Original Article

Childhood adversity and insomnia in adolescence

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ABSTRACT

Objective: The study aims to evaluate the association between exposure to childhood adversity and insomnia, with an emphasis on the role of adversity type, timing, and accumulation (i.e., the number of specific types of adversities the child reported being exposed to).
Methods: Our analytic sample comprised 9582 adolescents from the National Comorbidity Survey Replication Adolescent Supplement (NCS-A), a nationally representative population-based sample. We examined the association between 18 different types of retrospectively reported adversities (capturing interpersonal violence, accidents and injuries, social network or witnessing events, and other adverse events) and risk of self-reported past-year insomnia. We also examined whether the age at first exposure to adversity was associated with the risk of insomnia, and whether exposure to a greater number of different types of adversities (ie, accumulation) conferred an elevated risk of insomnia. In addition, we performed a sensitivity analysis excluding adolescents with a past-year diagnosis of major depression, dysthymia, post-traumatic stress disorder (PTSD), or generalized anxiety disorder.
Results: Almost one-third of adolescents reported insomnia, with a higher prevalence among girls and those from racial/ethnic minority groups. Adolescents exposed to at least one childhood adversity of any type (59.41%) were more likely than their nonexposed peers to experience insomnia (across adversities, prevalence ratios (PRs) ranged from 1.31 to 1.89). Risk of insomnia differed based on the age at first exposure to adversity as well as the type of adversity. Adolescents exposed to a greater number of different types of adversities had a higher risk of insomnia compared to those experiencing fewer adversities. These results were similar, by and large, to those obtained after excluding adolescents with at least one of the four past-year psychiatric disorders.
Conclusions: Exposure to adversity confers an elevated risk of insomnia. This association varied by type, timing, and accumulation of exposure and did not appear to be driven by psychiatric disorders. Given the well-documented physical and mental health consequences of insomnia, such findings further support the need for practitioners to screen children for exposure to childhood adversity and insomnia symptoms.

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1. Introduction

Upwards of 48% of children in the United States experience one or more types of childhood adversity, such as abuse or neglect, parental death, and witnessing violence [1,2]. Exposure to childhood adversity is now recognized as one of the major determinants of health across the life span [3]. Indeed, numerous studies in both youth and adults have shown that childhood adversity exposure is associated with a doubled risk of mental health problems [4–6], an increased risk of physical health risk factors and disease outcomes [7,8], and elevates risk for premature mortality [9,10].

Relatively little is known about the association between childhood adversity and sleep problems, especially insomnia or insomnia symptoms, which is the most reported type of sleep disturbance among adolescence [11–13], a major correlate of health problems [14], and among the top concerns raised by parents to health professionals [15]. To date, most studies of adversity and sleep have examined childhood maltreatment, namely exposure to abuse or neglect [16,17]. These studies have generally observed at least a 20% greater risk of insomnia, insomnia symptoms, or other sleep problems among adolescents and adults exposed to maltreatment during

childhood [16–24]. However, only a few of these studies have been conducted in population-based samples, especially of youth. Even fewer have examined other childhood adversities beyond maltreatment, such as witnessing violence, which may be more common than child maltreatment [25]. However, a few studies focusing on a broader array of adversities (see, for example, [24,26]) tend to show a significant dose–response relationship, whereby each additional exposure to a unique adverse event confers a greater risk for poor sleep quality in adulthood. In addition, it remains unclear whether all childhood adversities are equally damaging across all stages of development or whether there are "sensitive periods" when the negative effects of adversity are particularly heightened [27–30]. Identification of these sensitive periods is needed to determine the high-risk stages of development when efforts by practitioners would be most helpful to ensure healthy child development and build the foundation for adult health [31].

The goal of this study was to examine, in a large population-based sample of adolescents, the association between childhood adversity and insomnia. First, we examined whether children exposed to different *types of adversity* were more likely than their unexposed peers to experience insomnia. Second, we examined whether the *age at first exposure to adversity* was associated with the risk of insomnia, consistent with the notion of sensitive periods. Finally, to replicate previous findings, we also evaluated whether there was a dose–response relationship between the *number of different types of adversities reported (ie, accumulation)* and insomnia. This accumulation score, which was derived by summing across the unique type of adversities reported, is consistent with the "ACE score" (eg, adversity childhood experiences) calculated by the Adversity Childhood Experiences Study [9], a well-known study of the health consequences of childhood maltreatment among members of the Kaiser Permanente Health Maintenance Organization. In addition, we performed a sensitivity analysis to examine whether these results were the same after excluding adolescents experiencing a past-year diagnosis of major depression, dysthymia, post-traumatic stress disorder (PTSD), or generalized anxiety disorder, as these psychiatric disorders are known correlates of insomnia [32–36]. We hypothesized that exposure to adversity of any type and accumulation of adversity would be associated with insomnia symptoms. However, given the lack of prior research, we did not have any a priori hypotheses concerning the effects of age at onset to adversity and insomnia.

2. Methods

2.1. Sample

Data came from the National Comorbidity Survey Replication Adolescent Supplement (NCS-A), the first nationally representative study to provide estimates of the prevalence and correlates of mental and other health problems among English-speaking U.S. adolescents. Description of the sampling has been noted elsewhere [37]. Briefly, NCS-A investigators conducted face-to-face interviews with 10,148 adolescents ages 13 through 18 between February 2001 and January 2004 from the continental US. Adolescents were sampled through a dual-frame sample comprising adolescents from households in the National Comorbidity Survey Replication (NCS-R) [38] (household subsample *n* = 904) and adolescents from a representative sample of schools in the adult sample areas of the NCS-R (school subsample *n* = 9244 adolescents in 320 schools). The overall response rate was 75.6% (74.7% school-based sample and 85.9% household sample) [37]. The Human Subjects Committees of Harvard Medical School and the University of Michigan approved NCS-A study recruitment and informed consent procedures. Parent-written informed consent and adolescent-written informed assent were obtained prior to

interview completion. In this study, we analyzed data from adolescents with valid sampling weights and complete data on all variables (*n* = 9582; 94.42% of the total sample). Participants in our analytic sample (*n* = 9582) did not differ from those who were excluded (*n* = 566) with respect to most demographic characteristics, including age, race, gender, poverty level, and urbanicity. However, the excluded sample comprised fewer youth from families with college and graduate education (27.0% vs. 35.8%; *p* = 0.004).

