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CLINICAL RESEARCH ARTICLE

Impact of the COVID-19 pandemic on children's sleep habits: an ECHO study

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BACKGROUND: Sleep in childhood is affected by behavioral, environmental, and parental factors. We propose that these factors were altered during the COVID-19 pandemic. This study investigates sleep habit changes during the pandemic in 528 children 4–12 years old in the US, leveraging data from the Environmental Influences on Child Health Outcomes (ECHO) Program.
METHODS: Data collection occurred in July 2019–March 2020 (pre-pandemic) and two pandemic periods: December 2020–April 2021 and May–August 2021. Qualitative interviews were performed in 38 participants.
RESULTS: We found no changes in sleep duration, but a shift to later sleep midpoint during the pandemic periods. There was an increase in latency at the first pandemic collection period but no increase in the frequency of bedtime resistance, and a reduced frequency of naps during the pandemic. Qualitative interviews revealed that parents prioritized routines to maintain sleep duration but were more flexible regarding timing. Children from racial/ethnic minoritized communities slept less at night, had later sleep midpoint, and napped more frequently across all collection periods, warranting in-depth investigation to examine and address root causes.
CONCLUSIONS: The COVID-19 pandemic significantly impacted children sleep, but parental knowledge of the importance of sleep might have played a significant protective role.

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IMPACT:

- During the COVID-19 pandemic, US children changed their sleep habits, going to bed and waking up later, but their sleep duration did not change. Sleep latency was longer. Parental knowledge of sleep importance might have played a protective role. Regardless of data collection periods, children from racial/ethnic minoritized communities slept less and went to bed later.
- This is one of the first study on this topic in the US, including prospective pre-pandemic qualitative and quantitative data on sleep habits.
- Our findings highlight the pandemic long-term impact on childhood sleep. Results warrants further investigations on implications for overall childhood health.

INTRODUCTION

Sleep health in childhood is of paramount importance for overall health and neurodevelopment, with poor sleep leading to increased risk of chronic illnesses, behavioral difficulties, and poorer memory and executive function.[1–5] Although sleep is regulated intrinsically by both homeostatic and circadian processes, extrinsic factors play an important role in determining sleep duration, timing, and quality.[6] Behavioral factors (screen time, physical activity, bedtime routine), physical environmental factors (light and noise exposure), and parental factors (parent–child attachment, parental education, parental stress) all influence the sleep health of children.[7] Many of the factors

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influencing sleep health have been significantly impacted by the coronavirus disease 2019 (COVID-19) pandemic.[8–10] Since the declaration of the global pandemic by the World Health Organization (WHO) in March 2020, COVID-19 infections increased dramatically, leading to lockdowns and curfews to prevent the spread of the virus. These measures were essential to protect the public's health, but profoundly impacted daily routines crucial for circadian cues, such as physical activity or light exposure. In addition, the pandemic exposed many families to an unprecedented level of stress and alterations of social support networks.[11,12] Furthermore, increasing literature shows that, due to a system of structural inequity, the COVID-19 pandemic has differentially impacted the health behaviors of children by socioeconomic status, race and ethnicity and, in turn, potentially exacerbated existing disparities in health behaviors.[13]

Several studies have reported how the pandemic has affected sleep habits in childhood. Findings from early stages of the pandemic and mostly in early epicenters, such as Italy and China, indicate that during the COVID-19 pandemic children slept longer, went to bed later, had more irregular sleep schedules, and reportedly had more difficulties falling and staying asleep.[14–17] One study has reported that after the lockdown period, sleep habits returned to pre-pandemic ranges,[18] while another found that families of school-aged children still reported high prevalence of bedtime resistance and sleep onset delay (February 2021).[19] Few studies of child's sleep health during the pandemic are based on United States (US) populations; in a recent review only one study out of 14 included data from the US, while most studies were performed in China and Europe.[20] One recent study that investigated sleep, physical activity, and screen time in the US in a sample of 7–12 year olds in spring and summer 2020 reported findings similar to what was found in other countries: all health behaviors were adversely altered during the COVID-19 pandemic.[21]

This study leveraged longitudinal data collected via the Environmental influences on Child Health Outcomes (ECHO) Program pre-pandemic (July 1, 2019–March 1, 2020) and two intervals during the pandemic (December 1, 2020–April 30, 2021; May 1, 2021–August 31, 2021). In addition, we report qualitative data collected from a subset of participants ($N = 38$) from four of the participating ECHO sites that sought and received supplemental funding to describe parent perceptions of how the COVID-19 pandemic may have affected the sleep habits of their children to provide contextual information.

