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Sleep it off? Exploring sleep duration and bedtime regularity as potential moderators of early adversity's impact on mental health in infancy, childhood and adolescence

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Results

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Abstract

Introduction: Adverse Childhood Experiences (ACEs) are known to increase the risk of mental health challenges, and sleep is known to decrease risk. We investigated whether adequate sleep duration and sleep regularity would moderate the impact of ACE exposure on mental health risk.

Methods: We conducted secondary cross-sectional analyses on the 2020–2021 waves of the National Survey of Children's Health (NSCH; N = 92,669). Logistic and ordinal regressions explored the impact of ACEs (total, household, community and single) and sleep (duration and irregularity) and related interactions on mental health diagnosis and symptom severity.

Results: Known main effects of ACEs and sleep on mental health were replicated. Interactions between ACE exposure and sleep factors were not clinically significant, although some were statistically significant due to the large sample, such that adequate duration was associated with marginally increased risk of mental health diagnosis (Omnibus B = 0.048, $p < 0.0001$) and greater bedtime irregularity was associated with marginally decreased risk (Omnibus B = −0.030, $p < 0.001$).

Discussion: Dichotomous and categorical assessments of sleep health may not be sensitive to interaction effects, compared with continuous data. Examining mental health symptoms (rather than diagnosis status) may also allow for a nuanced understanding of potential interactions.

It is well established that many children and adolescents in the United States do not obtain sufficient sleep. For instance, recent estimates suggest that one-third of children ages 4 months through 17 years obtain less sleep than is recommended for their age (Wheaton, 2021), with rates climbing to 70% among adolescents, specifically (Wheaton, 2018). At the same time that sleep deprivation is a national epidemic, many minors also experience significant levels of childhood adversity. Nationally representative data suggests that nearly half of minors have experienced at least one adverse childhood experience (ACE), and 1 in 10 have experienced multiple ACEs (Sacks and Murphey, 2018). Individuals with ACEs have been found to be at increased risk for mental illness (Boullier and Blair, 2018; Chapman *et al.*, 2013; Merrick *et al.*, 2017). These findings have been replicated with data from the National Survey of Children's Health (NSCH), a project which focuses on biological, psychological, social and environmental facets of children's lives, with the aim of better understanding how intersecting identities and experiences influence long-term health within childhood. Analyses of pooled NCHS responses from 2016 to 2019 suggest a dose-dependent relationship between ACEs and physical, mental and neurodevelopmental health outcomes (Walker *et al.*, 2022). The overlap between childhood adversity and sleep health is important to consider, as some adverse experiences may interfere with opportunities for and personal ability to acquire safe sleep, and healthy sleep may also be able to mitigate some negative effects that have been associated with ACE exposure.

It is likely that children and adolescents with histories of adversity may be especially at risk for poor sleep. For example, within these age groups, trauma exposure has frequently been linked with delayed sleep onset (Glod *et al.*, 1997; Lai *et al.*, 2020; Schneiderman *et al.*, 2018; Wittmann *et al.*, 2012), increased frequency of sleep disturbances (Baddam *et al.*, 2019; Schneiderman *et al.*, 2018; Wamser-Nanney and Chesher, 2018; Xiao *et al.*, 2020) and reduced sleep duration (Geng *et al.*, 2018; Schneiderman *et al.*, 2018; Wittmann *et al.*, 2012). Previous studies in adults ages 18–65 have also implicated sleep as a mediating factor between childhood trauma and severe mental health conditions (Laskemoen *et al.*, 2021), with similarly predictive relationships observed between ACEs and physical health during later adulthood (Mishra *et al.*, 2020). Potential biological mechanisms driving such relationships may include epigenetic variations (Lang *et al.*, 2020; Palagini *et al.*, 2015), changes in metabolism (Lee *et al.*, 2014) and variations in inflammatory processes (Dolsen *et al.*, 2019; Irwin *et al.*, 2016), associated with increased adversity, lack of healthy sleep, or both bidirectionally. Sleep has also been linked with emotional regulation and hypothalamic pituitary adrenal (HPA) axis reactivity (Blake *et al.*, 2018; Nicolaides *et al.*, 2020; Palmer and Alfano, 2017), which are theorized to influence habitual stress responses, even after the active threat has been resolved (van Dalfsen and Markus, 2018). Time spent in Rapid Eye Movement (REM), specifically, may also be especially crucial in processing traumatic experiences, given its links to amygdala-hippocampus-medial prefrontal cortex circuitry and memory formation (Genzel *et al.*, 2015; Murkar and De Koninck, 2018). Appropriate sleep duration and depth have also been shown to prevent intrusive memories and ruminations in some adults (Colvonen *et al.*, 2019; Porcheret *et al.*, 2020). Despite these converging findings on sleep's potentially protective influence on maintaining wellbeing after adversity, to our knowledge, sleep health has not included in previous NSCH analyses on ACEs and mental health and has been rarely studied as a preventative measure in this context (Crouch et al., 2019).

Emerging research points towards a compelling yet complex relationship among ACEs, mental health and sleep. Overall, findings suggest that childhood adversity leads to increased difficulties with sleep and that increased mental health difficulties also often predict poorer sleep. However, there is some variance in which aspects of these relationships are observed as directly or indirectly causal. For example, a study of 529 adolescents (Calhoun *et al.*, 2019) found significant direct links among childhood adversity, increased externalizing symptoms and sleep problems reported on the Sleep Habits Survey (Wolfson *et al.*, 2003). Yet, more indirect interactions between these factors did not explain variance in internalizing or externalizing symptom levels (Calhoun *et al.*, 2019). This could suggest that different children experience sleep after adversity in different ways, some may go on to have poorer mental health as a result of poorer sleep, and some may encounter other factors that promote resilience in either or both domains. A separate child and adolescent study, which suggested that sleep duration was significantly linked with the onset of severe mental illness, found that the association between these factors was strongest in those youth who had also experienced psychosocial stressors, including discrimination, bullying and feeling unsafe in their neighborhoods or schools (Malika *et al.*, 2023). This may indicate that children with histories of adversity could be especially sensitive to sleep-related preventative interventions. In this vein, levels of sleep disturbance have also been shown to mediate the relationship between child maltreatment and increased depressive symptoms in Chinese youth (Chang *et al.*, 2023). Another study has tested sleep as an outcome instead of as a moderator, with levels of depression and anxiety moderating the relationship between sleep and ACEs (Park *et al.*, 2021). This can suggest that the interplay between these components may be complex or multidirectional (Park *et al.*, 2021). Considered in tandem, these studies may suggest that healthy sleep may be a protective factor against the development of some mental health conditions in the face of adverse events. However, effects may differ between mental health conditions (i.e. internalizing, externalizing, acquired, neurodevelopmental, etc.). Further understanding of which mental health symptoms these associations are present for could help identify those who would benefit most from sleep intervention after ACE exposure.

Just as it is important to improve understanding of specific components of mental health that may be most impacted by sleep in the context of adversity exposure, it is also important to consider which specific facets of sleep may be most salient within such relationships. Sleep health is a multidimensional construct, with models of pediatric sleep health such as the B-SATED encompassing **B**ehaviors, **S**atisfaction/quality, daytime **A**lertness/sleepiness, sleep **T**iming, sleep **E**fficiency and sleep **D**uration (Meltzer and Paisley, 2023). Duration is by far the most commonly studied aspect of sleep health, and short sleep has consistently been linked with poor mental health outcomes across developmental periods (Zhang *et al.*, 2017; Zhang *et al.*, 2024). It is possible that youth with ACEs, which are also associated with physical and mental health risks (Boullier and Blair, 2018; Chapman *et al.*, 2013; Merrick *et al.*, 2017), may be especially susceptible to the potential compounding effects of short sleep. Sleep duration is also closely linked with sleep regularity, which is one aspect of sleep timing. Sleep regularity can denote the level of consistency in the timing of available sleep windows, thereby informing consistency of sleep duration. Even if adequate sleep duration is achieved across a measurement period, if it is achieved in an irregular manner, it may reflect a mismatch between biological sleep drives and sleep behavior, which is also associated with mental health risk (Henderson *et al.*, 2019; Mathew *et al.*, 2019; Tamura and Okamura, 2023).