2.2. Measures

2.2.1. Exposure to childhood adversity

Adolescents reported through structured interviews whether they had experienced 18 potentially traumatic events and if so, the age at first experience. These events are commonly included in measures of childhood adversity [39] and were included in the NCS-A as part of the Composite International Diagnostic Interview (CIDI) to assess the presence or absence of PTSD. We grouped these events into four types (i.e., interpersonal violence, accidents and injuries, social network or witnessing events and others), consistent with prior studies based on the NCS-A [40] and other datasets [41]. We then generated three predictor variables from these data: presence or absence of each childhood adversity (18 events), presence or absence of each childhood adversity type (four types) and age at first exposure to each adversity or adversity type. Age at first exposure was characterized into three unique developmental timing windows, similar to prior studies [30,42,43]: (1) early childhood (between ages 0 and 5 years); (2) middle childhood (ages 6–10 years); and (3) adolescence (ages 11–18 years). Using these age groupings, we were able to maintain consistency with prior studies. Of note, adolescents were very good reporters of their age at onset to specific events. For instance, the correlation between parent- and child-reported age at onset to child major depressive disorder was very high (*r* = 0.81).

The first group of adversities included acts of *interpersonal violence*: (1) *Parent Violence*: "Badly beaten up by your parents or the people who raised you"; (2) *Other Violence*: "Badly beaten up by anyone else"; (3) *Rape*: ". . .someone either having sexual intercourse with you or penetrating your body with a finger or object when you did not want them to, either by threatening you or by using force"; (4) *Kidnapped*: "Kidnapped or held captive"; and (5) *Other sexual assault*: "Other than rape, ever sexually assaulted or molested."

The second group of adversities involved *accidents and injuries*: (6) *Car accident*: "Involved in a very serious or life-threatening car accident"; (7) *Disaster*: "Involved in a major disaster, like a devastating flood, hurricane, fire, bomb explosion, tornado, or earthquake"; (8) *Illness*: "Have a very serious or life threatening illness"; (9) *Chemical*: "Exposed to a poisonous chemical or substance that could cause you serious harm"; and (10) *Other accident*: "Have any other very serious or life threatening accident."

The third group involved *social network or witnessing events*: (11) *Witnessed fights at home*: "Witness serious physical fights at home, like when your father beat up your mother"; (12) *Witness death*: "Seen someone badly injured or killed or unexpectedly seen a dead body"; (13) *Other person died unexpectedly*: "Someone very close to you die unexpectedly, for example, they were killed in an accident, murdered, committed suicide, or had a fatal heart attack at a young age"; (14) *Other person unexpected threat*: "Anyone very close to you ever have a very stressful or life-threatening experience, like being kidnapped, tortured, or raped"; (15) *War Terror*: "Live in a place where there was war or ongoing terror"; and (16) *Refugee*: "A refugee, that is, did you ever flee from your home to a foreign country or place to escape danger or persecution).

The fourth group included *other adversities*: (17) *Other trauma*: "Experience any other extremely upsetting or life threatening event that I haven't asked you about"; (18) *Non-disclosed event*: "Sometimes people have experiences they don't want to talk about in interviews. I won't ask you to describe anything like this, but, without telling me what it was, did you ever have an extremely upsetting or life-threatening event that you didn't tell me about because you didn't want to talk about it."

2.2.2. Insomnia

Consistent with previous studies of adolescents [11,44] and the International Classification of Sleep Disorders II (ICSD-II) [45,46] insomnia definition for adults, insomnia was defined as the presence of daytime sleepiness in addition to at least one of the following other self-reported sleep problems, occurring for ≥2 weeks in the past year: (1) have problems getting to sleep, when nearly every night it took you a long time to fall asleep; (2) have problems staying asleep, when you woke up nearly every night and took a long time to get back to sleep; and (3) have problems waking too early, when you woke up nearly every morning much earlier than you wanted to. Response options to each sleep problem were binary (0 = no; 1 = yes). These four items were strongly correlated with each other (tetrachoric correlations ranged from 0.51 to 0.75). Daytime sleepiness was defined by the child as "feeling sleepy" during the day.

2.2.3. Covariates

All models adjusted for the following covariates: sex, age (continuous), highest level of parent education (less than high school; high school; some college; and college graduate), poverty index ratio, which was derived based on family size and the ratio of family income to the family's poverty threshold (≤1.5 = low income; 1.6–3 = low–middle income; > 3– ≤ 6 = high–middle income; and >6 = high income), race/ethnicity (non-Hispanic White; non-Hispanic Black; Hispanic; and others), region of the country (Northeast, Midwest, South, and West), and urbanicity (major metropolitan area, other urbanized area, and rural area).

2.3. Analysis

We first conducted basic univariate and bivariate analyses to examine the prevalence of insomnia symptoms and the demographic correlates of both insomnia and exposure to childhood adversity. We then used generalized estimating equations (GEE) to estimate the risk of insomnia by childhood adversity, focusing on exposure to each event and subtype (0 = unexposed; 1 = exposed). These multivariate analyses yielded prevalence ratios (PRs), which are preferred over odds ratios when the outcome is common (eg, has a prevalence of about 30%) [47–49]. In order to investigate the potential differences in the prevalence of insomnia by timing of exposure to childhood adversity, we estimated PRs corresponding to age at onset of each adversity subtype. We also examined whether accumulation of adverse events (ie, a count indicating the number of specific types of adversities the child reported being exposed to) was associated with a differential risk of insomnia. Finally, given the known association between mental disorders and sleep problems [35,36,50], we conducted sensitivity analyses to examine the association between exposure to childhood adversity and insomnia after excluding adolescents meeting the DSM-IV [51] criteria for a past-year diagnosis of major depression, dysthymia, PTSD, or generalized anxiety disorder as assessed by the CIDI. These disorders were examined based upon their association with sleep problems in previous studies and our finding that they were highly correlated with insomnia in our sample (0.45, 0.44, 0.44, and 0.39, respectively). These analyses were intended to evaluate whether our results were explained by recent experiences of a psychiatric disorder.

