Nocturnal Awakenings and Pediatric Injury Risk

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Objective This study was designed to examine relations between nocturnal awakenings and unintentional injury risk among toddlers. **Methods** A nationally representative sample of 799 children was followed longitudinally from birth through 36 months. Patterns of nocturnal awakening were assessed by parent-report at ages 6, 15, 24 and 36 months, and injury events were reported at quarterly intervals over the same time period. A range of external covariates, including positive and negative affect and externalizing behavior; maternal stress, maternal depression, and parenting style; and family socioeconomic status were measured. **Results** A persistent pattern of very mild nocturnal awakening was related to increased risk of injury during the toddler years, and that relation held after controlling for a range of potential covariates. **Conclusions** A pattern of persistent nocturnal awakening appears to be related to unintentional injury risk in toddlers.

Key words injury; nocturnal awakenings; safety; sleep; sleep problems.

Throughout the lifespan, sleep is among the most basic of human behaviors. During early childhood, sleep problems are very common, with some reports suggesting up to 50% of preschoolers experience some sort of sleep difficulty (Archbold, Pituch, Panabi, & Chervin, 2002; Kerr & Jowett, 1994; Mindell, Owens, & Carskadon, 1999). More specifically, about 8% of preschoolers have sleep-disordered breathing; about 10% have excessive daytime sleepiness; over 20% have symptoms of insomnia; about 30% have bedtime resistance; over 30% have nocturnal bruxism; and nearly 40% of preschoolers have sleep terrors (Archbold et al., 2002).

Among young children, sleep—or lack thereof—appears to play a central role in a range of developmental outcomes. It influences social, cognitive, and motor development (Loughlin, Carroll, & Marcus, 2000), and also appears to influence children's health. One understudied area within the domain of how sleep influences children's health, and the focus of this report, is the role of nocturnal awakenings on children's risk for unintentional injury.

Unintentional Injury and Sleep

Injury is the leading cause of mortality for children in the United States and most of the world (National Center for Injury Prevention and Control [NCIPC], 2007; World Health Organization [WHO], 2005). In the United States, injuries kill more children aged 1–18 than the next 20 causes of death combined (NCIPC, 2007).

A substantive body of research links sleepiness and sleep problems to injury risk in adults—and in particular to risk of injury in automobile crashes (Connor, Whitlock, Norton, & Jackson, 2001; Lyznicki, Doege, Davis, & Williams, 1998) and occupation-related injuries (Ayas et al., 2006; Bunn, Slavova, Struttmann, & Browning, 2005; Caruso, 2006). A recent report replicated these findings among adolescent farm workers (Stallones, Beseler, & Chen, 2006), but very little work addresses links between children's sleep habits and their injury risk.

One published study compared children ages 3–7 who had two or more medically attended injuries in the past two years to those who had just one or no medically-attended injuries during that time period

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(Owens, Fernando, & McGuinn, 2005). The high-injury group had more parent-reported sleep problems. Children who had higher levels of parent-reported risk taking also had more parent-reported sleep problems (Owens et al., 2005). A second study used a case-crossover design to compare children's sleep habits immediately prior to a medically attended injury versus their sleep habits a few days before the injury had occurred (Valent, Brusaferro, & Barbone, 2001). Less sleep was reported during the immediate pre-injury time period, especially among the younger children (ages 3–5) in the study.

Mechanisms that may underlie these tentative links between sleep and injury risk in childhood are poorly understood, partly because the behavioral factors that lead to unintentional injury are complex and multifaceted (see Schwebel & Gaines, 2007, for review). One likely contributor is the role of daytime sleepiness, the cause attributed to adult risk for driving and occupational injury. Fatigued children appear to have disrupted motor coordination, attention, and concentration (Fallone, Owens, & Deane, 2002), factors that may increase risk for injury. Fatigued children are also likely to be more oppositional to rules, to take more risks and behave impulsively, to have changes in mood, and to be hyperactive (Fallone et al., 2002); these symptoms are also correlated with injury risk (Schwebel & Gaines, 2007).