MATERIALS AND METHODS

Study design and population

Our study was based on a subset of caregiver–child dyads prospectively followed as part of the ECHO Program. ECHO is a consortium of 69 established pediatric cohort studies collecting new data under a common protocol since 2019,[22] with the primary aim to study the effects of early-life environmental exposures on child health. Single and cohort-specific institutional review boards monitored human subject activities and the centralized ECHO Data Analysis Center. All participants provided written informed consent.

Measurements

Pre-pandemic data were collected between July 1, 2019 and March 1, 2020, via the ECHO common protocol. Repeated measures of the same health behaviors were collected twice during the pandemic (December 1, 2020–April 30, 2021, and May 1, 2021–August 31, 2021) from the same dyads (Fig. 1). The pandemic data collection periods were selected a priori in May 2020, before the length or extent of the pandemic was known. The original intention was to assess behaviors during the school year and then again after the pandemic was over. The sample included 528 children from 14 cohorts with recruitment sites in 14 US states and 4 US Census regions (Fig. 2). Inclusion criteria for this study were: assessment of sleep habits in the 8-month period before March 2020 among children aged 4–12 years

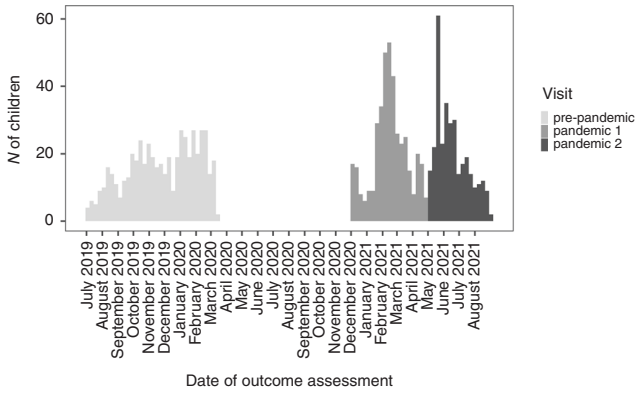

Fig. 1 Temporal distribution of data collection, July 2019 through August 2021. Bars in light grey show the distribution of data collection for the pre-pandemic assessment. Bars in grey show the distribution of data collection for the first assessment during the COVID-19 pandemic, while bars in dark grey show the distribution of data collection for the second assessment during the COVID-19 pandemic.

and at least one follow-up measure during December 1, 2020–April 30, 2021 or May 1, 2021–August 31, 2021. Participants' recruitment occurred by telephone, email, or text and assessments were completed in-person at a research visit or remotely.

Sociodemographic characteristics. Sociodemographic variables were collected via self-report or medical record abstraction. Categorical variables included child sex assigned at birth (male or female); child race and ethnicity (Hispanic all races, non-Hispanic Black, non-Hispanic other race, non-Hispanic White); and highest level of maternal education (high school or General Educational Development (GED); some college; Bachelor's degree; Master's or doctorate degree). Child age at the time of assessment was treated as a continuous variable in years.

Quantitative sleep habit measures. Sleep health measures during the past week were assessed with the ECHO Program's Sleep Health of Children and Adolescents Questionnaire, which relied on child self-report for ages 8 and older or a parent-proxy for younger children. Sleep domains assessed and included in this study are: nocturnal sleep duration, sleep midpoint for weekdays and weekends, sleep latency, frequency of delayed bedtime and frequency of daytime naps. Nocturnal sleep duration was assessed with the following question: "How many hours did your child usually spend sleeping during the NIGHT?" It was treated as a continuous measure in hours, with minimum and maximum values set as 5 and 14. Sleep midpoints were identified based on the parental or child report of bedtime and wakeup time. Values of bedtime and wakeup time outside the window of median plus 3 times the interquartile range were excluded. Specifically, the window was [17:39, 23:51] for weekday bedtime, [04:40,09:20] for weekday wakeup time, [16:13,02:31] for weekend bedtime, and [03:26,12:34] for weekend wakeup time. Sleep latency was assessed with the following question: "How long did it typically take your child to fall asleep when put to sleep at night?" It was treated as a continuous measure in minutes, with minimum and maximum values set up as 0 and 60. Frequency of delayed bedtime was assessed with the following question: "In the past 7 days, my child "put-off" or delayed bedtime." It was treated as a categorical variable with the following categories: Never/Almost Never; Sometimes; Almost Always/Always. Daytime nap frequency was assessed with the following question: "How many days did your child take a daytime nap?" It was treated as a categorical variable with the following categories: None; 1–3 days a week; 4–7 days a week.

