim 2: modifiable family factors contributing to sleep-related racial disparities in outcomes

To identify modifiable family-related socioecological factors and the impact of these factors on sleep-related racial disparities in the neuro-behavioural and social-emotional outcomes of Black and White preschoolers (secondary endpoint (Aim 2)), quantitative data will be analysed using linear regression, as in Aim 1. The three-way interaction between SDB, insufficient sleep and race used to represent groups A, B, C and D will serve as a covariate in these regression models, which aim to identify the strength of the association between each family factor and the Aim 1 neurobehavioural and social-emotional outcomes. Univariate analysis will be conducted to examine associations among family factors,

race, sleep group and child outcomes. The final linear regression models will include the significant family factors, adjusted for covariates as in Aim 1. To identify the magnitude of each family factor's contribution to child outcomes, we will compare standardised coefficients with 95% CIs and the percent of unique variance explained by the family factor of interest for each study group.

Aim 3: proximal and distal childcare and neighbourhood factors contributing to sleep-related racial disparities in outcomes

We will use descriptive analyses, linear regression and comparison of model coefficients to identify the proximal and distal childcare and neighbourhood factors, and the impact of these factors on sleep-related racial disparities (secondary endpoint, Aim 3). We will also compare the magnitude of coefficients for neighbourhood versus family factors in relation to child outcomes.

Qualitative analysis

Qualitative data from the caregiver sleep health beliefs interviews will be coded using an integrated approach to thematic analysis,[149] with a priori codes based on socioecological factors (eg, family-level barriers to or facilitators of healthy child sleep) and codes that emerge from early coder review of interviews as part of codebook development. A codebook will be created using the first six transcripts (two from each sample groups A, B and C). Once a stable codebook is established, 20% of qualitative data will be double coded to generate inter-rater reliability (κ). During analysis, we will stratify coding results by sampling characteristics (Black vs White race; study group) to draw comparisons of unique and shared emergent themes.

Sample size

Sample size and statistical power calculations were based on mean differences in neurobehavioural and social-emotional T-scores in our pilot data.[44] Assuming a mean T-score of 57.96 and an SD of 2 for White children with comorbid snoring and insufficient sleep, a sample size of 60 children (30 per racial group) will yield 90% power to detect a difference of 1.38 (2%) between Black and White participants at $p<0.05$. Considering an attrition rate of 10%, 100 children (50 per racial group) will be recruited in each group A, B, C and D. For the qualitative interview, the sample size of 5–7 Black caregivers and 5–7 White caregivers in each group (A, B, C; 30–42 interviews total) was determined by guidelines for thematic saturation and group comparisons.[150 151]

Patient and public involvement

This research was planned without patient involvement. However, research family partners from CHOP's Family Partners Program who have a child receiving care in the CHOP primary care network and live in Philadelphia are collaborating as advisors in this work. Family partners for this study are part of previous sleep-focused research conducted by the study team.[81]

DISCUSSION

SDB and insufficient sleep are highly prevalent sleep deficiencies in early childhood that frequently co-occur, disproportionately affect Black compared with White children and negatively impact crucial neurobehavioural and social-emotional outcomes. The innovative approach of this study is designed to address several understudied aspects of sleep health disparities in preschoolers that are necessary to inform equitable and effective intervention and to promote positive child development. Primarily, we expect that our findings will establish the magnitude of Black-White racial disparities in the sleep-related developmental outcomes of preschoolers with SDB only, insufficient sleep only, co-occurring SDB and insufficient sleep and controls. Our findings will also provide a nuanced understanding of how disparities in outcomes may vary across constructs and methods and yield novel information on the potential unique and additive impacts of SDB and insufficient sleep on the developing brain, informing future mechanistic and interventional research.

We expect that this study will additionally identify proximal and distal socioecological factors that contribute to racial disparities in SDB and/or insufficient sleep and their adverse developmental correlates. Recognising that there are multiple socioecological mechanisms underlying these sleep health disparities and their impacts, we will thoroughly assess family, childcare and neighbourhood factors, with a particular focus on modifiable factors. While some socioecological factors have been examined in prior research, significant knowledge gaps remain. In particular, little research exists on the potential impacts of these factors on co-occurring sleep deficiencies and the effects of childcare factors on sleep-related developmental outcomes in preschoolers. Our approach will provide insights into future targets for family, childcare and policy-level interventions to ameliorate sleep health disparities and their adverse impacts during the preschool period, which is a sensitive developmental period. For example, findings related to lead exposure and neighbourhood-level environmental factors could inform public health policies related to housing and air quality. Findings from caregiver-child interaction tasks could yield indicators of positive parenting that buffer against the adverse impacts of sleep deficiencies and could be integrated into existing paediatric sleep interventions. We will also examine the impact of racism across socioecological levels, including caregivers' experiences of personally mediated racism, preschoolers' internalised racism, teachers' racial bias and structural racism. Racism remains understudied in paediatric sleep health disparities research, despite its fundamental contribution to broader health disparities throughout the lifespan.[152] Findings could help motivate research on the possible benefits of teacher and healthcare clinician-focused training in cultural humility and implicit bias.