All analyses were conducted using the survey regression procedures available in SAS Version 9.4 to account for the complex survey design. We used sampling weights to account for the differential probability of selection of respondents within households (for the household subsample), differential non-response, and adjust for differences between the sample and the US population on selected sociodemographic characteristics, making this sample nationally representative of the US population on the variables included in this analysis. A false discovery rate (FDR) correction was used to adjust our alpha level for the multiple testing of 23 different childhood adversities (18 adversity events plus 5 exposure to any events).

3. Results

Insomnia symptoms were common in this sample. Nearly 38% reported daytime sleepiness, while 22% reported taking a long time to fall asleep and 17% reported waking up too early Table 1. Insomnia was more common among girls compared to boys (57.8% vs. 42.2%; $p < 0.0001$) and among adolescents from racial/ethnic minority groups compared to Whites Table 2. No differences were observed in the prevalence of insomnia by age, poverty level, parental education level, or urbanicity Table 2.

In the total sample, 59.41% reported at least one childhood adversity (mean = 1.17; standard deviation (SD) = 1.43; range = 0–11). Adolescents exposed to at least one childhood adversity were more likely to be older, Black and Hispanic, and to reside in families with low socioeconomic status and living in metro areas Table 2.

3.1. Adversity exposure and risk of insomnia

Overall, adolescents exposed to childhood adversity were more likely than their nonexposed peers to experience insomnia (Table 3). Those exposed to at least one type of adversity had 1.93 times the risk of insomnia relative to those who were unexposed (PR = 1.93; confidence interval (CI) = 1.68, 2.21). The effects of adversity also appeared to differ by type. Relative to other types of childhood adversity, exposure to interpersonal violence conferred the largest risk for insomnia symptoms. Exposure to rape conferred the largest risk relative to all other adversities (PR = 1.90, CI = 1.57, 2.30).

3.2. Timing of exposure to adversity and risk of insomnia

Although adolescents exposed to adversity at any age had a higher risk of insomnia relative to their nonexposed peers, by and large, the risk of insomnia did not differ by age at first exposure to adversity (Table 4). This is shown by the finding that the PRs (comparing those first exposed in one developmental period to those who were never exposed) were generally not statistically different from one another. In other words, the only significant differences we observed were based on timing of first exposure to interpersonal violence. Here, we found that those exposed to adversity in

Table 1
Prevalence of insomnia symptoms and insomnia among adolescents in National Comorbidity Survey Replication Adolescent Supplement (NCS-A; $N = 9582$).

Symptoms (≥2 weeks in the past year)	Yes	No	Percentage (%)
Took a long time to fall asleep	2133	7448	22.26
Took long time to get back to sleep	1288	8294	13.44
Woke up too early	1615	7966	16.86
Daytime sleepiness	3601	5981	37.58
Insomnia	2065	7517	21.55

Insomnia was defined as having at least one of the three primary sleep problems (long time to fall asleep, get back to sleep, or wake too early) with daytime sleepiness for ≥2 weeks in the past year. Note: The first and third rows do not total 9582 due to one respondent with missing data.

Table 2
Distribution of covariates in the total sample and by those reporting insomnia and exposure to any childhood adversity.

		Total Sample	With Insomnia	χ^2	p-value	Exposed to any childhood adversity	χ^2	p-value
		N = 9582	N = 2065 (21.6%)			N = 5693 (59.4%)		
Age	13	1564 (15.1)	287 (18.5)	6.85	0.23	776 (49.0)	73.53	<0.001
	14	2091 (20.8)	413 (21.7)			1109 (53.6)		
	15	1797 (20.8)	418 (24.0)			1061 (57.5)		
	16	1903 (20.9)	438 (23.0)			1206 (61.7)		
	17	1662 (17.0)	391 (22.4)			1139 (68.8)		
	18	565 (5.5)	118 (17.8)			403 (69.1)		
Sex	Men	4707 (51.3)	835 (17.9)	33.73	<.001	2774 (57.9)	0.46	0.50
	Women	4875 (48.7)	1230 (25.9)			2919 (59.3)		
Race	White	5357 (65.9)	1077 (20.8)	10.61	0.01	2983 (54.9)	72.93	<0.001
	Black	1849 (15.0)	458 (26.0)			1269 (70.7)		
	Hispanic	1803 (14.2)	396 (21.1)			1102 (63.2)		
	Other	573 (4.9)	134 (26.5)			339 (59.2)		
Parental Education	<HS	1554 (15.3)	359 (20.7)	2.12	0.55	943 (58.2)	45.34	<0.0001
	HS	2913 (29.7)	670 (22.8)			1801 (62.8)		
	Some college	1890 (19.2)	402 (22.9)			1203 (64.1)		
	College and Graduate	3225 (35.8)	634 (20.9)			1746 (52.2)		
Poverty	Low income	1603 (14.6)	356 (21.2)	1.25	0.74	1021 (64.4)	11.90	0.008
	Low–middle income	1911 (19.2)	425 (21.9)			1166 (60.9)		
	Middle-high income	2943 (31.9)	622 (22.6)			1718 (57.1)		
	High income	3125 (34.3)	662 (21.3)			1788 (56.6)		
Region	Northeast	1775 (18.0)	415 (23.3)	6.97	0.07	987 (54.4)	20.39	<0.001
	Midwest	2612 (23.1)	571 (21.2)			1535 (58.4)		
	South	3276 (36.2)	622 (19.9)			1947 (57.2)		
	West	1919 (22.7)	457 (24.2)			1224 (64.8)		
Urban	Metro	4264 (47.3)	963 (22.8)	5.45	0.06	2598 (61.1)	8.96	0.0113
	Other urban	3137 (37.9)	694 (21.9)			1854 (57.0)		
	Rural	2181 (14.8)	408 (18.2)			1241 (55.4)		

Cell entries are the number and percent. The percent entries under Total Sample sum up to 100% while the percent entries by insomnia and exposure to any adversity are proportions within each level of covariates. Exposed to any childhood adversity was defined as experiencing at least one of the following adversities: parent violence, other violence, rape, kidnapping, other sexual assault, car accident, disaster, illness, chemical exposure, other accident, witnessing fights at home, witnessing death, other person died unexpectedly, other person experienced unexpected threat, war/terror, refugee, other trauma, or non-disclosed trauma. Rao–Scott chi-squared values indicate whether the distribution of demographic covariates was significantly different by those with insomnia or reporting childhood adversity.

early childhood or adolescence had a significantly greater risk of insomnia relative to those exposed during middle childhood. All other types of adversities showed no significant difference in the PR when comparing those exposed for the first time at different ages. Results for each type of adversity are shown in Supplemental Table S1.