Statistical analyses for quantitative sleep habit measures. We computed descriptive information on sociodemographic characteristics of the study sample and sleep measures for the three time points when data was collected. Linear mixed-effects models for continuous outcomes (using the R package "lme4"[23]) and cumulative link mixed-models for categorical outcomes (using the R package "ordinal"[24]) were conducted, with time period of data collection as the exposure of interest (pre-pandemic, pandemic 1, pandemic 2), sleep measures as dependent variables, and random intercepts to control for within cohort correlation and repeated

measures for the same child. Child age, sex (male as reference group), race, ethnicity (non-Hispanic White as reference group), and maternal education (master's degree or higher as reference group) were included as covariates. Non-Hispanic White children were chosen as reference group because previous papers have shown that they generally sleep more and have earlier bedtime compared to children from racial and ethnically minoritized groups.[25] For this reason, we hypothesized that our results would mirror those already in the literature and thus non-Hispanic White children would display the best sleep profile. In addition, they were the largest group, and thus utilizing them as reference group was the optimal choice from a precision perspective.[26]

Qualitative interviews. We conducted qualitative, semi-structured, 60-min interviews via secure video conferencing among a subsample of parents from each of the four sites that had sought supplemental funding to carry out qualitative interviews, to assess parents' perspectives on the effects of the pandemic on children's health behaviors. Most of the qualitative interviews were conducted during December–April 2021. The focus was on families' daily routines during the pandemic and identifying the pathways by which societal changes shaped behavior. The interview guide was developed by a team with expertise in qualitative research, social determinants of health, health disparities, pediatric nutrition, environmental influences on child health, and life course approaches to obesity. The team relied on Ecocultural Theory as an approach to understand the factors that influence children's health behaviors during the pandemic period.[27] This theory focuses on daily routines as the unit of analysis and is based on the idea that families organize daily routines according to available social and economic resources and cultural values. Two of the components of Ecocultural Theory are the daily activities that are part of the routine and parents' goals and values for the daily routine. Ecocultural Theory was selected for the current study because (1) household routines have previously been linked to child sleep outcomes and, (2) conversation-style interviews, in which families are asked to discuss a typical day-in-the life during the pandemic, can provide insights into the pathways by which the societal changes shaped children's sleep.

Sample size was based on saturation, which occurs when adding new data does not improve a researcher's ability to answer the research question.[28] Interviews were conducted via secure video conferencing by researchers at the Colorado site.

Analyses for qualitative data. Qualitative data from all four sites was analyzed at the Colorado site. Each interview was recorded with the participant's permission. Audio recordings were transcribed verbatim and anonymized. Transcripts were uploaded to Atlas.ti software (version 9, Scientific Software Development GmbH, Berlin) for coding. Qualitative content analysis was used to systematically analyze and interpret interview transcripts.[29] This primarily inductive approach is common in the health sciences. Two members of the research team reviewed one transcript from each site to identify topics that appeared repeatedly (e.g., "remote schooling" or "bedtime routines"). Next, all transcripts were rigorously read and re-read to identify sub-categories (herein defined as codes) that appeared repeatedly. This process resulted in 28 distinct, inductively generated codes relevant for the present manuscript and a codebook in which each of the codes was assigned a definition, a sample quote, and exclusion criteria. Two members of the research team independently coded each transcript. After every three transcripts, the coders met as part

Fig. 2 Map of cohort recruitment sites. On this map are shown the sites where participants were recruited for this study. Different colors indicate the number of participants that each site contributed for the analyses: Yellow <25 participants; Green 25–49 participants; Blue ≥ than 50 participants. In grey are shown sites that contributed only to the qualitative analyses.

Table 1. Descriptive characteristics of study sample of children at ages 4–12 years in the Environmental Influences of Child Health Outcomes (ECHO) Program.

Sociodemographic characteristics	Analytic sample
N	528
Female sex, *n* (%)	253 (47.9%)
Child age at pre-pandemic assessment, years, mean (SD)	7.2 (2.3)
Child age at pandemic 1, years, mean (SD)	8.3 (2.3)
Child age at pandemic 2 years, mean (SD)	8.7 (2.4)
Race and ethnicity, *n* (%)	
Hispanic all races	110 (20.8%)
Non-Hispanic Black	44 (8.3%)
Non-Hispanic other[a]	80 (15.2%)
Non-Hispanic White	297 (56.3%)
Missing	<5
Maternal education, *n* (%)[b]	
Master's degree or higher	159 (30.1%)
Bachelor's degree	165 (31.3%)
Some college, no degree	146 (27.7%)
High school degree, GED or equivalent or less	55 (10.4%)
Missing	<5

[a]Non-Hispanic other includes 17 Asian, 22 American Indian or Alaska Native, and 41 Multiple race.
[b]Some college, no degree also includes associate degrees and trade school. Master's degree or higher also includes doctoral degree.

of consensus coding to review discrepancies and negotiate consensus. This resulted in a single, agreed upon application of codes in all 38 transcripts. Finally, the research team in Colorado reviewed a list of coded statements to identify major themes. Themes were presented to investigators at all four sites for discussion and feedback.