Alternative explanations for the link between pediatric sleep problems and injury risk are equally plausible, especially among young children for whom parental supervision plays a critical role in maintaining pediatric safety (Morrongiello, 2005). Sleep difficulties in children are known to be correlated to reduced sleep duration in adults (Boergers, Hart, Owens, Streisand, & Spirito, 2007), for example. When parents are sleep deprived, they may be less attentive or effective supervisors of their children. Fatigued parents may also develop dysfunctional parent-child relationships; create a situation whereby oppositional or noncompliant child behavior patterns develop; or inconsistently define, teach, and enforce safety-related rules. It is also plausible that some injuries might cause development of sleep problems in children. One recent report suggested, for example, that pediatric traumatic brain injury patients had disrupted sleep for several months postinjury (Beebe et al., 2007).

The Present Study

Given available evidence, this study was designed to probe further the links between sleep and risk for unintentional injury among young children. The study was conducted with data from the NICHD Study of Early Child Care, a nationally representative study of over 1,300 children being followed from birth into adolescence. Our primary goal was descriptive: do toddlers who have sleep problems—as defined by frequent nocturnal awakening—also have increased risk of injury? Based on previous evidence (Owens et al., 2005; Valent et al., 2001), we hypothesized a modest but consistent link.

We also had two secondary objectives. First, we sought to test whether the frequency of nocturnal awakening might be related to injury risk. We examined nocturnal awakening patterns through early development, as reported at ages 6, 15, 24, and 36 months, and categorized children into groups of no significant nocturnal awakening through early development, very mild frequency of nocturnal awakening through early development, mild frequency of nocturnal awakening through early development, and moderate/severe frequency of nocturnal awakening through early development. We expected more frequent patterns of nocturnal awakening to be associated with greater injury risk.

Second, in an attempt to begin understanding mechanisms that might explain the link between pediatric sleep and increased injury risk, we controlled statistically for potential covariates that might confound the relation between nocturnal awakening and injury risk: child gender, positive affect, negative affect, and externalizing behavior; family socioeconomic status (SES); and parenting style, maternal stress, and maternal depression. All of these covariates are known to correlate mildly with child injury risk (Schwebel & Gaines, 2007); several also correlate to sleep problems (Fallone et al., 2002). They were selected from available data as possible third-variable confounds that could create the illusion of a direct relation between sleep and injury risk. By including them in multiple regression models, we controlled for variance accounted for by the potential confounds to demonstrate more confidently a direct relation between nocturnal awakening and injury.

Methods

Data Source and Participants

Data came from the National Institute of Child Health and Human Development (NICHD) Study of Early Child Care, a longitudinal investigation of the effects of early child care on children's development. Participants were recruited at birth from 31 hospitals located in or near 10 US cities (Little Rock, AR; Irvine, CA; Lawrence, KS; Boston, MA; Morganton, NC; Philadelphia, PA; Pittsburgh, PA; Charlottesville, VA; Seattle, WA; Madison, WI). During selected 24 hr sampling periods,

8,986 women giving birth were visited in the hospital. Of these, 5,416 met the study's eligibility criteria (briefly, English-speaking mothers age 18 or over who planned not to put children up for adoption, not to relocate in the next year, and who lived in safe and accessible neighborhoods for research; for details, see NICHD Early Child Care Research Network, 2000). A subset of this group was selected in accordance with a conditional-random sampling plan designed to ensure recruited families reflected the economic, educational, and ethnic diversity of the catchment area at each site. When the infants were 1-month old, 1,364 families (58% of those contacted) enrolled in the longitudinal study (see NICHD Early Child Care Research Network, 1994, 2001, for details of study design and recruitment, including informed consent procedures).