3.3. Accumulation of exposure to adversity and risk of insomnia

There was a dose–response relationship between the number of specific types of adversities reported by the child and risk for insomnia, such that each additional exposure to a different type of adversity was associated with an elevated risk for insomnia as compared to those unexposed to adversity (Fig. 1; Supplemental Table S2). Specifically, youth exposed to five or more different types of adversities had 3 times the risk of those who were unexposed to experience insomnia (PR = 3.09, CI = 2.39, 4.00); this risk was more than double from those exposed to only one type of adversity (PR = 1.61; 1.37, 1.89).

3.4. Sensitivity analysis

Of the sample, 15% (n = 1430) experienced a major depressive episode (n = 829), dysthymia (n = 201), PTSD (n = 244), or generalized anxiety disorder (n = 156) in the past year. We reconducted our analyses after excluding these 1430 adolescents from the analytic sample. As shown (Supplemental Tables S3–S6), the overall prevalence of insomnia (18.1% vs. 21.55%) and exposure to at least one childhood adversity (56.6% vs. 59.41%) was similar in the sample excluding these adolescents compared to the larger analytic sample. Overall, the effect estimates for these associations were similar to the results including the adolescents with depression, dysthymia,

Table 3
Risk of insomnia by exposure to childhood adversity.

Childhood Adversity	Prevalence (%)	Prevalence Ratio (CI)	FDR p-value*
Exposure to any type	5693 (59.41)	1.93 (1.68, 2.21)*	4.20E-19
Interpersonal violence			
Parent violence	159 (1.66)	1.51 (1.05, 2.14)*	3.10E-02
Other violence	460 (4.80)	1.63 (1.27, 2.11)*	2.19E-04
Rape	250 (2.61)	1.90 (1.57, 2.30)*	1.82E-10
Kidnapped	58 (0.61)	0.87 (0.51, 1.48)	6.02E-01
Other sexual assault	331 (3.45)	1.89 (1.53, 2.32)*	5.63E-09
Any of above	1000 (10.44)	1.80 (1.52, 2.14)*	5.19E-11
Accidents and injuries			
Car accident	741 (7.73)	1.35 (1.09, 1.67)*	8.40E-03
Disaster	1088 (11.35)	1.31 (1.08, 1.60)*	8.40E-03
Illness	606 (6.32)	1.42 (1.19, 1.69)*	1.33E-04
Chemical	236 (2.46)	1.65 (1.31, 2.07)*	3.60E-05
Other accident	731 (7.63)	1.56 (1.33, 1.83)*	9.72E-08
Any of above	2727 (28.46)	1.59 (1.40, 1.81)*	2.49E-12
Social network or witness events			
Witness fights at home	705 (7.36)	1.53 (1.20, 1.95)*	7.74E-04
Witness death	1178 (12.29)	1.49 (1.30, 1.69)*	8.08E-09
Other person died unexpectedly	2841 (29.65)	1.46 (1.28, 1.67)*	4.99E-08
Other person unexpected threat	868 (9.06)	1.59 (1.40, 1.81)*	6.84E-12
War terror	214 (2.23)	1.11 (0.78, 1.58)	6.02E-01
Refugee	45 (0.47)	0.80 (0.36, 1.77)	6.02E-01
Any of above	3735 (38.98)	1.65 (1.45, 1.87)*	2.73E-13
Other events			
Other trauma	268 (2.80)	1.40 (1.11, 1.75)*	4.96E-03
Non-disclosed event	490 (5.11)	1.83 (1.56, 2.14)*	5.69E-13
Any of above	726 (7.58)	1.67 (1.44, 1.94)*	7.66E-11

Cell entries are the prevalence of each childhood adversity and results of the generalized estimating equation (GEE) models examining the risk of insomnia for each exposure to childhood adversity, after adjusting for covariates. The prevalence column lists the number and in parentheses, the percent. The prevalence ratio column lists the prevalence ratio and in parentheses, the 95% confidence interval. A false discovery rate (FDR) correction was applied to adjust our alpha level for the multiple testing of 23 different exposures (including exposure to any adversity). Statistical significance after imposing the FDR correction is denoted with an asterisk. P-values are expressed in scientific notation (e.g., p = 3.05E-02 = p = 0.0305).

Table 4
Risk of insomnia by timing of exposure to childhood adversity.

Childhood Adversity	Prevalence (%)	Prevalence Ratio (CI)	FDR *p*-value
Exposure to any type			
Early childhood	1438 (15.01)	1.95 (1.59, 2.39)*	1.36E-09
Middle childhood	1764 (18.41)	2.02 (1.77, 2.32)*	0.00E+00
Adolescence	2491 (26.00)	1.86 (1.58, 2.19)*	1.65E-12
Interpersonal violence††‡			
Early childhood	167 (1.74)	2.01 (1.55, 2.62)*	9.16E-07
Middle childhood	291 (3.04)	1.38 (0.99, 1.92)	9.81E-02
Adolescence	542 (5.66)	2.00 (1.71, 2.35)*	0.00E+00
Accidents and injuries			
Early childhood	784 (8.18)	1.44 (1.21, 1.71)*	1.61E-04
Middle childhood	850 (8.87)	1.67 (1.43, 1.94)*	2.91E-10
Adolescence	1092 (11.40)	1.65 (1.37, 2.00)*	8.04E-07
Social network or witness events			
Early childhood	597 (6.23)	1.56 (1.20, 2.02)*	2.20E-03
Middle childhood	1172 (12.23)	1.67 (1.37, 2.02)*	9.16E-07
Adolescence	2470 (25.78)	1.67 (1.47, 1.90)*	7.28E-14
Other events			
Early childhood	74 (0.77)	1.57 (1.01, 2.44)*	7.97E-02
Middle childhood	154 (1.61)	1.10 (0.73, 1.66)	7.22E-01
Adolescence	498 (5.20)	1.89 (1.59, 2.25)*	6.52E-12

Cell entries are the results of the generalized estimating equations (GEE) models examining the risk of insomnia for each exposure to childhood adversity, after adjusting for covariates. The reference group for each row is adolescents who were unexposed. A false discovery rate (FDR) correction was applied to adjust our alpha level for the multiple testing of 23 different exposures (including exposure to any adversity). Statistical significance after imposing the FDR correction is denoted with an asterisk.