RESULTS

Table 1 provides demographic information for the 528 children who met the inclusion criteria. Children were, on average, 7 years old at baseline, and 48% were female. Fifty-six percent of the children were non-Hispanic White, 8% non-Hispanic Black, and 21% Hispanic. Sixty-one percent of the mothers had a bachelor's degree or higher, and 10% of the mothers had a high school diploma, GED, or did not complete high school. Although race and ethnicity and maternal education attainment were correlated, each racial and ethnic group was represented in each category of educational attainment. Maternal educational attainment by race and ethnicity can be found in Supplement Table 1.

Table 2 contains descriptive statistics of the sleep habits outcomes at each of the three data collection periods. Median nocturnal sleep duration was 10 h during the pre-pandemic period and 9.5 h during both pandemic periods. Median weekday bedtime was 20:30 pre-pandemic and 21:00 during the two pandemic periods. Weekday waketime was 7:00 and sleep latency was 20 min for all data collection periods. The proportion of children who almost always/always delayed bedtime was 10.8% pre-pandemic and 17.6 and 17.0% in the two pandemic time periods, respectively. The proportion of children taking a nap 4–7 days a week was 12.3% pre-pandemic and 2.9 and 3.7% in the pandemic periods, respectively.

Linear regression analyses revealed no statistically significant change in nocturnal sleep duration between pre-pandemic and pandemic data collection periods (Table 3). Shorter sleep duration was reported among older children (−0.17 h per year of age older, 95% CI −0.22, −0.11). In Model 2, which only adjusted for race and ethnicity, both Hispanic children and non-Hispanic Black slept less than non-Hispanic White children, but after accounting for maternal educational attainment only Non-Hispanic Black children reported significantly shorter sleep duration than non-Hispanic White children (−0.77 h, 95% CI −1.20, −0.33). Children of mothers with some college education slept an average of 0.45 h less than children of mothers with a master's degree or higher (95% CI −0.73, −0.16). A similar trend was observed for children of mothers who reported having attained a high school degree, but it did not reach significance.

Compared to pre-pandemic, children reported a significant increase in sleep latency of 6.02 additional minutes in the first pandemic data collection period (95% CI 2.09, 9.94), but this increase was not sustained in the second pandemic data collection period (Table 3). Children of mothers with some college education reported an average of 7.74 min longer sleep latency than children of mothers with a master's degree or higher (95% CI 1.71, 13.77).

Weekday sleep midpoint shifted 11.10 min later during the first pandemic data collection period (95% CI 6.21, 15.98) and 16.68 min later in the second (95% CI 11.00, 22.35). Older children reported later weekday sleep midpoints (2.95 min per year of age older, 95% 0.58, 5.31). Compared to non-Hispanic White children, non-Hispanic Black children reported later sleep midpoints, even after adjusting for maternal educational attainment (Model 2: 23.13 min later, 95% CI 9.67, 36.59; Model 3: 18.46 min later, 95% CI 4.71, 32.22). Similarly, Hispanic children reported later sleep midpoints, both before and after adjusting for maternal educational attainment (Model 2: 15.34 min later, 95% CI 6.19, 24.49; Model 3:11.69 min later, 95% CI 2.26, 21.3). Children of mothers with some college education reported later sleep midpoints than those whose mothers have a master's degree or higher (11.48 min, 95% CI 2.00, 20.96). Weekend sleep midpoint was also shifted later in the first pandemic data collection period compared to pre-pandemic (6.68 min, 95% CI 0.92, 12.43). Older children reported later weekend sleep midpoints (8.05 min per year of age older, 95% CI 5.23, 10.86). Compared to non-Hispanic White children, non-Hispanic Black children reported later sleep midpoints, even after adjusting for maternal educational attainment (Model 2: 69.45 min later, 95% CI 46.32, 92.58; Model 3: 58.81 min later, 95% CI 35.59, 82.02). Similarly, Hispanic children reported later sleep midpoints, both before and after adjusting for maternal educational attainment (Model 2: 42.27 min later, 95% CI 27.97, 56.57; Model 3:32.97 min later, 95% CI 18.64, 47.31). Weekend sleep midpoint was later among children whose mothers had lower levels of education (32.10 min less for mothers with a high school degree or less, 95% CI 12.24, 51.96; 30.66 min later for mothers with some college, 95% CI 15.70, 45.62).