In the proposed study, we seek to investigate the potentially moderating influence of adequate sleep duration and consistent weekday sleep timing on the relationship between ACE exposure and child and adolescent mental health. In this secondary analysis of NSCH nationally representative datasets, we use a series of logistic and ordinal regressions to explore the interaction between the two available sleep-related variables (child sleeping an adequate amount and weekday bedtime regularity) and adverse childhood event exposure (total ACE count, household-based ACEs, community-based ACEs and single ACEs) and their influence on mental health outcomes (overall presence and severity of anxiety, depression, behavioral/conduct, ADHD). Our analysis is a replication and extension of the existing literature base. Specifically, 1) we hypothesize that higher ACE scores will significantly predict increased presence or severity of current mental health conditions (replication); 2) we hypothesize that decreased sleep health (lower duration or more irregular bedtime) will significantly predict increased presence or severity of current mental health conditions (replication); and 3) we hypothesize that the interaction between increased ACE count and decreased sleep duration or increased bedtime irregularity will significantly predict increased presence or severity of current mental health conditions (extension). We will also examine whether different types of ACEs (household count vs. community count vs. single) differentially drive relationships between ACE and sleep and mental health (exploratory aim).

Methods

Survey sampling and administration

We performed secondary analyses of cross-sectional data from the 2020–2021 waves of the National Survey of Children's Health (NSCH; Child and Adolescent Health Measurement Initiative, 2023b). A benefit of recent revisions in NSCH items is the inclusion of household and community ACEs, which may represent different types of exposure levels (internal vs. external, chronic vs. acute, interpersonal vs. environmental, etc.), and which may uniquely impact mental health and/or sleep attainability. Although this dataset includes timepoints within the COVID-19 pandemic, we selected this wave due to its inclusion of additional ACE items. Given that this data is publicly available, this analysis was not subject to IRB review. This US Census Bureau survey is administered online and by mail. After parents respond to an initial screening survey with the age and sex of minors in the home, one child from each household is randomly selected to participate. Selection and survey data are weighted to derive state- and nationally representative samples of non-institutionalized children and youth (0–17). More information on this process can be viewed in the 2021 National Survey of Children's Health codebook and methodology report (CAMHI, 2023a; CAHMI, 2023c). 92,669 completed surveys were available in the combined years' dataset (approximately 1,873 per state; 42,777 total in 2020, and 50,892 in 2021). Due to high levels of missing responses (18.8–19.7%) on some items informing demographic aggregates, values for income, household count, parent education and federal poverty level were imputed by the US Census Bureau with regression imputation methods. For variables with nearly 5% missingness (i.e. race, ethnicity, sex), the U.S. Census Bureau used hot-deck imputation. More information on rates of missingness and statistical corrections can be found in the NSCH 2020–2021 codebook (CAHMI, 2023b).

Measures

Additional information on all items is available in the NSCH codebook (CAHMI, 2023b).

Adverse childhood experiences

ACEs served as one main predictor in each of the models. NSCH ACEs encompass insufficient household income, parent/guardian divorce/separation, parent/guardian death, parent/guardian jailed, a child experiencing or witnessing domestic violence, the child witnessing or experiencing neighborhood violence, the child living with an individual with mental illness, the child living with individual abusing alcohol or drugs, the child being treated unfairly due to race/ethnicity and child being treated unfairly due to sexuality or gender identity. All items were dichotomous yes (1) no (2) answers and were recoded as 1 for yes and 0 for no, except for income, wherein responses of "somewhat often" or "very often" were recoded as yes (1). Additionally, the item on discrimination due to sexuality/gender was not administered to parents of children under 6 years and was not included in their cumulative ACE counts. The total ACE count was calculated by the sum (0–10) of ACEs coded as yes (1) for each child. Household ACE count was the sum of items ACE3 (divorce), ACE4 (parent/guardian death), ACE5 (parent/guardian jail), ACE6 (domestic violence), ACE8 (lived with someone with mental illness) and ACE 9 (lived with someone who had a problem with alcohol or drugs). Community ACE count was the sum of items ACE7 (experienced violence in neighborhood), ACE10 (treated or judged unfairly due to race/ethnicity) and ACE12 (treated or judged unfairly due to sexuality/gender).

Sleep duration

Adequate sleep duration was a main predictor in half of the models. Sleep duration was measured with one item. The Census Bureau asked parents to record children's average sleep duration on weeknights and then recoded responses above the American Academy of Sleep Medicine guidelines for each age as 1 and those below the guideline as 2. We recoded this as adequate sleep duration being 1 and inadequate sleep duration being 0.

Sleep irregularity

Sleep irregularity was also a main predictor in half of the models. Sleep irregularity was measured with an item where parents were asked how often their child goes "to bed at about the same time on weeknights." 1 denoted "Always," 2 "Usually," 3 "Sometimes" and 4 "Rarely or never." Thus, lower values indicated more regular sleep, and higher values more irregular sleep.

Diagnostic status

The presence of a mental health diagnosis (anxiety, depression, behavioral, ADHD, combined) served as the outcome in omnibus mental health and individual condition logistic regression models. Information on current mental health diagnoses was obtained from items K2Q31–34 ("Have you ever told by a health care provider that the child has [condition].") After parents indicated that their child had received the relevant mental health diagnosis at some point in their lifetime, parents indicated whether their child still currently had the diagnosis (1) or did not currently have the diagnosis (2). We recoded these entries with the current diagnosis represented with 1, and no current diagnosis represented by 0. We also created an omnibus mental health variable in Microsoft Excel Version 16 (Redmond, Washington), with the presence of one or more of the four tested mental health conditions being coded as 1, and the absence of all conditions coded as 0.

Symptom severity

Those who endorsed the current diagnosis of a condition were also asked about its severity. ("Would you describe this child's current [condition] as mild, moderate or severe.") Diagnosis severity for each condition was derived from items K2Q31–34C, with 1 denoting "mild," 2 "moderate," and 3 "severe." These single-item rankings served as an outcome in ordinal regression models.

Covariates. To select covariates, items describing factors known to be associated with ACEs were incorporated into a directed acyclic graph (DAG), representing a non-parametric structural equation model for variable interactions. We tested for federal poverty level (income and household size), parental education status, child age, child sex, neighborhood safety, neighborhood support and race/ethnicity (please see codebook for additional information on these items; CAHMI, 2023b). The final DAG indicated that models would be correctly adjusted when including all tested variables.

Data preparation

In the final dataset, the missingness of all variables did not significantly correlate with the missingness of any independent or dependent variable included in this analysis. Before performing the analyses, the dataset was examined for assumptions of linear and ordinal regression. There were no outliers due to the limited age of the sample and the categorical nature of all other values. The linearity of independent variables and log odds was visually inspected with scatter plots. Lack of significant multicollinearity was ensured with variance inflation factors (VIF) being under 10. Proportional odds between outcome groups were verified with nonsignificant brant test results ($p > 0.05$). In cases where one covariate did not meet this assumption, this covariate was eliminated from the model. In cases where more than one covariate did not meet this assumption, separate models were conducted with one covariate removed at a time.

All analyses were performed in RStudio. Version 2023.09.1+494 (Boston, MA). To facilitate self-replication and account for multiple comparisons, the full dataset was split into two randomized halves using the strata_col function. Age, sex, race, poverty status, parental education status, neighborhood support and neighborhood safety were stratified to be as equivalent as possible between the randomized halves. In all, there were 12 models where sleep duration was the sleep-related predictor. The first logistic regression model included total ACE as another predictor, and diagnostic status of any of the four mental health conditions (anxiety, depression, behavioral, ADHD) as the outcome. The next series of logistic regression models had the same predictors but used the diagnostic status of each individual mental health condition as a separate outcome. Four more ordinal regression models followed, with the outcome being the severity of each of the four mental health conditions, rather than the presence of diagnosis.