† refers to a significant difference ($p < 0.05$) between early versus middle childhood.

‡ refers to a significant difference ($p < 0.05$) between middle childhood and adolescence.

PTSD, or generalized anxiety disorder, although some coefficients displayed slight increases and decreases in an inconsistent fashion.

4. Discussion

In this study, we used data from a large, nationally representative sample of adolescents to examine the relationship between multiple types of childhood adversity and insomnia. In addition to examining whether there was an overall association between exposure to adversity and insomnia, we were also interested in whether there were "sensitive periods" when the effect of exposure to childhood adversity was most pronounced [27–29]. We also sought to determine whether accumulation of exposure to adversity (meaning the number of types of adversity an adolescent reported) predicted the risk of insomnia. This study builds upon previous literature stating the importance of sleep in adolescence and the potential negative mental and physical effects of insomnia [14]. We aimed to expand previous knowledge about the association between childhood adversity and insomnia by examining multiple different types of adversities, as prior studies have focused on a limited set of exposures. This study also advances the existing literature on childhood adversity and sleep disorders by examining the relationships between multiple childhood adversities and insomnia specifically during adolescence. Using an adolescent sample, we minimized potential bias due to retrospective recall (relative to studies conducted in adults), as most studies examining these associations have used self-reported data.

Three findings emerged from this study. First, we found that youth exposed to adversity were more likely to have insomnia compared to their nonexposed peers. However, the risk of insomnia differed as a function of type of adversity. For example, and similar to previous studies, those exposed to interpersonal violence (eg, parent violence or rape) in childhood or adolescence showed the highest risk of sleep disturbance [16,20,21]. Similar to previous

studies on trauma and risk of insomnia [18], we also found that those exposed to accidents or injuries in childhood or adolescence were more likely to develop insomnia in adolescence. In addition, we found a significant association between exposure to "other events" in adolescence and insomnia. We hypothesize that due to the recency of the exposure, there may be a stronger effect of these events on sleep. In addition, "other events" capture all other adversities besides those that could be classified; these events may encompass other risk factors, which should be disentangled.

Second, we observed a differential risk for insomnia based on the age at first exposure specifically for interpersonal violence events. Specifically, those exposed to interpersonal violence during early childhood (between 0 and 5 years of age) or adolescence (between 11 and 18 years of age) had a larger risk of insomnia relative to respondents who were never exposed and more specifically relative to those who were exposed during middle childhood. To our knowledge, this was the first study to examine developmental timing differences in the effect of adversity on sleep.

Third, there was a clear dose–response relationship between exposure to multiple types of adversity and risk for insomnia. This finding parallels previous population-based studies, which also have found that exposure to a greater number of childhood adversities conferred a larger risk of insomnia in adults [24,26].

Our finding that there were differences based on the type, timing, and accumulation of exposure – in both the larger sample and the smaller sample of adolescents without a history of past-year psychiatric disorders – underscore the need for future studies to consider specific features of childhood adversity exposure beyond simply characterizing individuals as "exposed" or "nonexposed." In addition, although the focus of the current study was on the long-term effects of adversity on sleep, future studies should more closely examine the immediate effects of adversity on sleep.

Converging lines of research on trauma, stress and sleep neurobiology, and psychophysiology provide insight on possible mechanisms that underlie associations between childhood adversities and risk of insomnia in adolescence [52]. Substantial evidence shows that exposure to trauma evokes an intense stress/fear response that initiates hyperarousal in specific brain areas (e.g., amygdala, prefrontal cortex, and reticular activating system) [52,53]. This hyperarousal in turn leads to exaggerated reactivity of the hypothalamic–pituitary adrenal axis and the sympathetic nervous system, which manifests in a generalized state of physiological and neurobiological hyperarousal that impedes sleep onset and continuity, and may ultimately contribute to chronic insomnia [52,54,55].