Frequency of delaying bedtime did not increase during the pandemic (Table 4). During the pandemic data collection periods, children reported fewer daytime naps compared to pre-pandemic: the odds of moving to a higher category of daytime nap frequency were 74% lower in the first pandemic time point (OR 0.26, 95% CI 0.17, 0.40) and 65% lower in the second pandemic time point (OR 0.35, 95% CI 0.21, 0.56) than in the pre-pandemic period. Older children were also less likely to report a higher category of daytime nap frequency (OR 0.71, 95% CI 0.63, 0.79). Compared to non-Hispanic White children, non-Hispanic Black children (Model 2: OR 5.23, 95% CI 2.4, 11.41; Model 3: OR 4.49, 95% CI 2.00, 10.09) and Hispanic children (Model 2: OR 2.24, 95% CI 1.24, 4.05; Model 3:OR 2.09, 95% CI, 1.14, 3.83) were more likely to report a higher category of daytime nap frequency, both before and after adjusting for maternal education.

Table 2. Overview of sleep habits between pre-pandemic and pandemic data collection periods among children aged 4–12 years in the subset of caregiver–child dyads from Environmental influences of Child Health Outcomes (ECHO) Program.

	Pre-pandemic[a]	Pandemic 1[b]	Pandemic 2[c]
N	528	415	323
Sleep habits, median (IQR)			
	$n = 377$	$n = 377$	$n = 310$
Nocturnal sleep duration, h	10 [9.0, 11.0]	9.5 [8.5, 10.0]	9.5 [8.7, 10.0]
Sleep pattern[d]	$n = 403$	$n = 368$	$n = 310$
Weekday bedtime	20:30 (20:00, 21:00)	21:00 (20:00, 21:30)	21:00 (20:30, 21:30)
Weekday wakeup time	7:00 (6:30, 7:00)	7:00 (6:30, 7:30)	7:00 (6:30, 7:30)
Weekday midpoint time	1:38 (1:15, 2:00)	1:53 (1:30, 2:15)	2:00 (1:30, 2:30)
Weekend bedtime	21:00 (20:30, 22:00)	21:30 (21:00, 22:30)	21:45 (21:00, 22:30)
Weekend wakeup time	7:30 (7:00, 8:30)	8:00 (7:00, 9:00)	8:00 (7:00, 9:00)
Weekend midpoint time	2:30 (1:45, 3:15)	2:45 (2:00, 3:30)	2:45 (2:00, 3:30)
	$n = 250$	$n = 195$	$n = 172$
Sleep latency, min	20 [15, 30]	20 [15, 45]	20 [15, 30]
Missing	278 (52.7%)	220 (53.0%)	151 (46.7%)
Delayed bed frequency/week, *n* (%)	$n = 360$	$n = 367$	$n = 309$
Never/almost never	156 (29.5%)	162 (39.0%)	140 (43.3%)
Sometimes	147 (27.8%)	132 (31.8%)	114 (35.3%)
Almost always/always	57 (10.8%)	73 (17.6%)	55 (17.0%)
Missing	168 (31.8%)	48 (11.6%)	14 (4.3%)
Daytime nap/week, *n* (%)	$n = 396$	$n = 366$	$n = 311$
None	240 (45.5%)	297 (71.6%)	249 (77.1%)
1–3 days	91 (17.2%)	57 (13.7%)	50 (15.5%)
4–7 days	65 (12.3%)	12 (2.9%)	12 (3.7%)
Missing	132 (25.0%)	49 (11.8%)	12 (3.7%)

[a]July 1, 2019–March 15, 2020.
[b]December 1, 2020–April 30, 2021.
[c]May 1, 2021–August 31, 2021.
[d]Out of range sleep time variables (weekday/weekend bedtime and wake-up time) have been coded as missing if outside the range of median +/− 3×IQR. 3, 43, 81, and 16 observations were coded as missing for weekday bedtime, weekday wake-up time, weekend bedtime, and weekend wake-up time variables, respectively.

Thirty-eight qualitative interviews were conducted among participants recruited from the cohorts in Colorado ($n = 10$), California ($n = 10$), New Hampshire ($n = 9$), and South Dakota ($n = 9$). Consistent with Ecocultural Theory, two themes emerged related to children's sleep routines: (1) the daily tasks or activities and (2) parents' goals and values.