After examining different mental health outcomes, the study extension involved examining different conceptualizations of ACEs. First, household ACE count was used as the predictor of the presence of any of the four tested mental health diagnoses, followed by community ACE count. Ten logistic regression models examining each single ACE as separate predictors were then conducted. All models were then repeated with sleep irregularity, rather than duration, as the sleep-related predictor.

After performing analyses on the first half of the dataset, any model that included significant main effects for ACE- or sleep-related variables or significant interactions between them was repeated in the second half of the dataset. Only models with significant outcomes in both runs were retained as significant.

If interactions between ACEs and sleep duration were significant such that inadequate sleep duration predicted worse mental health in the presence of ACEs, we planned to explore family resilience items as predictors (vs. ACEs) to examine the potential confounding impact of family traits potentially promoting healthy sleep behavior and improved mental health in tandem, without sleep being a moderating factor. If interactions between ACEs and sleep irregularity were significant such that greater sleep irregularity predicted worse mental health in the presence of ACEs, we planned to explore other aspects of family routines (screen and mealtime) to explore whether the effect was related to consistency in family routines across domains, rather than being unique to sleep behaviors.

Following these analyses, we also elected to perform post-hoc follow-up analysis by developmental period (0–5, 6–11, 12–17 years) to see whether directionality or magnitude was impacted by biological or social factors known to impact sleep in adolescence vs. early childhood. All models described above were repeated with data limited to each age-stratified category. These exploratory, stratified findings are reported within the same tables for each applicable model. Importantly, when dividing the NSCH dataset by anything other than state of residence, samples are no longer nationally representative, and analyses have the potential for inaccurate standard error estimation; exploratory findings are thus interpreted with caution. Because the sample size was reduced when splitting the sample by age, this data was not further split into halves for self-replication. Although all p-values were recorded in tables, for clinical interpretation, only $p < 0.01$ was deemed clinically significant, in an effort to correct for multiple comparisons in a conservative manner.

Results

In the initial full age group analysis, significant main effects of ACEs, sleep duration (see Tables 1–5) and bedtime regularity (see Tables 1, 4–7) were replicated across both halves of the split dataset for all models (Figure 1).

Hypothesis 1 ***(Replication): Higher ACE Scores Will Significantly Predict Increased Presence or Severity of Current Mental Health Conditions***

Across all age groupings in the models for sleep duration and regularity, higher cumulative ACE scores were significantly predictive of greater likelihood of currently experiencing any mental health condition (anxiety, depression, behavioral, or ADHD) (Duration: Bs = 0.257–0.359, *ps* < 0.001; Regularity: Bs = 0.387–0.458, *ps* < 0.001; Table 1). Cumulative ACE scores were similarly predictive of the presence of each separate mental health condition across models for both sleep variables and all age groupings (Duration: Bs = 0.222–0.641, *ps* < 0.001 (Table 2); Regularity: Bs = 0.358–1.027, *ps* < 0.001 (Table 5). In the models for sleep duration, cumulative ACE count was predictive of anxiety, depression, behavioral disorder and ADHD severity, with some variance between developmental groups identified during follow-up exploratory analyses (see Table 3). Findings were similar in the models for bedtime regularity, with higher ACE counts predicting greater anxiety, behavioral disorder and ADHD severity in the combined age models, but not depression severity, save within the 12–17 years group (see Table 5).

Hypothesis 2 ***(Replication): Decreased Sleep Health (Lower Duration or More Irregular Bedtime) will Significantly Predict Increased Presence or Severity of Current Mental Health Conditions***

The presence of adequate sleep duration was associated with a lower likelihood of a current mental health diagnosis across all age groups (B = –0.285 – 0.407, $p < 0.0001$; Table 1). This pattern was similar across all age groups for the presence of behavioral disorders (B = –0.362 – –0.524, $p < 0.0001$; Table 1) or ADHD specifically (B = –0.289 – 0.397, $p < 0.0001$; Table 1). It was also similar for the presence of anxiety (Bs = –0.285 – –0.140, *ps* < 0.01) and depression (Bs = –0.429 – 0.260, *ps* < 0.001) across all age groups except 0–5 years (Table 2).

In models exploring sleep duration and mental health condition severity, meeting sleep duration recommendations was variably associated with symptom intensity, with observed effects largely driven by younger cohorts as opposed to adolescent groups (see Table 3).

Greater bedtime irregularity was associated with an increased likelihood of any current mental health diagnosis across all age groups (Bs = 0.136–0.302, *ps* < 0.01) (Table 1). In models for individual diagnoses, this trend was consistent across all age groupings for the presence of depressive disorders (B = 0.103–0.574, $p < 0.0001$; Table 6) and for the presence of behavioral disorders (B = 0.133–0.332, $p < 0.01$; Table 6), with some variance for anxiety and ADHD. This may suggest that combined effects are driven by older cohorts. Increased bedtime irregularity was also variability predictive of increased severities for all tested conditions, with trends being most consistent within adolescent age groups (12–17 years Bs = 0.105–0.197, ps < 0.01) (Table 7).

Hypothesis 3 ***(Extension): The Interaction Between Increased ACE Count and Decreased Sleep Duration and/or Increased Bedtime Irregularity will Significantly Predict Increased Presence or Severity of Current Mental Health Conditions***

The presence of adequate sleep duration in conjunction with increased omnibus ACE count marginally increased the likelihood

Table 1. Overall presence of mental health conditions predicted by ACE count for sleep duration and bedtime regularity

	Sleep Duration β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.319 (0.032)***	0.359 (0.072)***	0.302 (0.039)***	0.257 (0.030)***
Sleep Duration	−0.309 (0.037)***	−0.407 (0.081)***	−0.285 (0.044)***	−0.320 (0.036)***
Age	0.111 (0.003)***	0.397 (0.042)***	0.120 (0.010)***	0.039 (0.008)***
Sex	−0.273 (0.028)***	−0.652 (0.068)***	−0.602 (0.034)***	−0.004 (0.026)
Race	−0.038 (0.010)***	−0.010 (0.021)	−0.027 (0.011)*	−0.058 (0.009)***
Poverty	0.041 (0.016)***	−0.066 (0.036)	0.028 (0.019)	0.051 (0.015)***
Education	0.150 (0.019)***	0.028 (0.046)	0.069 (0.023)**	−0.187 (0.018)***
Nbhd Support	−0.208 (0.032)***	−0.397 (0.075)***	−0.216 (0.039)***	−0.175 (0.030)***
Nbhd Safety	0.120 (0.028)***	0.141 (0.060)*	0.103 (0.033)**	0.076 (0.028)**
ACE*Duration	0.048 (0.019)***	0.050 (0.045)	0.056 (0.023)*	0.067 (0.017)***
	Bedtime Regularity β (SE)			
ACE Count	0.458 (0.025)***	0.414 (0.060)***	0.387 (0.030)***	0.396 (0.024)***
Bedtime Regularity	0.230 (0.024)***	0.136 (0.056)*	0.141 (0.030)***	0.302 (0.022)***
Age	0.104 (0.003)***	0.427 (0.041)***	0.126 (0.010)***	0.024 (0.008)**
Sex	−0.273 (0.028)***	−0.659 (0.068)***	−0.610 (0.034)***	−0.005 (0.026)
Race	−0.038 (0.010)***	−0.008 (0.021)	−0.028 (0.011)*	−0.058 (0.009)***
Poverty	0.036 (0.016)*	−0.077 (0.036)*	0.020 (0.018)	0.049 (0.015)***
Education	0.147 (0.019)***	0.007 (0.046)	0.055 (0.023)*	0.195 (0.018)***
Nbhd Support	−0.195 (0.032)***	−0.405 (0.075)***	−0.213 (0.039)***	−0.140 (0.030)***
Nbhd Safety	0.110 (0.028)***	0.128 (0.060)*	0.092 (0.033)**	0.067 (0.028)*
ACE* Regularity	−0.030 (0.011)**	0.009 (0.027)	0.003 (0.015)	−0.017 (0.010)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

of the presence of a current mental health condition in the combined age samples and for all age groups (Bs = 0.048 – 0.067, $ps < 0.01$), but not for ages 0–5 (B = 0.050, $p > 1$; Table 1). There were also some similarly small significant interactions between ACE count and sleep duration within older age groups for models representing individual mental health conditions (Table 2). These small coefficient values are likely flagged as statistically significant due to the large sample size but are an order of magnitude smaller than the main effects and are unlikely to be clinically significant. Across models for mental health symptom severity, the interaction between ACE count and sleep duration was nonsignificant, except for depression severity in ages 6–11 (B = −0.216, $p < 0.01$; Table 7). This model suggests that adequate sleep duration in the presence of ACEs was associated with reduced symptom severity in children of that age with a current depression diagnosis as compared with those in the same cohort who had lower ACE counts and inadequate sleep.

