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Sleep Disturbances and Delayed Sleep Timing are Associated with Greater Post-Traumatic Stress Symptoms in Youth following Hurricane Harvey

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Abstract

Sleep patterns following a natural disaster are associated with mental health difficulties, but research in youth samples has been limited to subjective reports of sleep. Participants (N = 68, 8-17 years old) completed an assessment 6-9 months after Hurricane Harvey, which included subjective measures of sleep, chronotype, hurricane-related post-traumatic stress symptoms, and one week of actigraphy. Prior to the hurricane, parents provided reports on emotional symptoms. Controlling for age, sex, socioeconomic status, participation time, and pre-hurricane emotional symptoms, subjective sleep disturbances and an eveningness chronotype were associated with greater post-traumatic stress, with the strongest effects observed for re-experiencing, negative cognitions/mood, and arousal/reactivity symptoms. Later sleep timing as measured by actigraphy was associated with greater arousal/reactivity symptoms and shorter sleep duration was associated with greater avoidance symptoms. As extreme weather-related events are expected to become more frequent and severe, these findings contribute to models of youth risk and resilience.

Keywords: sleep, circadian timing, post-traumatic stress, natural disaster, negative life events

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Hurricane Harvey made landfall in Southeast Texas in August of 2017, and was the most significant tropical cyclone rainfall event in United States history [1]. After making landfall, the hurricane stalled with the center near the Texas coast and the densely populated Houston metropolitan region for four days. This resulted in historic levels of rainfall, spurred 52 tornados, and caused large-scale destruction and flooding, with nearly all major highways and neighborhood roads inaccessible by car during this period. It is estimated that over 300,000 structures and 500,000 vehicles flooded. Harvey was the second-most costly hurricane in United States history with an estimated $125 billion in damage and was the most fatal hurricane in the state of Texas in nearly 100 years [2]. Children are often among the most vulnerable to the adverse effects of these natural disasters [3,4] and can experience emotional difficulties even years later [5-8]. Further, high-impact weather events are expected to continue increasing in frequency and severity [9,10]. Accordingly, it is critical to understand factors that may confer risk for mental health outcomes post-disaster.

Sleep-wake processes are highly sensitive to stress and trauma and may exacerbate post-disaster difficulties [11]. Alterations in the sleep-wake system have been found to contribute to the development, pathogenesis, and maintenance of post-traumatic stress disorder (PTSD) in adults experiencing trauma [12,13]. Normative neurobiological changes during late childhood and adolescence confer risk for both sleep and psychiatric difficulties [21, 23], so understanding these processes in youth samples is an important topic of investigation. However, to date, studies investigating youth sleep after natural disasters have been limited and have relied solely on subjective reports of sleep disturbances. Building on gaps in this literature, the current study

examined subjective and objective sleep patterns and post-traumatic stress in a sample of youth following Hurricane Harvey.

Trauma and the Impact of Natural Disasters in Childhood

Exposure to adverse experiences such as natural disasters can disrupt normative developmental trajectories and result in altered functioning across a number of domains [14]. Exposure to a natural disaster is a unique stressor, and usually includes threats to survival, property damage or threat of property damage, and can result in a cascade of other adversities or major life changes (e.g., school closures, relocation, family unemployment, increased financial strain) [15]. Studies suggest that exposure to severe natural disasters can result in long-term difficulties in youth populations, including PTSD, anxiety, and depressive symptoms for years following the disaster [16-18]. For example, children and adolescents exposed to Hurricane Katrina had elevated rates of severe emotional disturbance even years after the hurricane [5, 7, 8], and increased exposure to hurricane-related stressors during Hurricane Sandy was associated with increased post-hurricane internalizing symptoms [6]. Other data further suggests that childhood exposure to a natural disaster can result in persistent, negative effects, even into adulthood. For example, children exposed to Australian bushfires had had higher rates of psychiatric disorders in adulthood compared to those not exposed [19]. Despite robust evidence for the long-term effects of natural disasters on mental health among youth, reactions to natural disasters varies considerably, and little is known regarding factors that may buffer or accentuate these adverse responses and recovery.

Sleep, Natural Disasters, and Traumatic Stress

A growing body of research in adults demonstrates that objective and subjective sleep patterns in the aftermath of a trauma predict the development of subsequent emotional and

behavioral problems [20] and contribute to both the development and maintenance of PTSD [12]. However, the ability to uncover specific sleep-based deficits or abnormalities that may heighten emotional/behavioral risk post-trauma across the life-span has been largely limited by the reliance on broad assessments of subjective sleep problems [12]. Additionally, data on sleep and trauma in youth are more scarce, and the post-disaster responses of adults may differ considerably from those observed among youth. Developmental differences may result in heightened risk for youth populations, including increased overall risk for mental health difficulties during the adolescent years, and normative changes in sleep neurobiology that occur throughout childhood and with the onset of puberty [3, 21-23].

A number of studies in youth suggest that persistent sleep problems are a risk factor for psychiatric disorders more broadly [24,25], and certain sleep problems and patterns differentially predict emotional functioning [26,27]. However, to date, the majority of research on sleep and post-traumatic stress in youth has not examined specific sleep patterns based on objective measures, with a few exceptions [28]. A few studies have examined sleep using actigraphy among child victims of abuse or assault, and have found differences across victimized and non-victimized youth across various sleep disturbances such as increased sleep onset latency, less sleep continuity, shorter sleep duration, and a later bedtime [29-31].

To our knowledge, no study has examined objective sleep disturbances in a youth sample exposed to a natural disaster, although several studies have examined subjective reports of sleep. Among children exposed to Hurricane Katrina, a majority of youth self-reported sleep problems 24 months after the hurricane, and these sleep problems were associated with post-traumatic stress symptoms both cross-sectionally and six months later [32]. Another study on adolescents exposed to the Wenchuan earthquake found that participants experiencing high levels of post-

traumatic stress one-year post-disaster were also more likely to report difficulty falling asleep or maintaining sleep [33]. These insomnia symptoms also predicted increases in post-traumatic symptoms over the next year, highlighting the importance of identifying sleep-based risk factors that may contribute to maladaptive coping over time. Other data among adolescents exposed to the Wenchuan earthquake similarly reveal bidirectional relationships between insomnia symptoms and post-traumatic stress in the 1-2 years post-earthquake [34]. Conversely, among youth assessed both 8- and 15-months after Hurricane Ike, post-traumatic stress symptoms predicted later sleep problems, but sleep problems did not predict later post-traumatic stress [35]. Less research has focused on sleep timing following natural disasters, but one study among youth who experienced the 2011 Japan earthquake and tsunami found decreases in sleep duration and delays in sleep timing after the event [36]. However, more research on sleep timing and post-disaster functioning is needed, particularly during late childhood and adolescence, when sleep timing is undergoing dramatic shifts due to normative developmental changes [21].