For the first theme, many parents perceived no changes from pre-pandemic to during the pandemic in the daily activities, including wake time, bedtime, or sleep duration. However, several parents described sleeping routines during the pandemic as "not quite as structured," "more go with the flow," "more lenient with bedtime," and "a little bit more relaxed," which often resulted in later bedtimes. Another perceived cause of later bedtimes during the pandemic was low physical activity during the day. One parent said, "Sometimes, he just couldn't fall asleep. He's just like, 'I can't fall asleep.' There's just too much energy, that didn't get burned off during the day." Another common scenario was children having a later wakeup time during remote schooling versus in-person schooling. One parent said her child, "woke up at 7:00 instead of 8:00 because we had to get prepared to actually drive to school versus them just waking up, rolling over, and turning their computer on".

For the second theme, the most reported goals and values were maintaining consistent sleep routines and ensuring that children got an adequate amount of sleep. Parents perceived that this would ensure that the child was in a good mood in the morning and support the child's overall health. Parents said that "we've always tried to keep a set bedtime because everybody is much less grumpy when we get the right amount of sleep" and "I know with kids' brains and development that bedtimes are really important."

DISCUSSION

This longitudinal study investigated changes in multiple sleep habits among children 4–12 years old across the US from before to during the COVID-19 pandemic.

Results of quantitative data showed no significant changes in sleep duration in the three collections periods, but there was a shift to a later sleep midpoint both during the week and weekends at both pandemic data collections period. We also found a significant increase in sleep latency at the first pandemic collection period but no increase in the frequency of bedtime resistance, and a reduced frequency of daytime naps at both pandemic data collection periods.

The findings from studies conducted during the early pandemic lockdown are mixed; some indicate significant increases in children's sleep duration,[30–33] while others show no differences[34] or a slight decrease.[35,36] The results presented in this study provide novel data on changes beyond the initial lockdown period, since data collection began in December 2020, 8 months after the WHO declared COVID-19 a global pandemic. Thus, the

Table 3. Estimated associations between sleep duration, sleep latency, and weekday and weekend sleep midpoint and data collection period.

	Sleep duration (h) β[a] (95% CI)	Sleep latency (min) β (95% CI)	Weekday sleep midpoint[b] (min) β (95% CI)	Weekend sleep midpoint[b] (min) β (95% CI)
N of children	333	152	308	292
Time point[c]				
Pandemic 1	0.09 (−0.08, 0.26)	6.02** (2.09, 9.94)	11.10** (6.21, 15.98)	6.68* (0.92, 12.43)
Pandemic 2	0.16 (−0.03, 0.35)	0.92 (−3.44, 5.28)	16.68** (11.00, 22.35)	5.97 (−0.80, 12.75)
Age, years old	−0.17** (−0.22, −0.11)	0.24 (−1.59, 2.08)	2.95* (0.58, 5.31)	8.05** (5.23, 10.86)
Male	−0.07 (−0.28, 0.14)	3.77 (−0.52, 8.06)	−1.72 (−8.56, 5.12)	−5.72 (−16.55, 5.10)
Race and ethnicity				
Non-Hispanic White	REF	REF	REF	REF
Hispanic all races	−0.19 (−0.47, 0.09)	−0.07 (−5.77, 5.64)	11.69* (2.26, 21.13)	32.97** (18.64, 47.31)
Non-Hispanic Black	−0.77** (−1.20, −0.33)	−1.78 (−11.65, 8.09)	18.46** (4.71, 32.22)	58.81** (35.59, 82.02)
Non-Hispanic other	−0.16 (−0.46, 0.14)	1.86 (−4.58, 8.30)	11.73* (1.92, 21.55)	25.82** (10.21, 41.44)
Maternal education				
Master's degree or higher	Ref.	Ref.	Ref.	Ref.
Bachelor's degree	−0.17 (−0.44, 0.09)	0.82 (−4.81, 6.44)	3.60 (−5.24, 12.44)	7.08 (−6.62, 20.78)
Some college, no degree	−0.45** (−0.73, −0.16)	7.74* (1.71, 13.77)	11.48* (2.00, 20.96)	30.66** (15.70, 45.62)
High school degree	−0.35 (−0.77, 0.07)	−2.39 (−11.86, 7.07)	8.68 (−4.94, 22.29)	32.10** (12.24, 51.96)

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a]Beta coefficients from linear mixed effects models that include cohort and child as random intercepts to adjust for the within cohort and within child correlations. Maximum Likelihood method was used to fit model. *p* values were given from LMEM *t* test. The analysis was conducted using the R package "lme4."