Findings from this study must be evaluated in light of several limitations. First, adolescents retrospectively reported whether, and if so when, they were exposed to each adversity and whether they experienced insomnia symptoms. As a result of memory lapses or an unwillingness to disclose private matters, such retrospective reports may lead to over- or under-reporting. However, recent studies have found retrospective and prospective measures of child maltreatment, in particular, produce similar estimates of effect for health-related problems [56]. Second, this was a cross-sectional analysis, where exposure and outcome data were captured at the same time. Although a limitation, we maintained a prospective association between childhood adversity and insomnia symptoms, as youth retrospectively recalled their age at first onset to adversity and we focused on sleep problems measured in the past year. However, to replicate these findings, true prospective studies of adolescents will be needed; ideally, these studies should include measures of earlier sleep problems, which can aid in identifying sleep problems that are subsequent to (rather than prior to) adversity exposure. Third, we did not examine other indicators commonly included in studies of childhood adversity, such as parental mental illness, parental incarceration, and exposure to child neglect, or poverty. These constructs were either unmeasured in the current dataset or were
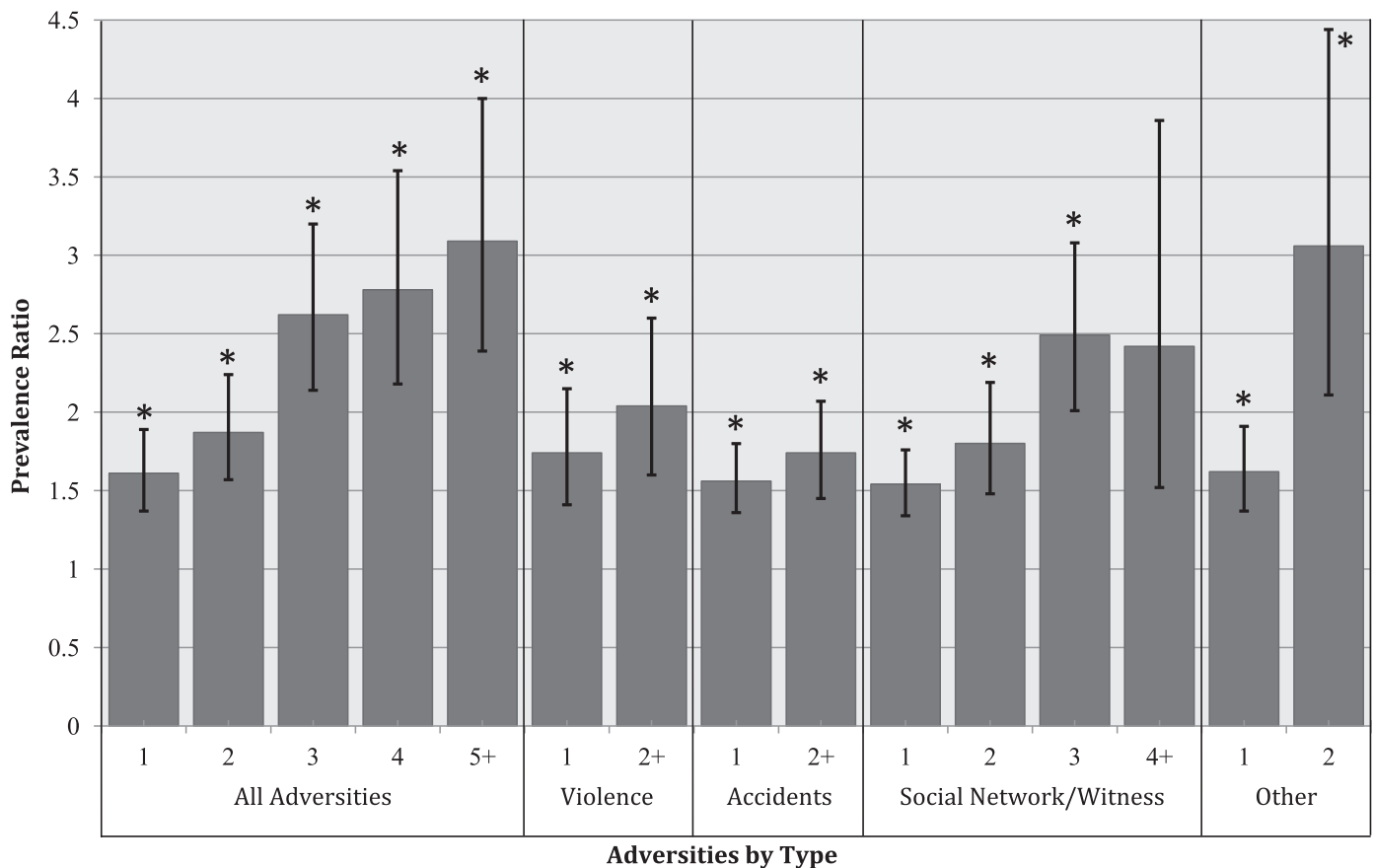
Fig. 1. Risk of insomnia by count of the number of exposures to childhood adversity.
This figure presents the results of the generalized estimating equation (GEE) model examining the risk of insomnia based on the count of the number of total adversities experienced as well as count of each subtype, after adjusting for covariates. The reference group refers to adolescents who experienced zero adversities. A false discovery rate (FDR) correction was applied to adjust our alpha level for the multiple testing of 23 different exposures (including exposure to any adversity). Statistical significance after imposing the FDR correction is denoted with an asterisk. Specific *p*-values for these associations are denoted in Supplemental Table S6.

measured without regard to developmental timing of exposure. For example, poverty was collected at only one specific time period and did not include information about timing of exposure to poverty. Studies examining the effects of multiple indicators of adversity on insomnia will be important for disentangling the role of specific types of adversity on sleep. Fourth, our study does not accurately test the biological mechanism(s) behind the association between insomnia and adversity; therefore, we are only able to hypothesize a possible mechanism of how trauma may affect insomnia in adolescence. Lastly, a large number of studies define insomnia in adulthood; however, the definition of insomnia in adolescence is less clear. Both ICSD-II [46] and the DSM-IV [46] definition of insomnia exist. Comparing the results of this study with those using a DSM-IV definition would be of interest. Finally, due to the small cell sizes, we were unable to examine the joint effect of timing and the number of adverse exposures. Studies examining these effects will further elucidate the way in which adverse events affect sleep.

5. Conclusion

The results of this analysis suggest that exposure to adversity confers an elevated risk for insomnia during adolescence. This association varied primarily by type and accumulation of exposure and to some extent, by timing of exposure. Given the well-documented physical and mental health consequences of insomnia, such findings add further support to the need for practitioners to screen children for exposure to both childhood adversity and in-

somnia symptoms. Based on our findings, screening efforts should focus on not just whether the child was exposed to an adverse event, but also when in the course of development the adversity first occurred (especially for interpersonal violence events) and how many total adversities the child experienced. By querying these domains, physicians may be able to better treat and possibly prevent insomnia symptoms and ultimately reduce the long-term health ailments associated with insomnia.

Conflict of interest

All authors list no conflicts of interest.
The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2016.01.011.

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Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.sleep.2016.01.011.

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Supplemental Table 1. Risk of insomnia by timing of exposure to childhood adversity