While these initial findings provide valuable evidence of connections between sleep and post-traumatic stress symptoms following a natural disaster, all of these studies have based their assessment on a few non-validated sleep-related questions taken from larger questionnaires and have primarily measured overall, broad sleep disturbances. In addition to the biases inherent in subjective measures or questions (which may be especially relevant in the context of emotional difficulties and distress), studies in youth suggest that subjective measures of sleep often do not correspond with actual (objective) sleep patterns [37]. As a result, specific sleep patterns that might be associated with emotional risk after a natural disaster in children and adolescents is currently unknown. Investigating associations between sleep and post-disaster functioning using

objective sleep methods and validated measures of subjective sleep complaints is a critical next step for this area of research.

The Current Study

Preliminary research suggests that subjective sleep problems in youth following exposure to a natural disaster are associated with heightened psychiatric risk and may contribute to the onset and maintenance of PTSD. The current study examined sleep patterns and post-traumatic stress after a large-scale natural disaster in a sample of children and adolescents. This study expands on this body of research in several ways. First, prior studies on sleep and post-traumatic stress post-disaster in youth have solely relied on the use of several non-validated sleep-related questions and have primarily assessed overall, broad sleep disturbances. The current study includes a validated measure of subjective sleep disturbances and assesses associations between post-traumatic stress and specific types of sleep patterns (e.g., sleep duration, sleep onset latency). Second, prior studies have not included objective measures of sleep, which often vary considerably from self-reported sleep patterns [37]. Thus, the current study also includes objective measures of sleep patterns (i.e., actigraphy). Finally, little research to date has examined sleep timing post-disaster in youth and it is unknown how this might relate to post-traumatic stress symptoms, despite connections between sleep timing and mental health more broadly [21]. The current study examines sleep timing preferences and patterns using a questionnaire and actigraphy.

Based on prior findings in child samples using subjective sleep reports [32, 33] and controlling for emotional symptoms prior to the hurricane, we expected that greater general subjective sleep disturbances would be associated with higher levels of post-traumatic stress. Although specific sleep patterns using objective methods and post-traumatic stress symptoms

remain unexplored in youth samples exposed to a natural disaster, we expected a shorter total sleep duration, longer sleep onset latency, and later sleep timing would be associated with greater post-traumatic stress post-hurricane based on prior studies linking these specific sleep patterns with general socioemotional responding [26, 38, 39] and based on studies investigating other types of trauma or stress [29-31]. We also examined associations between post-traumatic stress and sleep continuity measures (sleep efficiency and wake after sleep onset) based on studies linking insomnia symptoms and post-traumatic stress in adults [40]. Given marked heterogeneity in post-traumatic stress symptoms and the paucity of research on post-traumatic stress and sleep in youth, in addition to examining overall post-traumatic stress symptoms, exploratory analyses also examined associations between sleep patterns and specific symptom clusters.

Method

Participants

Participants in this study included 68 youth between the ages of 8-17 years (M = 12.25, SD = 2.10; 57.4% female) who were residing in Houston, TX during Hurricane Harvey in 2017. The majority of participants identified as white (63.2%, 19.1% Black or African American, 5.9% Asian, 10.3% multiracial, 1.5% other). A total of 36.8% of participants identified as Hispanic or Latino. The majority of families (41.2%) reported a yearly household income of greater than $100,000 (14.7% reported $80-100k, 17.6% reported $60-80k, 13.2% reported $40-60k, and 13.3% reported < $40k). Additionally, most participants had at least one parent with a college or advanced degree (89.7%). The sample race and ethnicity characteristics are similar to the estimated Houston, TX population based on US Census data (57.6% white, 22.5% Black or African-American, 6.9% Asian, 2.1% multiracial, and 44.8% Hispanic or Latino) [41].

Participants were recruited from a larger sample of 96 youth that participated in one of two prior research studies conducted by the last author. Both studies focused on sleep and mental health in children 7 to 11 years and utilized highly similar measures and protocols. Across the two studies, children with and without clinical levels of anxiety were recruited through postcard mailings using school lists, local publications, and community events from the Houston metropolitan area for a study on "behavior and emotion" or for a research study for children who "get sad or nervous sometimes". From the larger sample, a total of 71 participants (73.96%) opted to complete a follow-up assessment post-hurricane. Two of these participants had moved out of state prior to Hurricane Harvey and were excluded from the present analyses. An additional participant was excluded due to difficulty understanding questionnaires, resulting in the final analytic sample of 68 youth. Of the 68 youth in the current study, 17.6% (n = 12) were diagnosed with an anxiety disorder at the Time 1 assessment.

Procedures and Inclusion Criteria

On average, participation pre-hurricane occurred 3.26 years prior to the hurricane (SD = 1.60; all children were between the ages of 7-11 years at the pre-hurricane assessment). At Time 1, after completing informed consent and assent, parents and children completed diagnostic interviews and questionnaires regarding the child's emotional/behavioral symptoms and functioning. Children were required to live with a primary caretaker and be enrolled in regular education classes. Children were excluded at Time 1 if they had an IQ less than 80 (determined using the Wechsler Abbreviated Scale of Intelligence), a body mass index of more than 25 (due to strong relationships with breathing-related sleep disorders), were non-English speaking or did not have a English speaking caregiver, had any chronic medical conditions that might impact sleep, or any known or suspected sleep disorders (e.g., sleep apnea). Children were also excluded

during the pre-hurricane assessment if they had a current of lifetime history of depressive, psychotic, pervasive developmental, or bipolar disorders, or were suicidal.

In the 6-9 months after Hurricane Harvey, eligible participants were re-contacted through phone or email. Participants who provided consent/assent to participate completed a post-hurricane assessment, including a diagnostic clinical interview, and questionnaires assessing post-traumatic stress, sleep, and chronotype (i.e., morningness/eveningness preference). Following this assessment, participants wore an actigraph and kept a sleep diary for one week to track sleep patterns. A subset of participants (n = 9) participated when school was not in session (i.e., spring break or summer break). Families were compensated $250 for their time and were provided with up to $50 in reimbursement for travel to the research center. All research procedures at both time points were approved by the University of Houston Institutional Review Board.

Assessments

Clinical Interview. Children and a caregiver completed a clinical interview using the Anxiety Disorders Schedule for the DSM-IV for Children and Parents (ADIS-C/P) [42]. Children and their caregiver underwent separate interviews conducted by a Ph.D. level psychologist or trained doctoral student. All cases were fully reviewed by a licensed clinical psychologist prior to assigning a diagnosis. Prior research using the ADIS-C/P has demonstrated strong test-retest and interrater reliability, along with concurrent validity [43, 44]. A number of participants met clinical criteria for at least one psychiatric diagnosis (22.39%; n = 15), including generalized anxiety (n = 8), social anxiety (n = 5), major depressive disorder (n = 3), specific phobia (n = 3), ADHD (n = 1), disruptive mood dysregulation disorder (n = 1), pervasive developmental disorder (n = 1), and depressive disorder NOS (n = 1). One participant did not

finish the clinical interview due to reports of severe suicidal ideation, but this participant completed all other measures of interest and was still retained in the final sample.