The presence of increased sleep irregularity in conjunction with increased omnibus ACE count was associated with a marginally significant decrease in the likelihood of the presence of a current mental health condition in the combined age samples (B = −0.030, $p < 0.001$) but not by age group (see Table 1). As with findings for the interaction between sleep duration and ACEs, effects of such small magnitude are unlikely to be clinically significant. Models for individual mental health conditions followed a similar pattern, with increased bedtime irregularity in the presence of increased ACEs being associated with marginal decreases in mental health diagnoses for most conditions and age groups (see Table 6). Only one interaction for condition severity within diagnostic groups and age groups emerged as statistically significant. It followed the same pattern of directionality and magnitude as the omnibus model. Specifically, for ages 0–5, increased bedtime irregularity in the presence of increased ACEs was associated with a small decrease in behavioral disorder symptom severity ratings (B = −0.099, $p < 0.01$; Table 7).

Exploratory Aim: Different Types of ACEs (Household Count vs. Community Count vs. Single) May Drive Relationships Between ACE and Sleep and Mental Health

After examining the effects of total ACE count on mental health outcomes, we repeated omnibus models with ACE totals separated by household-based ACEs and community-based ACES. We observed no critical differences between models for each ACE grouping, with trends generally following the same direction and relative magnitude observed in models for overall ACE counts (see Tables 4 and 5). We also examined the predictive effects of each single ACE (see Supplementary Tables 1 and 2). The main effects for all individual ACEs (income, divorce, death, jail, domestic violence, neighborhood violence, caregiver/household mental health, drug, racial discrimination and sexual discrimination) on omnibus mental health outcomes were significant across sleep

Table 2. Specific mental health conditions predicted by ACE count and sleep duration

	Anxiety β (SE)				Depression β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.360 (0.017)***	0.431 (0.046)***	0.351 (0.021)***	0.324 (0.015)***	0.445 (0.021)***	0.641 (0.119)***	0.470 (0.413)***	0.407 (0.232)***
Sleep Duration	−0.228 (0.047)***	−0.251 (0.134).	−0.140 (0.059)*	−0.285 (0.042)***	−0.397 (0.074)***	−0.260 (0.568)	−0.425 (0.132)**	−0.429 (0.057)***
Age	0.139 (0.004)***	0.415 (0.067)***	0.150 (0.013)***	0.082 (0.009)***	0.271 (0.008)***	0.788 (0.277)**	0.358 (0.030)***	0.170 (0.012)***
Sex	0.227 (0.034)***	−0.156 (0.104)	−0.184 (0.043)***	0.510 (0.031)***	0.445 (0.052)***	−0.008 (0.381)	−0.185 (0.091)*	0.555 (0.040)***
Race	−0.056 (0.012)***	−0.020 (0.033)	−0.047 (0.015)**	−0.066 (0.011)***	−0.059 (0.018)**	−0.117 (0.130)	−0.005 (0.028)	−0.048 (0.014)***
Poverty	0.098 (0.020)***	−0.071 (0.057)	0.047 (0.024)	0.092 (0.017)***	0.018 (0.029)	−0.095 (0.210)	−0.066 (0.050)	0.032 (0.022)
Education	0.220 (0.025)***	0.093 (0.074)	0.205 (0.032)***	0.220 (0.021)***	0.135 (0.035)	0.119 (0.263)	0.025 (0.060)	0.165 (0.027)***
Nbhd Support	−0.230 (0.039)***	−0.430 (0.120)***	−0.219 (0.050)***	−0.206 (0.035)***	−0.319 (0.058)	−0.660 (0.483)	−0.191 (0.106)	−0.345 (0.045)***
Nbhd Safety	0.103 (0.034)**	0.071 (0.094)	0.176 (0.042)***	0.079 (0.032)*	0.073 (0.050)	0.388 (0.304)	0.227 (0.081)**	0.041 (0.039)
ACE*Duration	0.034 (0.021)	0.092 (0.061)	0.041 (0.026)	0.054 (0.018)**	0.033 (0.027)	0.070 (0.159)	0.004 (0.042)	0.055 (0.021)**
	Behavioral β (SE)				ADHD β (SE)			
ACE Count	0.357 (0.0175)***	0.380 (0.036)***	0.341 (0.021)***	0.336 (0.018)***	0.272 (0.017)***	0.355 (0.049)***	0.274 (0.020)***	0.222 (0.016)***
Sleep Duration	−0.404 (0.054)***	−0.524 (0.093)***	−0.372 (0.059)***	−0.362 (0.061)***	−0.289 (0.047)***	−0.397 (0.140)**	−0.328 (0.054)***	−0.312 (0.045)***
Age	−0.005 (0.005)	0.363 (0.048)***	−0.001 (0.013)	−0.133 (0.012)***	0.102 (0.004)***	0.699 (0.078)***	0.148 (0.012)***	−0.024 (0.010)*
Sex	−0.904 (0.043)	−0.875 (0.081)***	−0.94 (0.047)***	−0.879 (0.046)***	−0.764 (0.037)***	−0.944 (0.124)***	−0.813 (0.043)***	−0.756 (0.034)***
Race	0.012 (0.013)	−0.008 (0.024)	0.006 (0.014)	−0.003 (0.014)	−0.021 (0.012)	−0.054 (0.038)	−0.014 (0.013)	−0.041 (0.012)***
Poverty	−0.038 (0.022)	−0.073 (0.041)	−0.019 (0.024)	−0.064 (0.023)**	−0.016 (0.020)	−0.179 (0.061)**	−0.009 (0.023)	0.005 (0.018)
Education	0.037 (0.027)	0.039 (0.052)	−0.024 (0.029)	0.101 (0.028)***	0.058 (0.024)*	−0.089 (0.074)	−0.032 (0.028)	0.113 (0.022)***
Nbhd Support	−0.314 (0.046)***	−0.455 (0.087)***	−0.301 (0.050)***	−0.280 (0.049)***	−0.157 (0.041)***	−0.364 (0.130)**	−0.168 (0.047)***	−0.069 (0.038)
Nbhd Safety	0.192 (0.038)***	0.165 (0.067)*	0.163 (0.041)***	0.222 (0.041)	0.064 (0.036)	0.045 (0.102)	0.006 (0.041)	0.035 (0.035)
ACE*Duration	0.080 (0.022)***	0.094 (0.049)	0.087 (0.026)***	0.067 (0.022)**	0.050 (0.021)*	0.031 (0.069)	0.054 (0.026)*	0.089 (0.019)***

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Table 3. Severity of specific mental health conditions predicted by ACE count and sleep duration