[b]The midpoint sleep outcome is modelled as minutes from 12:00:00 a.m.

[c]The reference group is the pre-pandemic period: July 1, 2019–March 15, 2020. Pandemic 1 data collection occurred during December 1, 2020–April 30, 2021, and Pandemic 2 during May 1, 2021–August 31, 2021.

absence of a significant change might reflect sleep duration returning to pre-pandemic values. A similar pattern, in which sleep duration returned to pre-pandemic length after the lockdown period was also observed among US adults.[37] These results are supported by the emphasis that parents gave in the interviews on the importance of enforcing good habits to maintain adequate amount of sleep, even in face of changes in routines, to guarantee optimal mood, learning and growth. This underlines the crucial role of parental knowledge in buffering potential negative effects of the pandemic on children sleep health.

Results on sleep timing are consistent across studies, since all have shown a delay in bedtime and wakeup time, with a consequent shift to later sleep midpoint.[21,30] Some studies have suggested that this shift might have benefited older children, who generally display a later chronotype than in early childhood and may experience circadian pressure to advance their sleep period to align to social norms, such as school start time..[38] At the same time, a few studies have indicated that later bed/wake times are associated with less physical activity and poorer diet.[39,40] In addition, another study found that during the pandemic late wakeup was associated with higher odds of having mental illnesses.[30] Thus, further investigation is warranted to understand the potential impact of a shift in sleep timing on physical and mental health outcomes. The shift in bedtime documented with sleep questionnaire was consistent with findings from the qualitative interviews. Parents perceived that their children went to bed later during the pandemic because (1) children were less tired due to less physical activity and (2) parents were more lenient about sleep-related rules during the pandemic.

Stressors and routine changes associated with the pandemic may have impaired other sleep domains, such as sleep latency or disturbances during the night, but less information is available on these domains, because prior studies mostly utilized composite indices of sleep health or sleep quality. We found that reported sleep latency increased in the first data collection period during the pandemic. This is in line with the reports from parents indicating that the children were less tired due to less physical activity. Increased sleep latency could also reflect the effect of increased screen exposure.[41,42] Similar results regarding sleep latency were observed in a cohort of adolescents during the pandemic, where participants who used electronic devices >4 h/day compared with those who used them <4 h/day reported more frequently long sleep latency, low sunlight exposure, less physical activity, and weight gain.[43]

Our results indicated a significant decrease in frequency of daytime napping, which is in line with other reports.[16,32] Reasons for the observed changes could be related to children being less tired due to decreased physical activity and increased screen exposure, in addition to the lack of structured routine generally provided in school environments. A confounding factor could be the natural developmental decrease in the frequency of daytime napping as children get older, since in our cohort, the average age at the pre-pandemic collection was 7.2 years (SD 2.3), while at the second data collection period during the pandemic the average age was 8.7 years (SD 2.4).

While some published studies on sleep in children during the pandemic did include racially and ethnically diverse cohorts, they did not examine whether sleep habits differed across racial/ethnic groups.[21] Within this sample of ECHO cohorts, we found that regardless of the pandemic period, children from racial/ethnic minoritized communities slept less at night, had later sleep midpoint times both during the week and weekends, and took naps more frequently. These results were statistically significant even after adjusting for maternal education. These findings

Table 4. Estimated associations between delayed bedtime frequency, daytime nap frequency, and data collection period.

	Frequency of delayed bedtime[a] OR[b] (95% CI)	Frequency of daytime naps[c] OR (95% CI)
N of children	309	341
Time point[d]		
Pandemic 1	1.21 (0.82, 1.77)	0.26*** (0.17, 0.40)
Pandemic 2	1.00 (0.66, 1.53)	0.35*** (0.21, 0.56)
Age, years	0.92 (0.82, 1.03)	0.71*** (0.63, 0.79)
Male	1.57 (0.96, 2.55)	1.24 (0.78, 1.98)
Race and ethnicity		
Non-Hispanic White	Ref.	Ref.
Non-Hispanic Black	0.85 (0.34, 2.16)	4.49*** (2.00, 10.09)
Non-Hispanic other	0.56 (0.28, 1.13)	0.95 (0.48, 1.89)
Hispanic all races	0.82 (0.43, 1.56)	2.09* (1.14, 3.83)
Maternal education		
Master's degree or higher	Ref.	Ref.
Bachelor's degree	1.98* (1.08, 3.64)	1.15 (0.62, 2.16)
Some college, no degree	1.40 (0.73, 2.68)	1.57 (0.83, 2.94)
High school degree, GED or less	0.86 (0.30, 2.40)	1.36 (0.60, 3.08)

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a]In the past 7 days, I/my child "put-off" or delayed bedtime. Never/almost never, sometimes, almost always/always.