Post-Traumatic Stress. Post-traumatic stress was assessed with the child-reported short-form PTSD Reaction Index for Children and Adolescents – DSM-5 version [45]. The scale typically instructs youth to consider a number of potentially traumatic events, and to reflect on the event that bothers them the most now as they answer the items. In our study, because we were primarily interested in symptoms related to Hurricane Harvey, we specified in our instructions that participants should reflect on the hurricane, and each item that referred to "this event" was reworded to instead include the phrase "the hurricane." This scale included 11-items assessing symptoms within the past month related to the hurricane, such as: "When something reminds me of the hurricane, I get very upset, afraid, or sad." Participants responded to each item using a 5-point scale from 0 (none/never) to 4 (most/almost every day). This scale included one item assessing general sleep disturbances, which was removed for the current study. Total scores were calculated for overall post-traumatic stress symptoms, with higher values indicated greater symptoms ($\alpha = .90$). A small number of participants (n = 4, 5.88%) scored above the suggested clinical cut-off on this scale. Subscale scores for each symptom cluster, including negative cognitions/mood (3 items; $\alpha = .83$), arousal/reactivity (3 items; $\alpha = .91$), re-experiencing (3 items; $\alpha = .61$), and avoidance (2 items; inter-item correlation = .69).

Subjective Sleep Disturbances. Participants reported on their subjective sleep disturbances using 10-items from the Sleep-Wake Problems Behavior scale of the School Sleep Habits Survey [46]. Participants reported on a number of sleep disturbances over the last two weeks on a 5-point scale from 1 (never) to 5 (everyday/night), such as: "In the last two weeks,

how often have you felt tired, dragged out, or sleepy during the day?" Items were totaled, so that higher values indicated greater overall sleep disturbances ($\alpha = .78$).

Chronotype. Participants reported on their sleep timing preferences, also known as chronotype (whether or not they were a 'night owl' or evening type [greater eveningness], or a 'morning lark' or morning type [greater morningness] using the Morningness/Eveningness Scale for Children) [47]. This questionnaire includes 10 items assessing preferred overall sleep-wake timing and preferred time of day for activities. Responses were totaled, with higher values indicating greater morningness (or less eveningness; $\alpha = .75$).

Objective Sleep Patterns. Participants completed one week of sleep monitoring using a Micro MotionLogger Actigraphy Sleep Watch (Ambulatory Monitoring, Inc., Ardsley, NY), which is an accelerometer-based wrist-watch that records continuous movement and uses established algorithms to estimate sleep and wake periods. Data were recorded using the zero crossing mode and stored in one minute epochs. Participants were instructed to push an event button on the watch when they first got into bed and night and were trying to sleep, and when they first woke up and got out of bed in the morning. During the week of actigraphy, children also completed a sleep diary each morning and evening. Data was visually inspected in conjunction with sleep diaries [48] and was scored using the Sadeh algorithm [49]. Children were included in actigraphy analyses if they had at least 5 nights of valid data ($n = 63$), based on recommendations to obtain reliable measures of sleep in children and adolescents [50]. Several sleep variables were extracted by calculating averages across the week, including total sleep time (TST, number of minutes spent asleep during the sleep period), sleep efficiency (SE, percentage of time in bed spent sleeping), wake after sleep onset (WASO, minutes spent awake during the

sleep period), sleep onset latency (SOL, minutes taken to fall asleep), and mid-sleep point (MSP, the mid-point between the time that the sleep period began each night and ended each morning).

Demographics and Pre-Hurricane Symptoms. A caregiver completed several measures at during the assessment prior to the hurricane, including reports of their children's anxiety symptoms on the 6-item DSM-oriented anxiety scale on the Child Behavior Checklist [51]. Specifically, parents reported on their child's symptoms using a scale from 0 (not true of their child) to 2 (very true or often true of their child), and T-scores were calculated adjusting for age and gender. After the hurricane, caregivers reported demographic characteristics of the child and family, including current age, biological sex, and race/ethnicity, along with their education and their partner's current level of education (if applicable). Parental education was collapsed into one variable representing the highest level of education attained by either parent.

Analysis Plan

Preliminary analyses examined differences in demographic characteristics and pre-hurricane symptoms between participants returning for the post-hurricane assessment and those who did not participate. Bivariate correlations between demographic characteristics, post-traumatic stress, and sleep variables were then examined. To assess associations between post-hurricane sleep and post-traumatic stress, we ran a series of regression models predicting post-traumatic stress symptoms (overall symptoms, re-experiencing symptoms, avoidance symptoms, negative cognitions/mood symptoms, arousal/reactivity symptoms) using each sleep variable. Because sociodemographic variables such as parent education, age, and sex [52], along with prior emotional functioning have been shown to predict stress responses in children, we include these variables as covariates in our models. We also controlled for participation timing (school period or school break) to account for any differences in sleep patterns due to school schedules.

To prevent multicollinearity, all sleep variables were entered into separate regression models. Sample size estimates [53] indicated that a sample size of 55 would be sufficient to detect a medium effect with 80% power and $\alpha = .05$. Initial data checks using skewness values and Shapiro-Wilk tests indicated that all of the post-traumatic stress variables were significantly positively skewed (p's $< .001$), so regression analyses were conducted using maximum likelihood estimation with robust standard errors in R version 3.6.2 to account for this non-normality.

Results

Preliminary Analyses

Preliminary analyses indicated no significant differences between participants from the larger sample who did and did not participate in this follow-up study on pre-hurricane symptoms, age, sex, race, ethnicity, parental education, or income. Descriptive statistics and bivariate correlations for all variables of interest are reported in Table 1. Bivariate correlations indicated that older age was associated with less overall post-traumatic stress symptoms, and specifically less re-experiencing, negative cognitions/mood, and arousal/reactivity symptoms. Older participants also reported greater eveningness, shorter TST, later MSP, and less WASO. Females had a longer TST, greater SE, and less WASO. Participants with higher parental education also reported lower symptoms on all of the post-traumatic stress subscales and less overall sleep disturbances. Participation over school break was associated with later MSP and less eveningness.

[insert Table 1 about here]

Regression Analyses Predicting Total Post-Traumatic Stress Symptoms

A series of regression models examining sleep patterns (subjective sleep disturbances, chronotype, and the actigraphy variables) were conducted, with overall post-traumatic stress symptoms as the dependent variable. All models adjusted for pre-hurricane symptoms, age, sex, parent education, and school break status. In the model examining subjective sleep disturbances, results indicated greater subjective sleep disturbances were associated with greater post-traumatic stress symptoms. Reports of eveningness were also associated with greater post-traumatic stress symptoms. Model statistics are displayed in Table 2.