	Anxiety				Depression			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.151 (0.026)***	0.037 (0.086)	0.078 (0.035)*	0.183 (0.022)***	0.155 (0.035)***	0.359 (0.072)***	0.159 (0.059)**	0.161 (0.027)***
Sleep Duration	−0.056 (0.085)	−0.513 (0.252)*	−0.219 (0.110)*	0.044 (0.074)	0.041 (0.0141)	−0.407 (0.081)***	0.364 (0.274)	−0.074 (0.106)
Age	0.050 (0.008)***	0.191 (0.088)*	0.024 (0.024)	0.081 (0.015)***	0.081 (0.018)***	0.397 (0.042)***	0.105 (0.061)	0.061 (0.022)**
Sex	0.055 (0.060)	−0.031 (0.191)	−0.067 (0.079)	0.098 (0.052)	0.341 (0.093)***	−0.652 (0.068)***	0.240 (0.176)	0.278 (0.071)
Race	−0.033 (0.021)	−0.062 (0.059)	–	−0.012 (0.019)	−0.033 (0.032)	−0.010 (0.021)	0.049 (0.051)	−0.006 (0.024)
Poverty	−0.083 (0.031)**	−0.024 (0.093)	−0.120 (0.045)**	−0.043 (0.029)	−0.018 (0.051)	−0.066 (0.036)	−0.136 (0.099)	0.013 (0.035)
Education	–	–	−0.064 (0.060)	−0.065 (0.037)	0.040 (0.065)	0.028 (0.046)	−0.040 (0.122)	–
Nbhd Support	−0.195 (0.067)**	−0.231 (0.220)	−0.039 (0.091)	−0.167 (0.058)**	−0.159 (0.102)	−0.397 (0.075)***	0.340 (0.213)	−0.176 (0.077)
Nbhd Safety	0.022 (0.058)	0.227 (0.165)	0.065 (0.074)	0.024 (0.051)	0.123 (0.085)	0.141 (0.059)*	0.142 (0.160)	0.045 (0.066)
ACE*Duration	0.014 (0.033)	0.159 (0.111)	0.028 (0.044)	−0.035 (0.027)	−0.030 (0.044)	0.050 (0.045)	−0.216 (0.083)**	−0.02 (0.034)
	Behavioral				ADHD			
ACE Count	0.148 (0.029)***	0.122 (0.057)*	0.169 (0.034)*** 0.172 (0.034)***	0.138 (0.029)***	0.149 (0.028)***	−0.003 (0.084)	0.177 (0.032)***	0.137 – 0.140 (0.026)***
Sleep Duration	−0.174 (0.101)	−0.405 (0.166)*	−0.310 (0.108)** −0.324 (0.108)**	0.082 (0.113)	−0.089 (0.086)	−0.260 (0.262)	−0.299 (0.096)**	−0.032 – −0.037 (0.082)
Age	−0.008 (0.009)	0.098 (0.062)	−0.049 (0.023)* −0.049 (0.023)*	−0.34 (0.023)	−0.077 (0.009)***	0.087 (0.114)	−0.103 (0.023)***	−0.065 – −0.063 (0.017)***
Sex	−0.128 (0.078)	−0.184 (0.147)	−0.258 (0.085)** −0.255 (0.085)**	0.105 (0.082)	−0.162 (0.067)*	−0.099 (0.230)	−0.194 (0.077)*	−0.184 (0.061)
Race	–	−0.017 (0.041)	– −0.018 (0.024)	−0.018 (0.026)	–	0.009 (0.068)	−0.009 (0.024)	0.016 (0.021)
Poverty	−0.157 (0.040)***	−0.088 (0.072)	−0.119 (0.044)** −0.147 (0.039)***	−0.168 (0.041)***	−0.169 (0.035)***	–	−0.147 (0.037)***	−0.118 – −0.119 (0.032)***
Education	−0.038 (0.050)	−0.236 (0.094)*	−0.076 (0.054) –	−0.042 (0.051)	−0.018 (0.045)	−0.386 (0.125)**	–	−0.06 – −0.052 (0.041)
Nbhd Support	−0.083 (0.082)	−0.183 (0.157)	0.004 (0.089) 0.006 (0.089)	−0.130 (0.085)	−0.067 (0.071)	−0.302 (0.231)	−0.103 (0.083)	−0.184 – −0.178 (0.066)**
Nbhd Safety	0.069 (0.065)	0.003 (0.117)	0.163 (0.072) 0.168 (0.071)*	0.021 (0.069)	0.181 (0.061)**	0.047 (0.173)	0.152 (0.071)*	0.134 – 0.143 (0.059)
ACE*Duration	0.028 (0.037)	0.102 (0.081)	−0.037 (0.043) −0.038 (0.043)	−0.011 (0.037)	0.002 (0.035)	0.090 (0.125)	0.014 (0.042)	0.015 – 0.017 (0.032)

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– Denotes models in which question was not available to cohort or in which models did not meet assumptions of regression and are thus not interpreted; Range provided if more than one covariate resulted in significant Brant test; separate models were conducted with one covariate with Brant $p > 0.05$ removed at a time.

Table 4. Overall presence of mental health conditions predicted by household ACE count and sleep duration and bedtime regularity

	Sleep Duration β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.662 (0.052)***	0.983 (0.145)***	0.649 (0.070)***	0.664 (0.046)***
Sleep Duration	−0.311 (0.031)***	−0.400 (0.070)***	−0.267 (0.037)***	−0.285 (0.030)***
Age	0.122 (0.003)***	0.410 (0.041)***	0.133 (0.010)***	0.042 (0.008)***
Sex	−0.270 (0.027)***	−0.655 (0.067)***	−0.570 (0.033)***	−0.010 (0.025)
Race	−0.040 (0.009)***	−0.004 (0.021)	−0.027 (0.011)*	−0.064 (0.009)***
Poverty	−0.052 (0.015)***	−0.151 (0.035)***	−0.064 (0.018)***	−0.032 (0.014)*
Education	0.090 (0.019)***	−0.044 (0.044)	0.006 (0.022)	0.124 (0.017)***
Nbhd Support	−0.267 (0.031)***	−0.439 (0.074)***	−0.265 (0.038)***	−0.230 (0.029)***
Nbhd Safety	0.143 (0.027)***	0.178 (0.059)**	0.148 (0.032)***	0.101 (0.027)***
ACE*Duration	0.167 (0.068)*	0.052 (0.207)	0.089 (0.091)	0.123 (0.058)*
	Bedtime Regularity β (SE)			
ACE Count	0.922 (0.092)***	0.938 (0.272)***	0.871 (0.118) ***	0.729 (0.083)***
Sleep Duration	0.239 (0.020)***	0.202 (0.046)***	0.184 (0.025) ***	0.312 (0.018)***
Age	0.113 (0.003)***	0.443 (0.041)***	0.138 (0.009)***	0.025 (0.008)**
Sex	−0.270 (0.027)***	−0.664 (0.067)***	−0.581 (0.033)***	−0.012 (0.025)
Race	−0.040 (0.010)***	−0.003 (0.021)	−0.028 (0.011)*	−0.064 (0.009)***
Poverty	−0.056 (0.015)***	−0.161 (0.035)***	−0.073 (0.018)***	−0.032 (0.014)*
Education	0.086 (0.019)***	−0.062 (0.044)	−0.008 (0.022)	0.134 (0.017)***
Nbhd Support	−0.250 (0.031)***	−0.446 (0.074)***	−0.260 (0.038) ***	−0.189 (0.029)***
Nbhd Safety	0.131 (0.027)***	0.161 (0.059)**	0.135 (0.032)***	0.090 (0.027)***
ACE* Regularity	−0.078 (0.038)*	0.022 (0.115)	−0.091 (0.055)	−0.006 (0.034)

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duration models for combined ages as well as each age group (see Supplementary Table 1). The main effects for each ACE were also significant for all bedtime irregularity models, except for those examining death and racial discrimination within ages 0–5 (see Supplementary Table 2). Significant main effects for sleep duration and bedtime irregularity on omnibus mental health were also maintained for each single ACE model (See Supplementary Tables 1 and 2). The directionality of these effects was consistent with all combined ACE models (see Tables 1, 4 and 5 and Supplementary Tables 1 and 2).

Because combined age group interactions between ACEs and sleep duration and bedtime irregularity were not significant, we did not examine family resilience or routines (mealtime and screen use) as predictors in follow-up models.

Discussion

In this secondary analysis of a nationally representative dataset, known main effects for the influences of ACE and sleep duration and sleep irregularity were largely replicated, but interactions between these factors were clinically insignificant. Specifically, our first replication hypothesis was that higher ACE scores would significantly predict the increased presence or severity of current mental health conditions. Across age groups and conditions, higher levels of ACEs generally predicted a higher likelihood of mental health diagnosis or symptom severity. In regard to our exploratory aim surrounding types of adversity, this pattern was also maintained for conceptualizations of ACEs as a cumulative count, as separated by household and community exposure, and as single predictors, save some single-ACEs (jail and death) in ages 0–5. This can suggest that many types of early adversity correspond with negative mental health outcomes in minors.