Like all large data sets, there are some missing data points in the NICHD Study of Early Child Care data set. In many cases, data are missing due to attrition; in other cases, data are missing due to failure of parents to complete particular measures used in this investigation. Of the 1,364 families who took part in the NICHD Study of Early Child Care, data from 799 are reported in this study. Independent samples *t*-tests (for continuous data) and chi-squares (for categorical data) were conducted to compare the sample reported at present to the sample with missing data on major demographic variables (gender, SES, and child race/ethnicity). As is the case in many longitudinal studies, including previous reports with this data set (Schwebel & Brezausek, 2007; Schwebel, Brezausek, & Belsky, 2006), children dropped from this report were more likely to be of low SES and ethnic minority background.

The sample of 799 reported in this study included 408 boys (51%) and 391 girls (49%), and was 86% Caucasian, 9% African American, and 5% of other ethnicities. Average education for mothers in the sample was 14.64 years ($SD = 2.40$).

Measures

Several measures were chosen from the NICHD Early Child Care Study data for the present analysis, as detailed below. Unless otherwise indicated subsequently, the measures were taken when children were 6-, 15-, 24-, and 36-months old, and aggregates were created by averaging those four scores. If constructs were assessed using different scales at different ages, scores were standardized before they were averaged. Participants whose data were missing at any datapoint on any variable were dropped from analysis.

Nocturnal awakenings

Measurement of nocturnal awakening was based on three parent-reported criteria: the number of nights the child awakens per week, the number of times the child awakens per night awake, and the length of time the child is awake per night awakening. In each case, children were classified into a category only when they met the criteria at all four assessment points (6, 15, 24, and 36 months), and therefore this construct represents a measure of persistent sleep problems throughout early childhood. If children displayed high levels of awakening at some assessment points but lower levels at one or two assessments, the lower level of classification was assigned.

A pattern of very mild nocturnal awakening was identified when the child's parents reported an average of one or more nights awake per week, one or more awakenings per night awake, and a wakening of 5 min or more in length per night awake, at all four assessment points (ages 6, 15, 24, and 36 months). This level of nocturnal awakening is one that many experts would consider within the range of normal sleep for this developmental stage, and 23% of the sample was classified within this category.

A pattern of mild nocturnal awakening was identified when the child's parents reported an average of two or more nights awake per week, one or more awakenings per night awake, and a wakening of 10 min or more in length per night awake. Eighteen percent of the sample met these criteria at all four assessment points.

A pattern of moderate/severe nocturnal awakening was identified when the child's parents reported an average of three or more nights awake per week, two or more awakenings per night awake, and a wakening of 15 min or more in length per night awake. This level of nocturnal awakening was present in 2% of the sample at all four assessment points.

Maternal perception of child sleep as a problem

Mothers reported the extent to which the child's nighttime awakening was a problem on a three-point Likert scale at each assessment point (1 = not much of a problem; 2 = somewhat a problem; 3 = quite a bit of a problem). The four scores inter-correlated moderately over time (average inter-item correlation = .25).

Injury

Mothers reported their children's history of injuries requiring professional medical attention on a quarterly basis from birth to age 36 months, either through telephone interviews or during scheduled home visits by experimenters. A large body of empirical research

indicates that parental reports of child injury history are reliable (Pless & Pless, 1995), particularly when reports are collected at short intervals to reduce recall biases (Cummings, Rivara, Thompson, & Reid, 2005; Harel et al., 1994; Peterson, Harbeck, & Moreno, 1993). As is commonly found in the injury literature, injury events were relatively infrequent. Children experienced a mean of 0.21 injuries ($SD = 0.55$; range = 0–4) over the 3-year period.

Family SES

The SES aggregate was created by averaging the family's income-to-needs ratio when the child was 6-, 15-, 24-, and 36-months old (average intercorrelation = .77). The income-to-needs ratio calculated income based on the entire income of all members of the family living in the same household and estimated needs based on the poverty threshold during the year of measurement, the number of people in the household, and the number of children in the household (see Bilbrey, Batten, Appelbaum, & Wendell, 1994a, for details). An income-to-needs ratio that is less than 1 reflects significant poverty; the mean (3.84) and standard deviation (2.90) of this sample reflects a group of families that is generally middle and upper class, but which includes some impoverished families.