[insert Table 2 about here]

Exploratory Regression Models Predicting Post-Traumatic Stress Symptom Clusters

A series of regression models were conducted to examine how sleep patterns (subjective sleep disturbances, chronotype, and the actigraphy variables) were associated with specific post-traumatic stress symptom clusters (re-experiencing, avoidance, negative cognitions/mood, and arousal/reactivity symptoms). All models adjusted for pre-hurricane symptoms, age, sex, parent education, and school break status. When examining specific symptom clusters, subjective sleep disturbances were associated with greater symptoms across all four symptom clusters. Participants who reported more eveningness also experienced more re-experiencing symptoms, negative cognitions/mood symptoms, and more arousal/reactivity symptoms. Similarly, a later actigraphy-measured MSP was associated with greater arousal/reactivity symptoms. A shorter actigraphy-measured TST was associated with greater avoidance symptoms (Table 3).

[insert Table 3 about here]

Discussion

A growing body of research in adults demonstrates both objective and subjective sleep patterns following trauma exposure predict the development of subsequent emotional and behavioral problems and contribute to the development and maintenance of PTSD [12, 20]. A small number of studies in youth have found subjective sleep complaints are associated with greater post-traumatic stress following a natural disaster. However, prior studies on natural disasters and sleep in youth samples have relied solely on several questionnaire items to assess sleep. The current study included objective sleep data and validated questionnaires, providing a novel and important contribution to this literature. Understanding of objective sleep patterns represents a clinically-meaningful gap in this small but growing body of research in light of potential to inform post-disaster intervention efforts. Findings suggest that subjective sleep disturbances, self-reported chronotype, and objectively-measured sleep duration and timing were associated with post-traumatic stress symptoms, even after accounting for sociodemographic correlates and pre-hurricane emotional symptoms. A novel aspect of our study also examined symptom clusters, and sleep patterns varied by specific clusters of post-traumatic stress symptoms.

Reports of greater subjective sleep disturbances were associated with overall post-traumatic stress symptoms, and with each individual post-traumatic stress symptom cluster. These findings are in line with previous studies indicating that youth exposed to a natural disaster experience subjective sleep disturbances following these events, and that these disturbances predict poorer psychological functioning in the aftermath of the disaster [32-34]. Importantly, subjective sleep complaints have been shown to predict overall adjustment and maintenance of post-traumatic stress symptoms even years post-disaster [32], revealing sleep disturbances to be an important marker for longer-term risk. These relationships are likely to

reflect the bidirectional links between sleep-wake regulation and the body's primary stress response systems, including the hypothalamus–pituitary–adrenal (HPA) axis and the sympathetic nervous system, which are down-regulated during healthy sleep [54].

Building on prior studies that have used self-reports of broadly defined sleep disturbances, our findings suggest that several specific types of sleep patterns may be important for mental health in the aftermath of a natural disaster. Specifically, shorter actigraphy-measured sleep duration was associated with increased post-traumatic symptoms, but this was driven largely by the avoidance symptom cluster. This finding builds on prior research that has found overall decreases in sleep duration in the aftermath of a natural disaster [36], and further suggests that insufficient sleep may have important implications for post-disaster mental health and recovery. A number of experimental studies in adults, adolescents, and children suggest that sleep loss results in greater reactivity to emotional stimuli and poorer emotion regulation [38]. Increased reactivity and inability to regulate emotional responses following periods of insufficient sleep may generalize to an inability to regulate emotional responses to trauma reminders. As a result, shorter sleep duration may result in greater avoidance of these trauma reminders and ultimately lead to the maintenance of symptoms over time [55].

Later sleep timing was also associated with higher risk for post-traumatic stress, as measured with actigraphy as well as reports of chronotype. Greater eveningness was significantly associated with overall post-traumatic stress as well as greater negative cognitions/mood and greater re-experiencing symptoms specifically. Both of these objective and subjective indicators of sleep timing were also associated with greater arousal/reactivity symptoms. Reliable associations exist between an eveningness preference and the onset of affective disturbances and disorders in children and adolescents, most notably depression [56,

57]. While data on sleep timing and post-traumatic stress specifically is limited, one study found that among adult military veterans, eveningness was associated with greater lifetime PTSD symptoms, along with greater neural activity during wakefulness and rapid-eye movement (REM) sleep in regions specifically related to arousal regulation [58]. This suggests that eveningness and later sleep timing might confer risk for chronic elevated arousal in response to trauma exposure. In addition, it is also possible that increased hyperarousal post-disaster may inhibit nighttime sleep and result in delayed bedtime/sleep onset among youth [59].

Limitations and Future Directions

This study had several strengths. Notably, this is the first study to our knowledge to examine associations between youth sleep and post-traumatic stress after a natural disaster using an objective sleep assessment or a validated subjective sleep measure. Participants also completed a comprehensive clinical assessment prior to the hurricane, providing information on pre-hurricane emotional symptoms that is unavailable in the vast majority of natural disaster studies [60]. Nonetheless, the current study had several limitations. Despite adjusting for pre-hurricane emotional symptoms, our analyses were cross-sectional and it is not possible to determine causality. Prior studies (though not all) suggest that associations between insomnia symptoms and post-traumatic stress are bidirectional [34], so future studies tracking sleep and mental health symptoms at multiple time points pre- and post-disaster will be better positioned to determine directionality. Additionally, while post-disaster assessments were conducted within a relatively short time frame that was consistent across participants (within 6-9 months after the hurricane), youth often experience emotional and sleep-based symptoms following a natural disaster that persist for longer periods [32, 36]. Assessing long-term sleep patterns and symptoms, along with those immediately after the event in future studies would provide additional information [7, 61]. It is also important to note that while our sample was racially and

ethnically diverse, participants generally had high income and parental educational attainment. Additionally, no children were diagnosed with PTSD in the current study based on diagnostic clinical interviews and only a small percentage of our sample fell above the clinical cut-off suggested by the short-form PTSD Reaction Index scale. As a result, it is possible that these results may not generalize to lower socioeconomic populations or those experiencing more severe or clinical levels of post-traumatic stress symptoms. Future studies should examine these processes in higher-risk samples. It would also be useful in future studies to assess a broader range of emotional symptoms post-disaster (e.g., anxiety, depression).

Children who experience different types of natural disasters may share common experiences, such as loss of property, strong emotional responses/fear, altered daily routines, and changes to social ecosystems (e.g., changing schools or needing to move neighborhoods). However, every natural disaster likely has additional idiosyncratic features. While Hurricane Harvey shares many commonalities with other natural disasters, it is also possible that some experiences that children had during this particular hurricane were unique. For example, Hurricane Harvey resulted in the most rain ever recorded in the continental United States from a tropical cyclone, with rainfall in the Houston metropolitan area up to 3-5 feet [1, 62]. During the 4-day period when the hurricane stalled over the city of Houston and this rainfall occurred, residents were instructed to shelter in place and the majority of roadways were inaccessible by car. During this period, many homes experienced flood damage or were at-risk of flooding [62]. Prior studies have documented that the most common experiences by children during Harvey included thinking that they or loved ones would get hurt or die, seeing caregivers struggling with fear or sadness, getting trapped at home or needing to evacuate their home, and damage to their house, neighborhood, and belongings [62]. Studies examining sleep and mental health after other

types of natural disasters or in response to other types of disaster-related experiences are needed to understand the generalizability of these results. It is also important to note that we had a modest sample size. A post-hoc sensitivity analysis indicated that we were powered to detect medium effects ($f^2 = .12$), and thus future studies investigating sleep and post-traumatic stress among children who have experienced large-scale natural disasters using larger samples is needed.