Our second replication hypothesis was that decreased sleep health (lower duration or less regular bedtime) would significantly predict increased presence or severity of current mental health conditions. These hypotheses generally held, with some variance, especially within lower age groups. This indicates that multiple facets of sleep health are important to consider in assessments of mental health risk in early developmental periods.

Our third extension hypothesis was that the interaction between increased ACE count and decreased sleep duration would significantly predict the increased presence or severity of current mental health conditions, thus suggesting a moderating influence of sleep on the relationship between early adversity and current mental health. Although the main effects identified sleep duration and regularity as protective factors against negative mental health outcomes when ACEs were controlled, interaction effects between sleep outcomes in the presence of increased ACEs did not reveal clinically significant protective effects. In many models, improved sleep health (adequate duration or decreased irregularity) was associated with statistically significant increases in adverse mental health outcomes (diagnosis and severity). This is opposite in

Table 5. Overall presence of mental health conditions predicted by community ACE count and sleep duration and bedtime regularity

	Sleep Duration β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.415 (0.019)***	0.448 (0.041)***	0.405 (0.022)***	0.356 (0.018)***
Sleep Duration	−0.303 (0.036)***	−0.417(0.078)***	−0.281 (0.043)***	−0.320 (0.035)***
Age	0.116 (0.003)***	0.392 (0.041)***	0.124 (0.010)***	0.046 (0.008)***
Sex	−0.264 (0.028)***	−0.649 (0.067)***	−0.597 (0.034)***	0.003 (0.026)
Race	−0.026 (0.028)**	−0.003 (0.021)	−0.015 (0.011)	−0.046 (0.009)***
Poverty	0.010 (0.015)**	−0.107 (0.035)**	−0.001 (0.018)	0.021 (0.014)
Education	0.144 (0.019)***	0.024 (0.045)	0.066 (0.023)	0.179 (0.018)***
Nbhd Support	−0.246 (0.032)***	−0.430 (0.075)***	−0.242 (0.038)***	−0.211 (0.030)***
Nbhd Safety	0.171 (0.028)***	0.177 (0.059)***	0.150 (0.033)***	0.139 (0.027)***
ACE*Duration	0.034 (0.023)	0.051 (0.056)*	0.060 (0.028)*	0.069 (0.022)**
	Bedtime Regularity β (SE)			
ACE Count	0.491 (0.031)***	0.434 (0.074)***	0.406 (0.037)***	0.429 (0.030) ***
Bedtime Regularity	0.233 (0.023)***	0.157 (0.053)**	0.135 (0.029) ***	0.314 (0.022)***
Age	0.108 (0.003)***	0.424 (0.041)***	0.129 (0.010)***	0.029 (0.008)***
Sex	−0.265 (0.028)***	−0.658 (0.068)***	−0.605 (0.034)***	0.001 (0.026)
Race	−0.027 (0.009)**	−0.001 (0.021)	−0.016 (0.011)	−0.046 (0.009)***
Poverty	0.005 (0.015)	−0.117 (0.035)***	−0.010 (0.018)	0.020 (0.014)
Education	0.141 (0.019)***	0.002 (0.045)	0.052 (0.023)*	0.189 (0.018)***
Nbhd Support	−0.232 (0.032)***	−0.437 (0.075)***	−0.238 (0.038)***	−0.173 (0.030)***
Nbhd Safety	0.159 (0.028)***	0.163 (0.059)**	0.138 (0.033)***	0.126 (0.027)***
ACE*Regularity	−0.027 (0.014)*	0.019 (0.034)	0.019 (0.018)	−0.017 (0.013)

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direction to known main effects (see for example (Becker *et al.*, 2022; Blake and Allen, 2020; Wolfson *et al.*, 2015) and those replicated in this study. Given our large sample size and the small coefficient values for these effects, it is likely that these interactions are flagged as statistically significant even if they are not clinically significant.

In follow-up analyses by age group, one interaction was statistically significant and potentially clinically significant, suggesting that adequate sleep duration in the presence of ACEs was associated with significantly reduced depression severity in children ages 6–11 with a current depression diagnosis. This would be in line with past studies showing that low sleep duration corresponds with higher rates of depression in adolescents (Gao *et al.*, 2022; Short *et al.*, 2020); however, studies of depressive symptoms in younger cohorts are yet limited. Additionally, these stratified follow-up analyses were not established a priori or self-replicated, as were our omnibus models. We recommend that future studies explore these symptoms in this age group, in order to fully establish whether sleep interventions may be especially beneficial in this cohort. We also recommend that this finding be interpreted with caution, as it was not reflected within the broader pattern of interaction analyses.

Although it is possible that there is no clinically significant interaction between sleep health following adverse exposure and mental health difficulties within other conditions or other periods of childhood or adolescence, it is also possible that the single-item sleep constructs available in this dataset are not sufficiently sensitive to detect interaction effects. Analyses of continuous duration data may better account for individuals who sleep both under and over-recommended amounts to detrimental degrees. As hypersomnolence is a known symptom of depression and PTSD (American Psychological Association, 2013 Major Depressive Disorder criterion A4; Gupta, 2017; Kalantar-Hormozi and Mohammadkhani, 2024) this phenomenon may be especially important to capture in studies of individuals with ACE exposure. In this vein, a growing body of literature points towards health effects of sleep duration and regularity being curvilinear as opposed to linear, suggesting optimal protective benefits may be obtained in intermediate ranges (Dong *et al.*, 2022; Shimizu *et al.*, 2020; Tamura and Okamura, 2023). As dichotomized variables do not differentiate between participants obtaining adequate sleep and too much sleep, such effects remain uncaptured by this analysis. Given that continuous sleep data were reported by parents and then recoded by the US Census Bureau, reporting of original continuous sleep duration data may be possible with future datasets.

Additionally, the item for bedtime regularity only asked about weekday sleep routines. As we acknowledge that weekday sleep routines can potentially capture some elements of routine stability or family resilience, we also recognize the importance of contrasting weekday sleep with weekend sleep, in order to account for social jetlag (discrepancy in sleep timing between work and

Table 6. Specific mental health conditions predicted by ACE count and bedtime regularity