Child Positive Affect

Positive affect was assessed via a semi-structured mother–child play interaction adapted from Egeland and Heister (1993). Positive affect (6, 15, and 24 months) and enthusiasm (36 months) were rated on a Likert-style rating scale by two raters (4-point scale used at 6, 15, and 24 months; 7-point scale used at 36 months). Adequate inter-rater reliability was obtained between independent coders at all four ages (Appelbaum, Batten, & Wendell, 1994; Batten & Wendell, 1994; Bland, Batten, Appelbaum, & Wendell, 1995, 1996a). The four scores were standardized and then aggregated; they intercorrelated mildly (average inter-correlation $r = .12$).

Child Negative Affect

Negative affect was assessed via the same semi-structured mother–child play interaction as positive affect. Negative affect (6, 15, and 24 months) and negativity (36 months) were rated on a Likert-style rating scale by two raters (4-point scale used at 6, 15, and 24 months; 7-point scale used at 36 months). Adequate inter-rater reliability was obtained between independent coders at all four ages (Appelbaum et al., 1994; Batten & Wendell, 1994; Bland et al., 1995, 1996a). The four scores were standardized and then aggregated; they inter-correlated mildly (average inter-correlation $r = .11$).

Child Externalizing Behavior

Externalizing behavior was measured by summing the aggressive and destructive behavior scales of mother-reported Achenbach's Child Behavior Checklist (CBCL; Achenbach, 1992) at 24 and 36 months. The two scores correlated well in the sample, $r = .70$. No assessment of externalizing behavior was made at 6 or 15 months. The CBCL is a widely used measure with excellent psychometric properties (test–retest reliability and Cronbach's α for internal reliability of both scales $> .70$; Achenbach, 1992).

Parenting

The total score of the Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1984) was used as a measure of quality and style of caregiving. The infant/toddler version (45 items) was used at 6 and 15 months and the early childhood version (55 items) at 36 months; the three measures correlated moderately, average inter-correlation $r = .50$. No assessment was made at 24 months. Items in both versions address a wide range of topics related to the home environment, including language and academic stimulation available in the home, responsiveness, acceptance, enrichment, and modeling by the caregiver, and variety and safety of the physical environment. Items are scored in a binary fashion, and the total number of ''yes'' responses in the environment is summed to create a score. Psychometric qualities of the measure are good (Cronbach's $\alpha = .76$ at 6 months, .77 at 15 months and .87 at 36 months; Bland, Batten, Appelbaum, & Wendell, 1996b; Little, Appelbaum, Batten, & Wendell, 1993a, 1994).

Maternal Stress

The maternal stress measure was created by averaging measures of parenting stress from the 15-, 24-, and 36-month assessment times (average inter-correlation = .62). No measure was available from the 6-month assessment. Parenting stress was assessed using an abbreviated version of the Parent Role Quality Scale (Barnett & Marshall, 1991). The total score from 20 items answered on a 4-point scale was used; higher scores represent higher levels of parenting stress. Psychometrics were good (Cronbach's $\alpha = .79$, .80, and .79 at the three ages, respectively; Coleman, Batten, Appelbaum, & Wendell, 1995c, 1995d; Wilkerson, Appelbaum, Batten, & Wendell, 1994).

Maternal depression

Maternal depression was measured using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977), a self-report scale designed to assess depression in nonclinical populations. The measure was assessed at all four time points and the scores intercorrelated moderately (average inter-correlation = .53). The CES-D includes a rating of the frequency of 20 depressive symptoms over the past week using a 4-point scale; higher scores represent higher levels of depression. Psychometrics are good (Cronbach's $\alpha = .89$, .90, .91, and .90 at the four assessment points, respectively; Bilbrey, Batten, Appelbaum, & Wendell, 1994b; Coleman, Batten, Appelbaum, & Wendell, 1995a, 1995b; Little, Appelbaum, Batten, & Wendell, 1993b).