It is also unknown how sleep may confer risk for post-traumatic stress differently for our sample (comprised of youth during late childhood or adolescence) as compared to adults or young children. Children are often among the most vulnerable to the adverse effects of natural disasters [3,4] and unique but normative neurobiological changes occur during late childhood and adolescence that confer risk for both sleep and psychiatric difficulties [21, 23], suggesting that important developmental differences may exist. For example, adolescents experience normative developmental delays in sleep timing, which when combined with early school start times often results in insufficient sleep [21]. Indeed, the average sleep duration in our sample based on actigraphy was approximately 7 hours a night, which is less than the recommended amount of sleep needed for the age of our sample. It is possible that teens, who are already at-risk for sleep disturbances, may be more affected by some adverse hurricane experiences (e.g., moving to a school that requires an earlier wake up time to commute). Future studies should examine how age moderates associations between sleep and psychiatric functioning post-disaster.

Conclusions

High-impact weather events are expected to continue increasing in frequency and severity [9, 10] and children may be most at risk for the deleterious effects of these natural disasters [3, 4]. Findings from the current study suggest that overall sleep disturbances,

chronotype, and objective sleep patterns (sleep duration and sleep timing) are associated with post-traumatic stress after a natural disaster in youth. These findings extend research suggesting that sleep closely following a trauma may confer risk for the development and maintenance of post-traumatic stress disorder (PTSD) in adults [12, 13]. While many children and adolescents experience resilience in the face of disaster, a number of youth experience adverse mental health outcomes [63]. Importantly, evidence-based interventions for children and youth following natural disasters are limited [64]. Understanding which youth are most at-risk following these disasters is critical for advancing our understanding of when and how to intervene. These data suggest that including screeners to assess sleep patterns in youth post-disaster may be important for identifying youth at risk. While future research is still needed, these data also suggest that directly targeting sleep disturbances may be an important addition for interventions for youth with emotional difficulties post-disaster. These data build on studies in adults and preliminary research in youth to provide further support for the role of sleep as a behavior that may buffer or accentuate adverse functioning in the months following exposure to a natural disaster.

Summary

High-impact weather events are expected to continue increasing in frequency and severity, and thus it is critical to understand factors that may confer risk for mental health outcomes post-disaster. Poor sleep may be one health behavior that exacerbates post-disaster difficulties. Studies in adults have found that stress-related alterations in sleep-wake patterns contribute to the development, pathogenesis, and maintenance of PTSD. However, research on sleep and post-traumatic stress in youth experiencing a natural disaster is limited, and studies have solely relied on subjective reports of sleep patterns. The current study included 68 youth between the ages of 8-17 years old who were exposed to Hurricane Harvey. Participants completed an assessment 6-9 months after the hurricane, which included subjective measures of sleep, chronotype, hurricane-related post-traumatic stress symptoms, and one week of actigraphy. Prior to the hurricane, parents provided reports on emotional symptoms. Controlling for sociodemographics and pre-hurricane emotional symptoms, results revealed that post-hurricane sleep patterns were associated with greater post-traumatic stress.

Specifically, subjective sleep disturbances were associated with greater post-traumatic stress, along with sleep timing (as measured by actigraphy and self-reported chronotype). The strongest effects were observed for re-experiencing, negative cognitions/mood, and arousal/reactivity symptoms. Additionally, a shorter sleep duration was associated with greater avoidance symptoms. As extreme weather-related events are expected to become more frequent and severe, understanding which youth are most at-risk following these disasters is critical for advancing our knowledge of when and how to intervene. These findings highlight the importance of sleep in our models of youth risk and resilience.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

References

1. National Oceanic and Atmospheric Administration (2018) *Hurricane Harvey (AL09017).* National Hurricane Center Tropical Cyclone Report.

2. Blake ES, Zelinsky DA (2018) National Hurricane Center Tropical Cyclone Report: Hurricane Harvey (Report No. AL092017). Retrieved from: https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf

3. Norris FH, Friedman MJ, Watson PJ, Byrne CM, Diaz E, Kaniasty K (2002) 60,000 disaster victims speak: Part I. an empirical review of the empirical literature, 1981-2001. Psychiatry 65: 207-239. https://doi.org/10.1521/psyc.65.3.207.20173

4. Philipsborn RP, Chan K (2018) Climate change and global child health. Pediatr 141: e20173774. https://doi.org/10.1542/peds.2017-3774

5. McLaughlin KA, Fairbank JA, Gruber MJ, Jones RT, Osofsky JD, Pfefferbaum B, Sampson NA, Kessler RC (2010) Trends in serious emotional disturbance among youths exposed to Hurricane Katrina. J Am Acad Child Adolesc Psychiatry 49: 990-1000. https://doi.org/10.1016/j.jaac.2010.06.012

6. Meyer A, Danielson CK, Danzig AP, Bhatia V, Black SR, Bromet E, Carlson G, Hajcak G, Kotov R, Klein DN (2017) Neural biomarker and early temperament predict increased internalizing symptoms after a natural disaster. J Am Acad Child Adolesc Psychiatry 56: 410-416. https:/doi.org/ 10.1016/j.jaac.2017.02.005

7. Weems CF, Taylor LK, Cannon MF, Marino RC, Romano DM, Scott BG, Perry AM, Triplett V (2010) Post traumatic stress, context, and the lingering effects of the Hurricane Katrina disaster among ethnic minority youth. J Abnorm Child Psychol 38: 49-56. https://doi.org/10.1007/s10802-009-9352-y

8. Weems CF, Graham RA (2014) Resilience and trajectories of posttraumatic stress among youth exposed to disaster. J Child Adolesc Psychopharmacol 24: 2-8. https://doi.org/10.1089/cap.2013.0042

9. Karl TR, Meehl GA, Miller CD, Hassol SJ, Waple AM, Murray WL (2008) *Weather and Climate Extremes in a Changing Climate; Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.* Washington, D.C., USA: Department of Commerce, NOAA's National Climatic Data Center.