Childhood Adversity	Prevalence (%)	Prevalence Ratio (CI)	FDR p-
Interpersonal violence			
Parent violence			
Early childhood	57 (0.6)	1.54 (1.01, 2.35)	8.44E-0
Middle childhood	71 (0.7)	1.53 (0.87, 2.70)	2.11E-0
Adolescence	31 (0.3)	1.31 (0.78, 2.19)	3.79E-0
Other violence			
Early childhood	17 (0.2)	1.74 (0.71, 4.26)	3.10E-0
Middle childhood	116 (1.2)	1.05 (0.63, 1.73)	8.87E-0
Adolescence	327 (3.4)	1.88 (1.51, 2.35)*	1.25E-0
Rape			
Early childhood	40 (0.4)	2.47 (1.70, 3.60)*	9.55E-0
Middle childhood	57 (0.6)	2.00 (1.34, 2.97)*	1.83E-0
Adolescence	153 (1.6)	1.74 (1.32, 2.29)*	2.35E-0
Kidnapped			
Early childhood	29 (0.3)	0.93 (0.45, 1.94)	8.87E-0
Middle childhood	17 (0.2)	0.74 (0.26, 2.07)	6.57E-0
Adolescence	12 (0.1)	0.84 (0.32, 2.19)	7.92E-0
Other Sexual Assault ‡			
Early childhood	55 (0.6)	1.87 (1.16, 3.01)*	2.22E-0
Middle childhood	92 (1.0)	1.51 (1.01, 2.27)	8.44E-0
Adolescence	184 (1.9)	2.10 (1.71, 2.58)*	9.32E-1
Accidents and injuries			
Car accident			
Early childhood	107 (1.1)	1.38 (0.82, 2.34)	3.10E-0
Middle childhood	189 (2.0)	1.57 (1.21, 2.04)*	2.03E-0
Adolescence	445 (4.6)	1.24 (0.94, 1.64)	2.02E-0
Disaster			
Early childhood	264 (2.8)	1.29 (0.99, 1.67)	9.27E-0
Middle childhood	455 (4.8)	1.35 (1.07, 1.70)*	2.27E-0
Adolescence	369 (3.9)	1.28 (0.89, 1.83)	2.59E-0
Illness			
Early childhood	274 (2.9)	1.24 (0.93, 1.66)	2.11E-0
Middle childhood	136 (1.4)	1.50 (0.91, 2.47)	1.86E-0
Adolescence	196 (2.0)	1.59 (1.18, 2.13)*	5.80E-0
Chemical			
Early childhood	24 (0.3)	1.44 (0.73, 2.85)	3.67E-0
Middle childhood	66 (0.7)	1.32 (0.78, 2.25)	3.78E-0
Adolescence	146 (1.5)	1.83 (1.37, 2.44)*	1.60E-0
Other accident † ┤			
Early childhood	169 (1.8)	1.12 (0.82, 1.52)	5.64E-0
Middle childhood	187 (2.0)	1.71 (1.31, 2.23)*	2.35E-0

Supplemental Table 3. Prevalence of insomnia symptoms and insomnia among adolescents without past-year major depression, dysthymia, post-traumatic stress disorder, or generalized anxiety disorder (N = 8549)

Symptoms (2 weeks or longer in the past year)	Yes	No	Percent (%)
Took a long time to fall asleep	1,624	6,925	19.0
Took long time to get back to sleep	885	7,664	10.4
Woke up too early	1,252	7,296	14.7
Daytime sleepiness	2,912	5,637	34.1
Insomnia with daytime sleepiness	1,544	7,005	18.1

Insomnia was defined as having at least one of the three primary sleep problems (long time to fall asleep, get back to sleep, or wake too early) with daytime sleepiness for two weeks or longer in the past year. Note: The third row does not sum to 8549 due to one respondent with missing data.

Supplemental Table 4. Risk of insomnia by exposure to childhood adversity among adolescents without past-year major depression, dysthymia, post-traumatic stress disorder, or generalized anxiety disorder (N = 8549)

Childhood Adversity	Prevalence (%)	Prevalence Ratio (CI)	FDR p-value*
Exposure to any type	4836 (56.6)	1.83 (1.59, 2.10)*	7.46E-16
Interpersonal violence			
Parent violence	97 (1.13)	1.09 (0.60, 1.96)	8.48E-01
Other violence	361 (4.22)	1.44 (1.08, 1.92)*	1.91E-02
Rape	138 (1.61)	1.84 (1.32, 2.55)*	4.93E-04
Kidnapped	30 (0.35)	0.91 (0.40, 2.06)	8.55E-01
Other sexual assault	207 (2.42)	1.64 (1.28, 2.12)*	2.55E-04
Any of above	690 (8.07)	1.50 (1.21, 1.85)*	4.84E-04
Accidents and injuries			
Car accident	602 (7.04)	1.26 (0.97, 1.64)	9.97E-02
Disaster	936 (10.95)	1.35 (1.06, 1.72)*	2.32E-02
Illness	492 (5.76)	1.48 (1.23, 1.79)*	9.20E-05
Chemical	198 (2.32)	1.78 (1.39, 2.28)*	2.00E-05
Other accident	605 (7.08)	1.49 (1.19, 1.86)*	6.73E-04
Any of above	2307 (26.99)	1.56 (1.32, 1.84)*	1.42E-06
Social network or witness events			
Witness fights at home	525 (6.14)	1.38 (1.00, 1.91)	6.76E-02
Witness death	940 (11.00)	1.47 (1.23, 1.74)*	5.10E-05
Other person died unexpectedly	2384 (27.89)	1.48 (1.27, 1.72)*	2.43E-06
Other person unexpected threat	654 (7.65)	1.52 (1.28, 1.80)*	5.60E-06
War terror	177 (2.07)	1.22 (0.82, 1.83)	3.78E-01
Refugee	40 (0.47)	1.00 (0.45, 2.23)	9.99E-01
Any of above	3551 (41.54)	1.59 (1.39, 1.82)*	3.65E-10
Other events			
Other trauma	196 (2.29)	1.31 (0.97, 1.77)	9.97E-02
Non-disclosed event	350 (4.09)	1.64 (1.31, 2.06)*	5.30E-05
Any of above	532 (6.22)	1.51 (1.24, 1.85)*	1.18E-04

Cell entries are the prevalence (number and percent, in parentheses) of each childhood adversity and results of the generalized estimating equations (GEE) models examining the risk of insomnia for each exposure to childhood adversity, after adjusting for covariates. A FDR (false discovery

Supplemental Table 5. Risk of insomnia by timing of exposure to childhood adversity among adole without past-year major depression, dysthymia, post-traumatic stress disorder, or generalized anxi disorder (N = 8549)