Analytic Plan

Following consideration of descriptive data, data were analyzed in three steps. First, univariate Poisson regression models were computed to predict injuries from birth through 36 months, based on the level of nocturnal awakenings reported across that time period. Poisson is the recommended curve for modeling count variables such as injury incidents (Cameron & Trivedi, 1998). Second, potential confounds to the relation between sleep and injury were considered in a correlation matrix. Sleep was included in the matrix but injuries were not due to the nonlinear distribution of the injury variable. Third, and most critical to the testing of primary hypotheses, multivariate Poisson models predicting injury were computed with all confounds included in the models.

Results

Descriptive Data

Table I displays descriptive data for all variables of interest. Note that the positive affect, negative affect, and parenting variables are aggregated *z*-scores because they combine measures taken on different scales at different age points. Other continuous variables are reported as the average of raw scores from the four assessment points.

Table II illustrates more detailed descriptive data concerning the injury rates of children in the various nocturnal awakenings groups. Children without significant awakening patterns persisting through early development reported a mean of 0.16 injuries ($SD = 0.24$; range = 0–3); there were 515 children (64% of sample) in this group. One hundred and sixty-one children (20%) fell into the category of very mild awakening throughout early development. This group had a mean of 0.25 injuries ($SD = 0.63$; range = 0–4). The mild ($n = 111$; 14%) and moderate/severe ($n = 12$; 2%) awakening groups had means of 0.28 ($SD = 0.64$) and 0.27 ($SD = 0.59$) injuries, respectively. Thus, from a descriptive data perspective, children with any pattern of persistent nocturnal awakening—including very mild but persistent patterns that many experts might consider within the normal range of functioning—had a higher rate of injury than children without significant awakening throughout early development. Contrary to our hypothesis, more severe levels of nocturnal awakening did not appear to be associated with greater injury risk over less frequent awakening patterns.

Table I. Descriptive Data ($N = 799$)

Variable	Mean (*SD*)
Demographic variables	
Sex	51% male
Income: needs ratio	3.84 (2.90)
Child variables	
Positive affect	0.02 (0.58)
Negative affect	−0.01 (0.58)
Externalizing behavior	13.78 (6.61)
Mother variables	
Parenting	0.14 (0.73)
Stress	34.13 (5.49)
Depression	8.80 (6.41)
Sleep problems	
No significant awakening	64% of sample
Very mild awakening	20% of sample
Mild awakening	14% of sample
Moderate/severe awakening	2% of sample
Maternal sleep perception[a]	1.31 (0.39)
Child injuries	
Injuries	0.21 (0.55)

[a]On three-point Likert scale. Higher scores reflect perception of more significant sleep.

Univariate Prediction of Nocturnal Awakening

Table II also illustrates univariate Poisson models predicting injury counts based on nocturnal awakening patterns. One model was conducted with the nocturnal awakenings pattern entered as an ordinal variable with four levels predicting injury, and a second with the maternal perception variable entered as a continuous variable predicting injury. As shown, and consistent with our hypothesis, presence of very mild awakening over the first 3 years of life was associated with increased injury risk over that same time period ($\chi^2 = 5.93$, $p < .05$, 95% CI = 0.08, 0.78). There was a statistical trend for mild nocturnal awakening patterns to be related to increased risk of injury ($\chi^2 = 2.69$, $p = .10$, 95% CI = −0.08, 0.75),

Table II. Descriptive Data and Univariate Poisson Models Predicting Injuries ($N = 799$)

	Injury rates		Poisson regression			
	M (*SD*)	Range	*B*	*SE*	χ^2	95% CI
No significant awakening ($N = 515$)	0.16 (0.46)	0–3	–	–	–	–
Very mild awakening ($N = 161$)	0.25 (0.63)	0–4	0.44	0.18	5.93*	0.08, 0.78
Mild awakening ($N = 111$)	0.28 (0.64)	0–4	0.35	0.21	2.69	−0.08, 0.75
Moderate/severe awakening ($N = 2$)	0.27 (0.59)	0–2	−0.79	1.01	0.62	−3.66, 0.71
Mother's perception of sleep	- -	-	−0.05	0.18	0.08	−0.39, 0.30

*$p < .05$.