10. Liu M, Vecchi GA, Smith JA, Knutson TR (2019) Causes of large projected increases in hurricane precipitation rates with global warming. Clim Atmos Sci 2: 1-5. https://doi.org/10.1038/s41612-019-0095-3

11. Irwin MR (2015) Why sleep is important for health: A psychoneuroimmunology perspective. Ann Rev Psychol 66: 143-172. https://doi.org/10.1146/annurev-psych-010213-115205

12. Mellman TA (2019) A new meta-analysis of sleep findings in PTSD, toward integration and coherence. Sleep Med Rev 48: 101220. https://doi.org/10.1016/j.smrv.2019.101220

13. Zhang Y, Ren R, Sanford LD, Yang L, Zhou J, Zhang J, Wing Y, Shi J, Lu L, Tang X Sleep in posttraumatic stress disorder: A systematic review and meta-analysis of polysomnographic findings. Sleep Med Rev 48,:101210. https://doi.org/10.1016/j.smrv.2019.08.004

14. Weems CF, Overstreet S (2008) Child and adolescent mental health research in the context of Hurricane Katrina: An ecological needs-based perspective and introduction to the special section. J Clin Child Adolesc Psychol 37: 487-894. https://doi.org/10.1080/15374410802148251

15. Dodd CG, Hill RM, Oosterhoff B, Layne CM, Kaplow JB (2019) The Hurricane Exposure, Adversity, and Recovery Tool (HEART): Developing and validating a risk screening instrument for youth exposed to Hurricane Harvey. J Fam Strengths 19: 5.

16. Bokszczanin A (2008) Parental support, family conflict, and overprotectiveness: Predicting PTSD symptom levels of adolescents 28 months after a natural disaster. Anxiety Stress Coping 21: 325-335. https://doi.org/10.1080/10615800801950584

17. Maclean JC, Popovici I, French MT (2016) Are natural disasters in early childhood associated with mental health and substance use disorders as an adult? Soc Sci Med 151: 78-91. https://doi.org/10.1016/j.socscimed.2016.01.006

18. Swenson CC, Saylor CF, Powell MP, Stokes ZJ, Foster KY, Belter RW (1996) Impact of a natural disaster on preschool children: Adjustment 14 months after a hurricane. Am J Orthopsychiatry 66: 122-130. https://doi.org/10.1037/h0080162

19. McFarlane AC, Van Hooff M (2009) Impact of childhood exposure to a natural disaster on adult mental health: 20-year longitudinal follow-up study. Br J Psychiatry 195: 142-148. https://doi.org/10.1192/bjp.bp.108.054270

20. Babson KA, Feldner MT (2010) Temporal relations between sleep problems and both traumatic event exposure and PTSD: A critical review of the empirical literature. J of Anxiety Disord 24: 1-15. https://doi.org/10.1016/j.janxdis.2009.08.002

21. Crowley SJ, Wolfson AR, Tarokh L, Carskadon MA (2018) An update on adolescent sleep: New evidence informing the perfect storm model. J Adolesc 67: 55-65. https:/doi.org/10.1016/j.adolescence.2018.06.001

22. Dunn EC, Nishimi K, Powers A, Bradley B (2017) Is developmental timing of trauma exposure associated with depressive and post-traumatic stress disorder symptoms in adulthood? J Psychiatric Res 84: 119-127. https://doi.org/10.1016/j.jpsychires.2016.09.004

23. Lee FS, Heimer H, Giedd JN, Lein ES, Sestan N, Weinberger DR, Casey BJ (2014) Adolescent mental health – opportunity and obligation. Sci 346: 547-549. https://doi.org/10.1126/science.1260497

24. Bai S, Ricketts EJ, Thamrin, H., Piacentini, J., Albano, A., Compton, S. N., Ginsburg, G. S., Sakolsky, D., Keeton, C. P, Kendall, P. C., & Peris, T. S. (2019). Longitudinal study of sleep and internalizing problems in youth treated for pediatric anxiety disorders. J Abnorm Child Psychol 48: 67-77. https://doi.org/10.1007/s10802-019-00582-x

25. Gregory, A. M., Caspi, A., Eley, T. C., Moffitt, T. E., O'Connor, T. G., & Poulton, R. (2005). Prospective longitudinal associations between persistent sleep problems in childhood and anxiety and depression disorders in adulthood. J Abnorm Child Psychol 33: 157-163. https://doi.org/10.1007/s10802-005-1824-0

26. Reynolds, KC, & Alfano, CA (2016). Childhood bedtime problems predict adolescent internalizing symptoms through emotional reactivity. J Pediatr Psychol 41: 971-982. https://doi.org/10.1093/jpepsy/jsw014

27. Palmer CA, Alfano CA, Bower JL (2020). Adolescent sleep patterns are associated with the selection of positive and negative emotional situations. J Sleep Res 29: e12917. https://doi.org/10.1111/jsr.12917

28. Kovachy, B., O'Hara, R., Hawkins, N., Gershon, A., Primeau, M. M., Madej, J., & Carrion, V. (2013). Sleep disturbances in pediatric PTSD: Current findings and future directions. J Clin Sleep Med 9: 501-510.

29. Glod, C. A., Teicher, M. H., Hartman, C. R., & Harakal, T. (1997). Increased nocturnal activity and impaired sleep maintenance in abused children. J Am Acad of Child and Adolesc Psychiatry 36: 1236-1243.

30. Sadeh, A., McGuire, J. P., Sachs, H., Seifer, R., Tremblay, A., Civita, R., & Hayden, R. M. (1995). Sleep and psychological characteristics of children on a psychiatric inpatient unit. J Am Acad of Child and Adolesc Psychiatry 34: 813-819.

31. Spilsbury, J. C., Babineau, D. C., Frame, J., Juhas, K., & Rork, K. (2014). Association between children's exposure to a violent event and objectively and subjectively measured sleep characteristics: A pilot longitudinal study. J Sleep Res 23: 585-594.

32. Hall Brown, T., Mellman, T. A., Alfano, C. A., & Weems, C. F. (2011). Sleep fears, sleep disturbance, and PTSD symptoms in minority youth exposed to Hurricane Katrina. J Trauma Stress 24: 575-580. https://doi.org/10.1002/jts.20680

33. Geng F, Zhou Y, Liang Y, Zheng X, Li Y, Chen X, Fan F (2019) Posttraumatic stress disorder and psychiatric comorbidity among adolescent earthquake survivors: A longitudinal cohort study. J Abnorm Child Psychol 47: 671-681. https://doi.org/10.1007/s10802-018-0462-2

34. Zhou, X., Wu, X., An, Y., & Fu, F. (2014). Longitudinal relationships between posttraumatic stress symptoms and sleep problems in adolescent survivors following the Wenchuan earthquake in China. *PLoS One*, *9*(8), e104470. https://doi.org/10.1371/journal.pone.0104470

35. Lai, B. S., La Greca, A. M., Colgan, C. A., Herge, W., Chan, S., Medzhitova, J., Short, M., & Auslander, B. (2020). Sleep problems and posttraumatic stress: Children exposed to a natural disaster. J Pedtric Psychol 45: 1016-1026. https://doi.org/10.1093/jpepsy/jsaa061