This study has some anticipated limitations. First, as this is a cross-sectional study, the results cannot be used to establish causal associations. However, results may

highlight important constructs of interest, including putative mechanisms, that will inform future longitudinal and interventional studies to identify causality. Caregiver-rated and teacher-rated measures may be limited by social desirability biases and/or limited awareness of child sleep and functioning. To address potential bias related to some outcomes, we will use both objective and subjective measures, such as using actigraphy data to confirm caregiver-reported and teacher-reported child sleep patterns. In addition, to address the limitations of previous research, we will employ a multi-informant and multimethod assessment approach. For example, we will use a combination of task-based, caregiver-rated and teacher-rated measures to evaluate preschoolers' developmental functioning. Observational caregiver-child interaction tasks will assess parenting practices, along with caregiver-reported parenting practices, and any sleep-related beliefs relevant to parenting assessed qualitatively.

It is important to note that this study is focused on racial disparities among non-Latine Black and non-Latine White preschool-aged children, and results will not represent the total population of children in these age groups. Children in other racial and ethnic groups will not be included. We chose to focus on Black-White racial disparities given that existing research suggests that the magnitude of racial differences in paediatric SDB and insufficient sleep are largest between these two groups, and due to our desire to maximise study feasibility, power and implications. Comparing across multiple racial and ethnic groups and across sleep deficiency comorbidities would necessitate a much larger sample, which would be challenging to feasibly recruit within 5 years. We also acknowledge that racial and ethnic groups are not monolithic, and that culture and related family beliefs and practices may vary significantly within racial and ethnic groups due to other sociodemographic differences (eg, religious beliefs, immigration status, family structure, etc). We will quantitatively assess some of these variables, with online supplemental information from qualitative interviews. We will also seek input on cultural factors from our family advisors and indicate in our study findings that the results are not reflective of all cultural groups.[153] From a statistical perspective, dichotomising continuous measures of sleep to create our four sleep profile groups (A, B, C and D) can reduce power and variability. We elected to focus on the presence/absence of each sleep health deficiency to better align with diagnostic criteria and guideline-related screening in real-world practice. By using national guidelines to identify SDB and insufficient sleep, this work has more direct implications for integration in clinical practice. In addition, racial disparities and related child development consequences occur along the continuum of SDB severities.

To control for bias and confounding, the co-investigator interpreting the sleep studies and laboratory evaluations will be blinded to the participants' group. Additionally, caregivers from each group A, B and C will be randomly invited for the qualitative interview to avoid selection bias. We will also systematically randomise the sequence of the caregiver-child interaction task as well as the child-only tasks to reduce any order effects that might arise during the neurobehavioural tasks.

This research is innovative as we will comprehensively examine the unique and additive effects of SDB and insufficient sleep on key outcomes during a sensitive developmental period. We expect findings to directly impact sleep health equity promotion, as understanding co-occurring sleep deficiencies and identifying putative socio-ecological mechanisms can inform multilevel efforts to reduce sleep health disparities and their adverse impacts.

ETHICS AND DISSEMINATION

This study was reviewed and approved by the Children's Hospital of Philadelphia (protocol number: 21-019506). The project was approved through cooperative agreement at the University of Oregon (STUDY00001044). All participant recruitment, consent procedures, and compensation payments will occur at the Children's Hospital of Philadelphia. Informed consent is obtained from legal guardians for themselves and their child's participation. Also, consent is obtained from teachers of child participants. The consent process is conducted electronically via REDCap. This study is supported by a technical committee that meets every 8 weeks to address specific issues relating to the project implementation. If a protocol amendment is necessary, this will be prepared with the agreement of the principal investigator and submitted to the Children's Hospital of Philadelphia IRB and local IRB of participating site. The protocol amendment will not be implemented before the required approvals are obtained.

This project was designed to compare neurobehavioural (executive functioning, attention, vigilance) and social-emotional functioning (social skills, emotion regulation) in Black and White preschoolers with and without SDB and/or insufficient sleep. Results of the research will be disseminated through peer-reviewed publications, national and international scientific conference presentations and local stakeholder-relevant conferences. No individually identifiable PHI will be published.

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