Table III. Correlation Matrix, Predictor Variables ($N = 799$)

Variable	2	3	4	5	6	7	8	9	10	11	12
Child variables											
1. Gender[a]	.08*	−.11**	−.05	.07	.07	.02	.06	−.05	−.04	−.02	−.01
2. Positive Affect	–	−.32**	−.12**	.14**	.21**	−.06	−.16**	−.00	.02	−.00	.05
3. Negative affect		–	.22**	−.11**	−.18**	.07*	.15**	−.02	.01	−.03	−.00
4. Externalizing behavior			–	−.18**	−.26**	.37**	.36**	.05	.05	.02	.08*
Family variables											
5. SES				–	.43**	−.12**	−.25**	−.01	.01	−.00	.09**
Mother variables											
6. Parenting					–	−.20**	−.35**	.05	.00	.00	.04
7. Stress						–	.45**	.04	.09**	.06	.15**
8. Depression							–	.01	.07	.13**	.18**
Nocturnal awakening											
9. Very mild awakening[b]								–	–	–	.05
10. Mild awakening[b]									–	–	.15**
11. Moderate awakening[b]										–	.23**
12. Parental sleep perception											–

[a]1 = boy, 2 = girl.
[b]0 = no, 1 = yes.
*$p < .05$, **$p < .01$.

but moderate/severe levels of awakening and mother's perception of sleep were not related to injury.

Multivariate Prediction of Nocturnal Awakening

The next step of the analysis was to build multivariate Poisson regression models. Prior to that, however, we considered the possibility of shared variance among predictor variables. As shown in Table III, several predictor variables were moderately correlated to each other, but none appeared to be highly collinear. Table III also demonstrates that nocturnal awakening was associated slightly with a few other predictor variables. One notable finding was that parental depression appeared to be modestly related to a pattern of moderate/severe child nocturnal awakening ($r = .13$, $p < .01$); a second was a relation between maternal stress and a persistent pattern of mild levels of nocturnal awakening ($r = .09$, $p < .01$).

Given univariate results, a multivariate Poisson regression model was constructed to predict a pattern of very mild nocturnal awakening. The model included all hypothesized confounds. As shown in Table IV, the effect of very mild nocturnal awakening remained a significant predictor of injury incidence ($\chi^2 = 4.42$, $p < .05$, 95% CI = 0.02, 0.63), even after including variance from the potential confounds in the model. Child sex ($\chi^2 = 9.20$, $p < .01$, 95% CI = −0.81, −0.18) and negative affect ($\chi^2 = 5.95$, $p < .05$, 95% CI = −0.70, −0.08) also emerged as statistically significant predictors, with boys and children with higher levels of negative affect having more injuries than girls and children with lower levels of negative affect.

Discussion

Results from this study suggest persistent nocturnal awakening through early childhood is correlated to toddlers' risk for unintentional injury, even after controlling for a range of individual, parent, and family

Table IV. Multivariate Poisson Regression Model Predicting Injury, Very Mild Nocturnal Awakening as Predictor ($n = 799$)

Predictor	*B*	*SE*	χ^2	95% CI
Sex (1 = male, 2 = female)	−0.49	0.16	9.20**	−0.81 to −0.18
Positive affect	0.00	0.14	0.00	−0.28 to 0.28
Negative affect	−0.38	0.16	5.95*	−0.70 to −0.08
Externalizing behavior	0.00	0.01	0.01	−0.02 to 0.03
SES	−0.07	0.04	3.70	−0.14 to −0.00
Parenting	0.13	0.12	1.09	−0.11 to 0.37
Maternal stress	0.02	0.02	1.79	−0.01 to 0.05
Maternal depression	0.02	0.01	1.43	−0.01 to 0.04
Very mild awakening	0.33	0.15	4.42*	0.02 to 0.63

*$p < .05$, **$p < .01$.

covariates. Previous work suggested some links between sleep and injury risk (Owens et al., 2005; Valent et al., 2001), but this study is the first to suggest persistent nocturnal awakening may be related to young children's injury risk over a concurrent period of development, and that this relation holds even after controlling for potential covariates known to relate to child injury risk.