[b]Odds ratios estimating the odds of reporting a higher category of the outcome from Cumulative link mixed models fitted with the Laplace approximation. We include cohort and child as random intercepts to account for within-cohort and within-child correlations. *p* values were given from LMEM Wald test. The analysis was conducted by the R package "ordinal."

[c]How many days did you/your child take a daytime nap? None, 1–3 days, or 4–7 days.

[d]The reference group is the pre-pandemic period: July 1, 2019–March 15, 2020. Pandemic data collection period 1 is December 1, 2020–April 30, 2021, and pandemic period 2 is May 1, 2021–August 31, 2021.

highlight disparities by race/ethnicity in sleep habits during childhood are in line with previous studies indicating that non-Hispanic White children are more likely to go to bed earlier and more regularly, have longer nocturnal sleep, and nap less than most racial and ethnic minoritized groups.[44,45]

Although there is an increasing amount of evidence in the literature that attesting to sleep health disparities, the causal mechanisms and principal contributory factors remain largely unknown. Due to a system of structural discrimination, racial and ethnic minoritized groups often have less resources and opportunities (e.g., education, income, employment, housing) and experience more psychosocial stressors linked to interpersonal discrimination, which are all factors known to negatively affect sleep.[25] In additional, various cultural beliefs and practices regarding sleep and parenting might affect sleep specifically during childhood. Nonetheless, the potential contribution of these factors to racial and ethnic differences in sleep health, particularly during childhood, has not been fully investigated. Further studies are needed to evaluate these disparities through a socio-ecological lens, incorporating factors at multiple levels, from the individual, family and other direct interpersonal relationships, broadening to neighborhood and community influences, and public policy. Such studies are essential to identify upstream determinants and potential points of intervention to reduce sleep disparities.[46] Given our limited sample size, we were not able to investigate interactions between race/ethnicity and data collection periods, thus we were not able to assess whether changes during the pandemic differed across racial/ethnic groups. Differential changes might be expected because the COVID-19 pandemic disproportionately impacted racially and ethnically minoritized groups.[47,48] In particular, the pandemic might have affected child health behaviors differently. For example, children from some racial and ethnic minority groups were also more likely to attend school via online learning compared with non-Hispanic White counterparts. This might be due to the fact that lower income neighborhoods received less state and local funding than schools that serve a lower proportion of these groups with implications for availability of student supports, classroom sizes, and a myriad of other factors that affected school reopening.[49] In addition, neighborhood environment is tightly associated with health behaviors, with living in high-density neighborhoods being a negative predictor for health behaviors during the pandemic.[50] Consequently, several studies are reporting on how the pandemic has exacerbated disparities in health outcomes in childhood. For example, one study reported disparities in childhood health behaviors during the pandemic leading to accelerated body mass index gain in minoritized groups.[51] Thus, further investigation is needed to better understand potential exacerbation of sleep health disparities in children during the COVID-19 pandemic.

Limitations of this study include the use of subjective sleep data, which is known to present risk for bias.[52] In addition, given that the three data collection time periods occurred at different times during the year, additional confounding factors might include seasonal effects, and changes in routines due to school calendars, especially since Pandemic 2 data collection mostly took place during summer/non-school schedule. Nonetheless, we were unable to account for this, since at each site different school calendars were implemented. This study has also several strengths, including a longitudinal design, with pre-pandemic and post-pandemic data. In addition, we include data from several site across the US, thus our sample is diverse in terms socio-demographic and geographic representation. Lastly, we report results on several sleep domains, and we include qualitative data from parental interviews providing critical contextual information for quantitative findings.

In conclusion, our findings support the hypothesis that the pandemic has significantly impacted sleep health during childhood, and parental knowledge of the importance of sleep health

might have played a significant protective role. Thus, further investigation is necessary to understand potential implications for long-term health outcomes of the pandemic. Our study corroborates the existing literature by highlighting substantial racial/ethnic disparities in sleep health in children in the US, warranting further studies to examine and address root causes.

DATA AVAILABILITY

The datasets for this manuscript are not publicly available because, per the NIH-approved ECHO Data Sharing Policy, ECHO-wide data have not yet been made available to the public for review/analysis. Requests to access the datasets should be directed to the ECHO Data Analysis Center, ECHO-DAC@rti.org."

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The authors declare no competing interests.

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All participants provided written informed consent.

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ENVIRONMENTAL INFLUENCES ON CHILD HEALTH OUTCOMES

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