36. Iwadare, Y., Usami, M., Ushijima, H., Tanaka, T., Watanabe, K., Kodaira, M., Harada, M., Tanaka, H., Sasaki, Y., & Saito, K. (2014). Changes in traumatic symptoms and sleep habits among junior high school students after the Great East Japan Earthquake and Tsunami. Sleep Biol Rhythms 12: 53-61. https://doi.org/10.1111/sbr.12047

37. McMakin DL, Alfano CA (2015) Sleep and anxiety in late childhood and early adolescence. Curr Opin Psychiatry 28: 483-489. https://doi.org/10.1097/YCO.0000000000000204

38. Palmer CA, Alfano CA (2017) Sleep and emotion regulation: An organizing, integrative review. Sleep Med Rev 31: 6-16. https://doi.org/0.1016/j.smrv.2015.12.006

39. Schlarb, AA., Sopp, R., Ambiel, D., & Grünwald, J. (2014). Chronotype-related differences in childhood and adolescent aggression and antisocial behavior—A review of the literature. Chronobiol Int 31: 1-16. https://doi.org/ 10.3109/07420528.2013.829846

40. Babson, K. A., Feldner, M., Badour, C., Trainor, C., Blementhal, H., Sachs-Ericsson, N., & Schmidt, N. (2011). Posttraumatic stress and sleep: Differential relations across types of symptoms and sleep problems. J Anxiety Disord 25: 706-713. https://doi.org/10.1016/j.janxdis.2011.03.007

41. U.S. Census Bureau (2019) *QuickFacts Houston City, Texas (V2019).* Retrieved October 20, 2020, from https://www.census.gov/quickfacts/fact/table/houstoncitytexas/PST045219#.

42. Silverman WK, Albano AM (1996) *Anxiety disorders interview schedule for children for DSM-IV: Child and parent versions.* Psychological Corporation, San Antonio.

43. Lyneham HJ, Abbott MJ, Rapee RM (2007) Interrater reliability of the anxiety disorders interview schedule for DSM-IV: Child and parent versions. J Am Acad Child Adolesc Psychiatry 46: 731–736. https://doi.org/10.1097/chi.0b013e3180465a09

44. Silverman WK, Saaverdra LM, Pina AA (2001) Test-retest reliability of anxiety symptoms and diagnoses with the anxiety disorders interview schedule for DSM-IV: Child and parent versions. Adolesc Psychiatry 40: 937–944. https://doi.org/10.1097/00004583-200108000-00016

45. Rolon-Arroyo, B., Oosterhoff, B., Layne, C. M., Steinberg, A. M., Pynoos, R. S., & Kaplow, J. B. (2020). The UCLA PTSD Reaction Index for DSM-5 Brief Form: A screening tool for trauma-exposed youths. J Am Acad Child Adolesc Psychiatry 59: 434-443. https://doi.org/10.1016/j.jaac.2019.06.015

46. Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. Child Dev 69: 875-887. https://doi.org/10.1111/j.1467-8624.1998.tb06149.x

47. Carskadon, M. A., Vieira, C., & Acebo, C. (1993). Association between puberty and delayed phase preference. Sleep 16: 258–262. https://doi.org/10.1093/sleep/16.3.258

48. Meltzer, L. J., Montgomery-Downs, H., Insana, S. P., & Walsh, C. M. (2012). Use of actigraphy for assessment in pediatric sleep research. Sleep Med Rev 16: 463-475. https://doi.org/10.1016/j.smrv.2011.10.002

49. Sadeh, A., Sharkey, K. M., & Carskadon, M. A. (1994). Activity-based sleep—wake identification: An empirical test of methodological issues. Sleep 17: 201–207. https://doi.org/10.1093/sleep/17.3.201

50. Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Wolfson, A. R., Hafer, A., & Carskadon, M. A. (1999). Estimating sleep patterns with activity monitoring in children and adolescents: How many nights are necessary for reliable measures? Sleep 22: 95-103. https://doi.org/10.1093/sleep/22.1.95

51. Achenbach, T.M., & Rescorla, L.A. (2001). Manual for the ASEBA School-Age Forms & Profiles. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.

52. Shannon, M. P., Lonigan, C. J., Finch, A. J., & Taylor, C. M. (1994). Children exposed to disaster: I. epidemiology of post-traumatic symptoms and symptom profiles. J Am Acad Child Adolesc Psychiatry 33: 80-93. https://doi.org/ 10.1097/00004583-199401000-00012

53. Faul F, Erdfelder E, Lang AG, Buchner A (2007) G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 39:175-191.

54. Besedovsky, L., Lange, T., & Born, J. (2012). Sleep and immune function. Pflügers Archiv-European J Physiol 463: 121-137. https://doi.org/10.1007/s00424-011-1044-0

55. Rothbaum, B. O., & Mellman, T. A. (2001). Dreams and exposure therapy in PTSD. J Traum Stress 14: 481-490. https://doi.org/10.1023/A:1011104521887

56. Dolsen, M. R., & Harvey, A. G. (2018). Dim light melatonin onset and affect in adolescents with an evening circadian preference. J Adolesc Health 62: 94-99. https://doi.org/10.1016/j.jadohealth.2017.07.019

57. Haraden, D. A., Mullin, B. C., & Hankin, B. L. (2017). The relationship between depression and chronotype: A longitudinal assessment during childhood and adolescence. Depress Anxiety 34: 967-976. https://doi.org/10.1002/da.22682

58. Hasler, B. P., Insana, S. P., James, J. A., & Germain, A. (2013). Evening-type military veterans report worse lifetime posttraumatic stress symptoms and greater brainstem activity across wakefulness and REM sleep. Biol Psychol 94: 255-262. https://doi.org/10.1016/j.biopsycho.2013.06.007

59. Mellman TA (1997) Psychobiology of sleep disturbances in posttraumatic stress disorder. In R. Yehuda, & A. C. McFarlane (Eds.), *Psychobiology of posttraumatic stress disorder; psychobiology of posttraumatic stress disorder* (pp. 142-149). New York Academy of Sciences, New York, NY.

60. Masten, A., S., Osofsky, J. D. (2010). Disasters and their impact on child development: Introduction to the special section. Child Dev 81: 1029-1039.

61. Silverman, W. K., & La Greca, A. M. (2002). Children experiencing disasters: Definitions, reactions, and predictors of outcomes. In A. M. La Greca, W. K. Silverman, E. M. Vernberg & M. C. Roberts (Eds.), *Helping children cope with disasters and terrorism; helping children cope with disasters and terrorism* (pp. 11-33) American Psychological Association, Washington, DC.

62. Dodd, C. G., Hill, R. M., Oosterhoff, B., Layne, C. M., & Kaplow, J. B. (2019). The Hurricane Exposure, Adversity, and Recovery Tool (HEART): Developing and validating a risk screening instrument in youth exposed to Hurricane Harvey. J Family Strengths 19: 5.