As is the case in many novel areas of inquiry, our findings raise as many questions as they answer. One prominent question is that of the mechanism that might explain links between sleep and pediatric injury risk. An appealing explanation is that children who are fatigued become less attentive, less diligent, and perhaps more risky in their behavior patterns, leading to injury. Other explanations are also plausible. It may be, for example, that lower quality parenting is related to both poor supervision of children's risk-taking and poor monitoring of children's sleep health. Parents may become fatigued because their children are awake frequently during the night. Injuries also appear to lead to poor sleep habits in some instances; recent research with pediatric traumatic brain injury (TBI) patients suggests sleep problems are common post-TBI, for example (Beebe et al., 2007).

A second unanswered question is the role comorbid mental health might play. Children with developmental disabilities and mental retardation have higher rates of nocturnal awakenings (Didden, Curfs, & van Driel, 2002; Johnson, 1996), and also appear to have slightly higher rates of the injury risk (Dunne, Asher, & Rivara, 1993; Slayter, Garnick, & Kubisiak, 2006). Post hoc analyses with this sample did not suggest children with nocturnal awakenings scored lower on cognitive screenings using the Bayley (15 and 24 months) and Reynell (36 months), but other dysfunction (e.g., internalizing disorders) was not assessed.

A final unanswered question is why very mild patterns of nocturnal awakening (those that might be described as within the normal range of functioning) were related to injury risk, but more significant persistent patterns of awakening were not. The most plausible explanation for this finding is underpowered analyses, especially among the moderate/severe awakening group. The results should be replicated. Beyond that, future research might consider other explanations for the results, including the role of behavioral covariates omitted from this report.

Effect sizes in this study were modest, probably for a few reasons. First, injuries requiring professional medical attention are rare events. Many children—even those with significant risk—thrive for several months or years without experiencing an injury that requires professional medical attention. Statistically, long time periods are needed for injuries to ''accumulate'' to the point that regression models might predict them strongly. Second, injuries are caused by a wide range of intrapsychic, interpersonal, and environmental factors. This study tested the broad unmediated relation between sleep and injury risk and controlled for only some of the many external risk factors that may be involved.

In closing, limitations of the research should be noted. Most concerning are the limitations due to the archival nature of the analyses. The analyses suffered from missing data points, and omitted participants more likely to be impoverished and of ethnic minority background. We were limited to analysis of the variables available, making tests of mediational models not feasible.

Also limiting was the fact that sleep-related data were available only on nocturnal awakening, and were based only on parent report. Injury history data were also based only on parent report. Future research should consider whether our findings extend to other aspects of pediatric sleep health, including sleep duration, bedtime resistance, napping habits, and so on. Future research might also utilize more objective measures of sleep (e.g., polysomnography or actigraphy) and injury history (e.g., insurance or medical records).

Despite the limitations, we feel the results are meaningful and offer important applied and theoretical implications. The consequences of sleep dysfunction on learning, peer relations, immune functioning, and a range of other physiological, social, and cognitive abilities are well documented (Loughlin et al., 2000). This study offers evidence that poor sleep, as measured by nocturnal awakening, may also be related to risk for unintentional injury. From an applied perspective, our findings reinforce the need to aggressively treat sleep difficulty in young children, as a means to maintain not just cognitive

and social development, but also physical health. From a theoretical perspective, the findings underscore the complexity of risk for pediatric injury, and the need to consider the multifaceted aspect of risk in development of appropriate empirically-supported intervention strategies.

Conflicts of interest: None declared.

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