Childhood Adversity	Prevalence (%)	Prevalence Ratio (CI)	FDR p
Exposure to any type			
Early childhood	1164 (13.6)	1.78 (1.46, 2.18)*	2.02E-(
Middle childhood	1504 (17.5)	1.96 (1.66, 2.33)*	4.69E-?
Adolescence	2168 (25.3)	1.75 (1.47, 2.10)*	1.53E-(
Interpersonal violence			
Parent violence			
Early childhood	32 (0.37)	0.72 (0.26, 1.99)	6.60E-(
Middle childhood	47 (0.55)	1.36 (0.60, 3.06)	6.07E-(
Adolescence	18 (0.21)	1.08 (0.42, 2.79)	9.20E-(
Other violence			
Early childhood	11 (0.13)	1.97 (0.73, 5.33)	2.86E-(
Middle childhood	92 (1.08)	1.03 (0.56, 1.89)	9.35E-(
Adolescence	258 (3.02)	1.59 (1.23, 2.05)*	1.53E-(
Rape ┤			
Early childhood	18 (0.21)	2.98 (1.91, 4.65)*	1.10E-(
Middle childhood	34 (0.4)	2.29 (1.21, 4.32)*	2.91E-(
Adolescence	86 (1.01)	1.50 (0.97, 2.32)	1.37E-(
Other Sexual Assault			
Early childhood	40 (0.47)	1.52 (0.76, 3.05)	3.51E-(
Middle childhood	49 (0.57)	1.00 (0.49, 2.04)	9.94E-(
Adolescence	118 (1.38)	2.04 (1.58, 2.62)*	2.98E-(
Any of above			
Early childhood	101 (1.18)	1.64 (1.09, 2.48)*	4.45E-(
Middle childhood	199 (2.33)	1.23 (0.77, 1.95)	5.27E-(
Adolescence	390 (4.56)	1.62 (1.31, 1.99)*	3.60E-(
Accidents and injuries			
Car accident			
Early childhood	86 (1.01)	1.46 (0.78, 2.74)	3.55E-(
Middle childhood	156 (1.82)	1.47 (1.04, 2.06)	6.19E-(
Adolescence	360 (4.21)	1.11 (0.80, 1.55)	6.60E-(
Disaster			
Early childhood	227 (2.66)	1.09 (0.82, 1.47)	6.68E-(
Middle childhood	384 (4.49)	1.45 (1.14, 1.85)*	7.51E-(
Adolescence	325 (3.8)	1.38 (0.89, 2.14)	2.48E-(
Illness			
Early childhood	229 (2.68)	1.31 (0.95, 1.80)	1.83E-(
Middle childhood	118 (1.38)	1.58 (0.83, 3.00)	2.67E-(
Adolescence	145 (1.7)	1.71 (1.27, 2.30)*	1.50E-(

Supplemental Table 6. Risk for insomnia by counts of exposure to childhood adversity among adolescents without past-year major depression, dysthymia, post-traumatic stress disorder, or generalized anxiety disorder (N = 8549)

	Counts	Frequency (%)	Prevalence Ratio (CI)	FDR-p value
Exposure to any type	0	3713 (43.43)		
	1	2536 (29.66)	1.61 (1.36, 1.89)*	3.88E-08
	2	1278 (14.95)	1.76 (1.43, 2.17)*	2.27E-07
	3	571 (6.68)	2.63 (2.17, 3.19)*	0.00E+00
	4	259 (3.03)	2.41 (1.86, 3.11)*	1.39E-10
	5+	192 (2.25)	2.65 (1.91, 3.68)*	1.73E-08
Interpersonal violence	0	7859 (91.93)		
	1	568 (6.64)	1.42 (1.07, 1.89)*	1.64E-02
	2+	122 (1.43)	1.82 (1.38, 2.41)*	3.20E-05
Accidents and injuries	0	6242 (73.01)		
	1	1865 (21.82)	1.51 (1.25, 1.82)*	2.20E-05
	2+	442 (5.17)	1.75 (1.39, 2.22)*	3.99E-06
Social network or witness events	0	4998 (58.46)		
	1	2629 (30.75)	1.48 (1.29, 1.70)*	3.88E-08
	2	709 (8.29)	1.82 (1.39, 2.38)*	1.90E-05
	3	181 (2.12)	2.40 (1.82, 3.15)*	1.60E-09
	4+	32 (0.37)	1.72 (0.86, 3.43)	1.26E-01
Other events	0	8017 (93.78)		
	1+	532 (6.06)	1.51 (1.24, 1.84)*	5.80E-05

Cell entries are the results of the generalized estimating equations (GEE) models examining the risk of insomnia for counts of exposure to childhood adversity, after adjusting for covariates. These counts were derived by summing over the total number of adversities reported to any type or each subtype. The reference group refers to adolescents who were unexposed. A FDR (false discovery rate) correction was applied to adjust our alpha level for the multiple testing of 19 different exposures (including exposure to any adversity). Statistical significance after imposing the FDR correction is denoted with an asterisk.

Supplemental Table 2. Risk for insomnia by counts of exposure to childhood adversity

	Counts	Frequency (%)	Prevalence Ratio (CI)	FDR-p valu
Exposure to any type	0	3889 (40.6)		
	1	2813 (29.4)	1.61 (1.37, 1.89)*	5.68E-09
	2	1483 (15.5)	1.87 (1.56, 2.24)*	3.28E-11
	3	711 (7.4)	2.61 (2.13, 3.19)*	0.00E+00
	4	368 (3.9)	2.77 (2.17, 3.52)*	0.00E+00
	5+	318 (3.3)	3.08 (2.39, 3.96)*	0.00E+00
Interpersonal violence	0	8582 (89.6)		
	1	794 (8.3)	1.74 (1.41, 2.15)*	2.33E-07
	2+	206 (2.2)	2.03 (1.59, 2.57)*	8.79E-09
Accidents and injuries	0	6856 (71.6)		
	1	2160 (22.6)	1.56 (1.36, 1.79)*	1.05E-09
	2+	566 (5.9)	1.73 (1.44, 2.06)*	4.06E-09
Social network or witness events	0	5343 (55.8)		
	1	3029 (31.6)	1.53 (1.34, 1.76)*	1.86E-09
	2	879 (9.2)	1.79 (1.48, 2.18)*	5.68E-09
	3	265 (2.8)	2.48 (2.00, 3.07)*	0.00E+00
	4+	66 (0.7)	2.43 (1.55, 3.82)*	1.11E-04
Other events	0	8856 (92.4)		
	1+	726 (7.6)	1.62 (1.44, 1.94)*	5.44E-11

Cell entries are the results of the generalized estimating equations (GEE) models examining the risk of insomnia for counts of exposure to childhood adversity, after adjusting for covariates. These counts were derived by summing over the total number of adversities reported to any type or the tot number of adversities reported to each subtype. The reference group refers to adolescents who were unexposed. A false discovery rate (FDR) correction was applied to adjust our alpha level for the multiple testing of 19 different exposures (including exposure to any adversity). Statistical significance after imposing the FDR correction is denoted with an asterisk.