	Anxiety β (SE)				Depression β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.467 (0.028)***	0.611 (0.079)***	0.362 (0.034)***	0.400 (0.026)***	0.588 (0.037)***	1.027 (0.221)***	0.475 (0.056)***	0.564 (0.030)***
Bedtime Reg	0.269 (0.030)***	0.167 (0.090)*	0.078 (0.041)	0.330 (0.026)***	0.523 (0.045)***	0.103 (0.314)***	0.309 (0.086)***	0.574 (0.034)***
Age	0.131 (0.004)***	0.423 (0.066)***	0.151 (0.013)***	0.067 (0.009)***	0.252 (0.008)***	0.811 (0.276)**	0.366 (0.030)***	0.148 (0.012)***
Sex	0.230 (0.034)***	−0.165 (0.104)	−0.183 (0.043)***	0.516 (0.031)***	0.446 (0.052)***	−0.063 (0.381)	−0.188 (0.091)*	0.558 (0.040)***
Race	−0.057 (0.012)***	−0.029 (0.034)	−0.048 (0.015)***	−0.065 (0.011)***	−0.063 (0.018)***	−0.127 (0.130)	−0.005 (0.028)	−0.047 (0.014)**
Poverty	0.095 (0.020)***	−0.075 (0.057)	0.043 (0.024)	0.092 (0.017)***	0.011 (0.029)	−0.043 (0.208)	−0.078 (0.049)	0.030 (0.022)
Education	0.221 (0.025)***	0.085 (0.074)	0.204 (0.032)***	0.231 (0.021)***	0.148 (0.035)	0.172 (0.262	−0.00008 (0.059)	0.189 (0.027)***
Nbhd Support	−0.211 (0.039)***	−0.429 (0.120)***	−0.215 (0.050)***	−0.169 (0.035)***	−0.275 (0.059)	−0.561 (0.480)	−0.182 (0.106)	−0.276 (0.045)***
Nbhd Safety	0.089 (0.034)**	0.070 (0.094)	0.165 (0.042)***	0.065 (0.032)*	0.043 (0.050	0.320 (0.305)	0.188 (0.082)*	0.018 (0.039)
ACE*Regularity	−0.042 (0.012)***	−0.066 (0.037)	0.007 (0.016)	−0.023 (0.011)*	−0.058 (0.015)***	−0.161 (0.086)*	−0.004 (0.025)	−0.056 (0.012)***
	Behavioral β (SE)				ADHD β (SE)			
ACE Count	0.466 (0.030)***	0.390 (0.065)***	0.473 (0.034)***	0.405 (0.031)***	0.402 (0.028***	0.403 (0.090)***	0.367 (0.033)***	0.358 (0.027)***
Bedtime Reg	0.258 (0.035)***	0.133 (0.064)*	0.243 (0.040)***	0.332 (0.037)***	0.219 (0.031)***	0.097 (0.096)	0.171 (0.037)***	0.272 (0.028)***
Age	−0.012 (0.005)**	0.401 (0.047)***	0.005 (0.013)	−0.154 (0.013)***	0.096 (0.004)***	0.733 (0.078)***	0.156 (0.012)***	−0.037 (0.010)***
Sex	−0.907 (0.043)***	−0.878 (0.081)***	−0.947 (0.047)***	−0.889 (0.046)***	−0.763 (0.037)***	−0.953 (0.125)***	−0.821 (0.043)***	−0.759 (0.034)***
Race	0.011 (0.013)	−0.006 (0.024)	0.006 (0.014)	−0.002 (0.014)	0.022 (0.012)	−0.053 (0.038)	−0.013 (0.013)	−0.041 (0.012)**
Poverty	−0.045 (0.022)*	−0.090 (0.041)*	−0.031 (0.024)	−0.063 (0.023)**	−0.022 (0.020)	−0.195 (0.061)**	−0.020 (0.023)	0.003 (0.018)
Education	0.032 (0.027)	0.016 (0.052)	−0.039 (0.029)	0.112 (0.028)***	0.057 (0.024)*	−0.112 (0.074)	−0.049 (0.028)	0.122 (0.022)***
Nbhd Support	−0.298 (0.046)***	−0.459 (0.087)***	−0.297 (0.050)***	−0.236 (0.049)***	−0.145 (0.041)***	−0.386 (0.130)**	−0.170 (0.047)***	−0.041 (0.038)
Nbhd Safety	0.183 (0.038)***	0.153 (0.068)*	0.149 (0.041)***	0.220 (0.041)***	0.059 (0.035)	0.040 (0.103)	−0.006 (0.041)	0.027 (0.035)
ACE*Regularity	−0.030 (0.013)**	0.017 (0.029)	−0.042 (0.016)**	−0.016 (0.012)	−0.047 (0.011)***	−0.016 (0.040)	−0.033 (0.016)*	−0.038 (0.011)***

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Table 7. Severity of specific mental health conditions predicted by ACE count and bedtime regularity

	Anxiety β (SE)				Depression β (SE)			
	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years	All Ages (Rep.)	0–5 Years	6–11 Years	12–17 Years
ACE Count	0.099 (0.043)*	0.299 (0.136)*	0.122 (0.0562)*	0.112 (0.038)**	0.105 (0.062)	–0.967 (0.739)	–0.008 (0.106)	0.144 (0.049)*
Bedtime Reg	0.081 (0.052)	0.169 (0.169)	0.178 (0.0714)*	0.104 (0.043)*	0.201 (0.083)*	–1.999 (1.330)	0.101 (0.167)	0.289 (0.061)**
Age	0.045 (0.0085)***	0.158 (0.087)	0.032 (0.0241)	0.070 (0.016)***	0.068 (0.018)	–0.035 (0.515)	0.106 (0.061)	0.039 (0.022)
Sex	0.043 (0.060)	–0.047 (0.192)	–0.073 (0.0787)	0.086 (0.052)	0.346 (0.093)	2.599 (1.653)	0.224 (0.175)	0.288 (0.071)**
Race	–0.036 (0.021)	–0.039 (0.059)	–	–0.014 (0.018)	–0.040 (0.032)	–0.094 (0.520)	0.044 (0.051)	–0.011 (0.024)
Poverty	–0.079 (0.031)*	–0.025 (0.094)	–0.126 (0.0444)**	–0.042 (0.029)	–0.021 (0.051)	–2.803 (1.117)*	–0.138 (0.097)	0.021 (0.035)
Education	–	–	–0.073 (0.0595)	–0.059 (0.037)	0.060 (0.064)	–2.567 (1.069)*	–0.057 (0.120)	–
Nbhd Support	–0.187 (0.067)**	–0.264 (0.218)	–0.044 (0.0905)	–0.140 (0.058)*	–0.139 (0.101)	1.498 (1.555)	0.320 (0.212)	–0.137 (0.077)*
Nbhd Safety	0.001 (0.058)	0.227 (0.164)	0.037 (0.0745)	0.017 (0.051)	0.079 (0.085)	0.476 (0.833)	0.072 (0.161)	0.033 (0.066)
ACE*Regularity	0.026 (0.018)	–0.088 (0.063)	–0.016 (0.0262)	0.019 (0.015)	0.011 (0.024)	0.240 (0.269)	0.027 (0.046)	–0.001 (0.018)
	Behavioral β (SE)				ADHD β (SE)			
ACE Count	0.218 (0.048)***	0.393 (0.099)***	0.150 (0.054)**	0.139 (0.049)**	0.145 (0.046)**	0.218 (0.155)	0.141 (0.054)**	0.197 – 0.203 (0.044)***
Bedtime Reg	0.138 (0.060)*	0.005 (0.105)	0.150 (0.067)*	0.132 (0.062)*	0.144 (0.052)**	–0.005 (0.159)	0.095 (0.062)	0.238 – 0.242 (0.048)***
Age	–0.012 (0.009)	0.076 (0.062)	–0.045 (0.023)	–0.042 (0.023)	–0.084 (0.009)**	0.060 (0.109)	–0.096 (0.022)***	–0.081 (0.017)***
Sex	–0.126 (0.078)	–0.175 (0.147)	–0.261 (0.085)**	0.105 (0.082)	–0.166 (0.067)*	–0.116 (0.230)	–0.197 (0.077)*	–0.189 (0.061)**
Race	–0.003 (0.023)	–0.003 (0.041)	–0.018 (0.024)	–0.017 (0.026)	0.031 (0.022)	0.022 (0.068)	–0.006 (0.024)	0.016 (0.021)
Poverty	–0.153 (0.040)***	–0.105 (0.072)	–0.172 (0.038)***	–0.171 (0.041)***	–0.169 (0.035)***	–	–0.165 (0.036)***	–0.116 (0.032) ***
Education	–0.043 (0.050)	–0.280 (0.094)**	–	–0.030 (0.051)	–0.013 (0.044)	–0.404 (0.124)**	–	–0.050 – –0.042 (0.040)
Nbhd Support	–0.063 (0.082)	–0.216 (0.156)	–0.016 (0.089)	–0.100 (0.086)	–0.048 (0.071)	–0.338 (0.232)	–0.108 (0.083)	–0.163 – –0.157 (0.066)*
Nbhd Safety	0.074 (0.065)	0.022 (0.117)	0.158 (0.071)*	0.021 (0.069)	.169 (0.062)**	0.058 (0.174)	0.140 (0.071)*	0.127 – 0.137 (0.059)*
ACE*Regularity	–0.025 (0.020)	–0.099 (0.042)*	–0.0002 (0.025)	–0.006 (0.019)	–0.00057 (0.019)	–0.087 (0.070)	0.022 (0.025)	–0.025 – –0.026 (0.017)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; – Denotes models in which the question was not available to cohort or in which models did not meet assumptions of regression and are thus not interpreted; Range provided if more than one covariate resulted in significant brant test; separate models were conducted with one covariate with brant $p > 0.05$ removed at a time.