63. Rubens, S. L., Felix, E. D., & Hambrick, E. P. (2018). A meta-analysis of the impact of natural disasters on internalizing and externalizing problems in youth. J Traum Stress 31: 332-341. https://doi.org/10.1002/jts.22292

64. Kaplow, J. B. (2018). Building resiliency in the aftermath of Hurricane Harvey: Lessons learned and ongoing recovery efforts. J Am Acad Child Adolesc Psychiatry 57: S29. https://doi.org/10.1016/j.jaac.2018.07.125

Table 1

Bivariate correlations and descriptive statistics for all variables of interest

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.Child Age																	
2.Child Sex	.03																
3.Parental Education	.19	-.01															
4.Break Status	-.07	-.01	.04														
5.T1 Anxiety	.27*	.02	.11	-.05													
6.T2 PTSS	-.28*	.06	-.27*	-.12	.11												
7.T2 PTSS Cat B	-.25*	.05	-.31**	-.11	.16	.91***											
8.T2 PTSS Cat C	-.18	.01	-.27*	-.10	.05	.85***	.79***										
9.T2 PTSS Cat D	-.20	.04	-.25*	-.14	.14	.85***	.67***	.57***									
10.T2 PTSS Cat E	-.31**	.09	.01	-.03	-.07	.62***	.40***	.40***	.42***								
11.SSHS	.04	.21	-.28*	-.06	-.03	.50***	.43***	.38**	.44***	.38**							
12.Chronotype	-.30*	.20	-.16	.24*	-.16	-.24+	-.21	-.02	-.31*	-.20	-.44***						
13.TST	-.44***	.37**	.06	.10	.11	-.04	-.02	-.12	-.06	.10	-.11	.01					
14.WASO	-.31*	-.39**	.07	.08	.001	.06	.10	.09	.04	-.06	-.14	.19	-.16				
15.SOL	.04	.001	-.04	.10	-.11	-.02	.11	-.02	-.14	-.03	.08	-.10	-.27*	.21			
16.SE	.07	.36**	-.05	-.03	-.03	-.03	-.12	-.05	.05	-.05	-.02	-.04	.46***	-.79***	-.68***		
17.MSP	.48***	-.09	.01	.51***	.14	-.16	-.15	-.03	-.26*	-.01	.18	-.14	-.22	-.27*	.13	.04	
Mean	-	-	-	-	53.99	4.91	1.18	1.03	1.37	1.34	19.28	28.37	426.73	60.05	18.59	82.71	3:08
SD	-	-	-	-	6.53	7.23	2.68	1.92	2.58	1.58	6.53	4.31	50.71	30.39	17.30	7.12	00:56
Range	-	-	-	-	50-80	0-36	0-12	0-8	0-12	0-6	10-36	20-37	283.86-513.14	16.17-141.83	4.60-100.43	59.27-91.04	01:24-06:28

Notes. ***p < .001, **p < .01, *p < .05, +p = .05. Child sex is coded as 1 = male, 2 = female. Break status is coded as 0 = participation occurred during school, 1 = participation occurred during a school break (i.e., spring break, summer). PTSS = post-traumatic stress symptoms (note that one sleep item was removed). Cat B = re-experiencing symptoms. Cat C = avoidance symptoms. Cat D = negative cognitions/mood symptoms. Cat E = arousal/reactivity (note that one sleep item was removed). SSHS = School Sleep Habits Questionnaire. TST = total sleep time (minutes). WASO = wake after sleep onset (minutes). SOL = sleep onset latency (minutes). SE = sleep efficiency (%). MSP = midsleep point (clock time in HH:MM).

Table 2

Regression models predicting post-traumatic stress symptoms after the hurricane adjusting for age, sex, parent education, break status, and pre-hurricane symptoms

	Post-Traumatic Stress Symptoms			
	B	SE	Beta	95% CI
SSHS	.55	.12	.50***	.32, .78
Chronotype	-.47	.21	-.28*	-.90, -0.06
TST	-.05	.02	-.31+	-.09, .002
SOL	.01	.03	.02	-.06, .07
SE	-.04	.11	-.04	-.25, .18
WASO	.01	.04	.02	-.07, .08
MSP	.67	1.31	.08	-1.89, 3.23

Notes. . ***$p < .001$, **$p < .01$, *$p < .05$, +$p = .058$. All models controlled for child age, child sex, parent education, school break status, and pre-hurricane anxiety symptoms. SSHS = School Sleep Habits Questionnaire. TST = total sleep time. SOL = sleep onset latency. SE = sleep efficiency. WASO = wake after sleep onset. MSP = midsleep point. The PTSS scale has one item pertaining to sleep disturbances. Analyses were conducted using PTSS scores with and without this item, and results were consistent. Results without this item are presented here.

Table 3

Regression models predicting post-hurricane post-traumatic stress symptom clusters adjusting for age, sex, parent education, break status, and pre-hurricane symptoms

	Category B: Re-Experiencing				Category C: Avoidance				Category D: Cognitions/Mood				Category E: Arousal/Reactivity			
	B	SE	Beta	95% CI	B	SE	Beta	95% CI	B	SE	Beta	95% CI	B	SE	Beta	95% CI
SSHS	.17	.04	.41***	.09, .25	.11	.04	.36**	.03, .18	.17	.05	.43***	.07, .27	.11	.02	.45***	.07, .15
Chronotype	-.14	.07	-.23*	-.28, -.01	.01	.06	.02	-.11, .12	-.21	.08	-.34**	-.37, -.04	-.13	.06	-.36*	-.24, -.02
TST	-.02	.01	-.29++	-.03, .001	-.01	.02	-.32*	-.02, -.001	-.02	.01	-.30	-.03, .003	-.002	.01	-.07	-.01, .01
SOL	.02	.02	.15	-.01, .05	.001	.01	.01	-.02, .02	-.01	.01	-.10	-.03, .003	-.001	.01	-.01	-.01, .01
SE	-.05	.04	-.15	-.13, .03	-.01	.03	-.05	-.07, .05	.02	.04	.05	-.06, .09	.01	.02	.05	-.03, .05
WASO	.007	.01	.08	-.02, .03	.01	.01	.09	-.01, .02	.002	.01	.02	-.02, .03	-.01	.01	-.18	-.02, .003
MSP	.10	.45	.04	-.77, .98	.43	.37	.20	-.30, 1.15	-.61	.47	-.22	-1.54, .32	.75	.25	.45**	.26, .1.25

Notes. ***$p \leq .001$, **$p \leq .01$, *$p < .05$, +$p = .07$. All models controlled for child age, child sex, parent education, school break status, and pre-hurricane anxiety symptoms. SSHS = School Sleep Habits Questionnaire. TST = total sleep time. SOL = sleep onset latency. SE = sleep efficiency. WASO = wake after sleep onset. MSP = midsleep point. The PTSS arousal/reactivity subscale has one item pertaining to sleep disturbances. Analyses were conducted using subscale scores with and without this item, and findings were consistent. Results without this item are presented here.