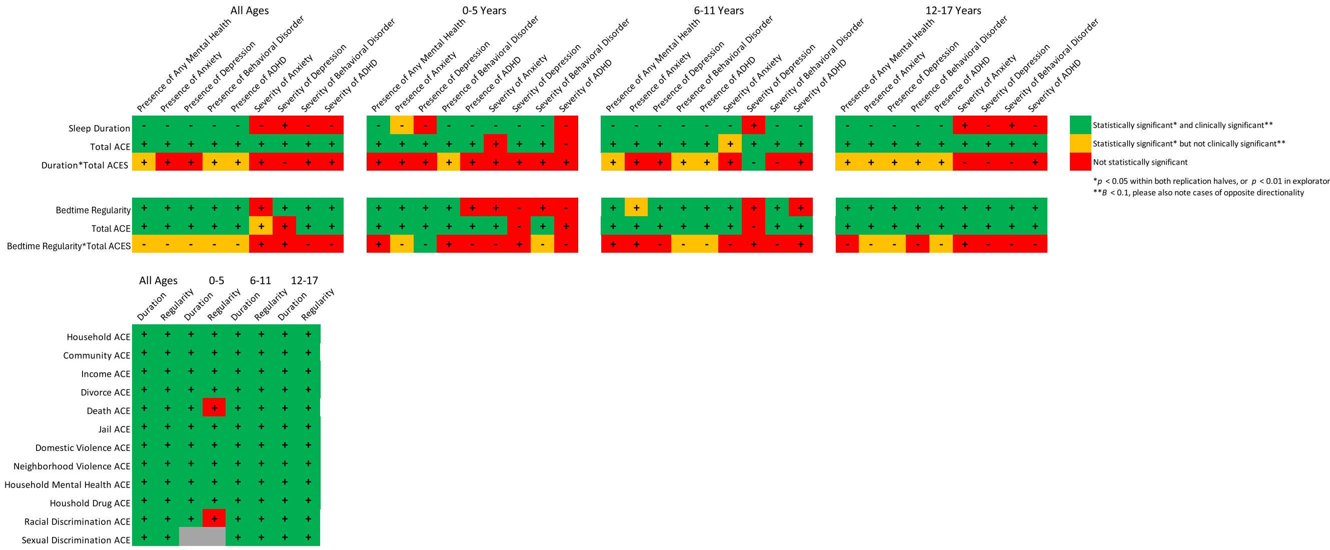

Figure 1. Summary of findings across models for sleep duration, sleep regularity, and ACE conceptualization. Green denotes statistically significant* and clinically significant.** Yellow denotes statistically significant* but not clinically significant.** Red denotes not statistically significant. *$p < 0.05$ within both replication halves, or $p < 0.01$ in exploratory **B < 0.1, please also note cases of opposite directionality.

non-work days). This facet of circadian misalignment is known to be associated with higher levels of depression and anxiety symptoms in adolescents (Henderson *et al.*, 2019; Mathew *et al.*, 2019; Tamura and Okamura, 2023). Previous studies of adolescents have similarly linked increased mental health symptoms with oversleeping on weekends (Zhang *et al.*, 2017). Oversleeping on weekends has also been associated with factors associated with some ACEs including lower income and unstable employment status (Noh *et al.*, 2022). Together, these findings can suggest that the likely complex relationship between sleep irregularity and mental health may not be captured without data on weekend sleep, which may be especially relevant to cohorts with high ACEs who are likely at increased risk for disrupted sleep routines.

Only duration and bedtime regularity were captured in this dataset. However, many individuals also experience sleep disturbance such as nighttime awakenings or nightmares in the wake of adverse events (Baddam *et al.*, 2019; Lancel *et al.*, 2021; Schneiderman *et al.*, 2018; Wamser-Nanney and Chesher, 2018; Xiao *et al.*, 2020). Increases in levels of nighttime fears are also common after stressful experiences, especially in younger cohorts (Kanady *et al.*, 2018; Werner *et al.*, 2021). Further, PTSD was not a diagnosis captured in this dataset and may be another mental health outcome of some ACEs involving risk to own or a caregiver's life (Lee *et al.*, 2020). Thus, other facets of sleep and mental health may more fully capture the potential protective benefits of sleep in the presence of ACE exposure.

In addition to the lack of measurement specificity, it is also possible that significant interaction effects were not observed because individuals with higher ACEs who also have inadequate or irregular sleep represent an especially high-risk group with lower access to or utilization of mental healthcare, as compared with groups without ACE exposure or who have been able to retain adequate sleep in the face of ACE exposure. Thus, lower diagnostic rates identified in models may correspond to the inability to access diagnostic services rather than to the absence or reduced levels of symptoms. Further, there may be mental health symptoms that are common across comorbid diagnoses that are especially impacted by ACE exposure. Future nationally representative surveys could include items on the presence and severity of specific symptoms, rather than relying solely on diagnostic status, in order to address disparities in diagnosis as well as to identify most symptom clusters that may be most impacted by ACEs and sleep (Kamhout and Duraccio, 2025).

Conclusions

Our analysis is unique not only in its focus on sleep as a protective factor against negative mental health outcomes previously associated with ACEs, but also in its focus on the child and adolescent periods, as opposed to retrospective analyses on adulthood outcomes. Examination of moderating influences present earlier in development may illuminate ages at which sleep interventions may be most useful. On one hand, it is possible that children may be especially susceptible to the effects of poor sleep as foundational habits are laid and more developmental years are impacted. On the other hand, it is possible that certain periods of childhood, such as adolescence, may be more sensitive to protective aspects of sleep due to the biological changes and social factors that place additional strain on sleep duration and sleep timing. Although we believe that more advanced measurement methods are needed to fully answer the question of whether sleep is a protective factor against the negative mental health effects of ACEs, in the meantime, addressing sleep in high-ACE cohorts is still likely beneficial to many aspects of youth's current wellbeing. The main effects of improved sleep duration and regularity on improved mental health are well established in the literature (Becker *et al.*, 2022; Blake and Allen, 2020; Wolfson *et al.*, 2015) and were also self-replicated in this analysis. These findings suggest that healthy sleep can decrease adverse mental health outcomes in clinical groups and in the general population. Given the prevalence of ACEs (Sacks and Murphey, 2018) and poor sleep health (Crowley *et al.*, 2018; Paruthi *et al.*, 2016; Wheaton, 2018) in the general population, it is likely that many youths with ACEs also experience sleep difficulties. Youth with increased ACEs are likely not excluded from the benefits of sleep treatment on mental health, even if they do not experience extra benefits of this treatment compared with non-ACE cohorts, or benefits that entirely supersede the negative impacts of early adversity.

In sum, the main effects of our analysis demonstrated that increased ACEs, inadequate sleep duration and increased sleep irregularity predict greater mental health diagnosis and condition severity. Clinically insignificant interaction effects suggest the need for more sensitive sleep and mental health measures in future studies. Despite these limitations, this study had several strengths, including a very large sample size, representative sampling in omnibus age models, multiple conceptualizations of ACEs, self-replication of original models and stratified follow-up analyses across age groups to examine potential changes across developmental stages. If future cross-sectional analyses suggest significant interactions between sleep and ACE level, future laboratory experiments could examine sleep behavior and mental health outcomes in high- versus low-ACE cohorts, ideally incorporating gold-standard physiological measurements of sleep health such as actigraphy and dim light melatonin onset (DLMO), and eventually progressing to clinical trials where sleep intervention is provided following ACE exposure in addition to and versus treatment as usual.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/slp.2025.3

Data availability statement. The data that support the findings of this study are openly available through the Data Resource Center for Child and Adolescent Health supported by the U.S. Department of Health and Services at www.childhealthdata.org.

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Author's contributions. SLHK and KMD were both active in project conceptualization. SLHK wrote all initial text and conducted final analyses. KMD assisted with analysis design and interpretation, as well as review of manuscript drafts.

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Connections references

Sephton SE and Kay DB (2024). How do psychosocial and cultural factors influence sleep and circadian health disparities? *Research Directions: Sleep Psychology* **1**, e1, 1–2. https://doi.org/10.1017/slp.2023.3

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