

Childhood trauma and stressful life events are independently associated with sleep disturbances in adolescents

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Abstract: Adolescence is a critical developmental period associated with an increase in stress, the appearance of anxiety and depressive symptoms, and changes in sleep patterns. Even though the disruption of sleep patterns in stress and anxiety and depressive disorders is well known, the independent effects of childhood trauma and stressful life events on sleep patterns are less understood. We tested the independent effects of stress (childhood trauma and stressful life events) while controlling for anxiety and depression on adolescent sleep patterns. Seven hundred fifty-two adolescents completed self-report questionnaires about childhood trauma, stressful life events, anxiety, and depression. Four sleep factors identifying movement during sleep, sleep regularity, sleep disturbances and sleep pressure were extracted in the principal component analysis of sleep questions. Both childhood trauma and recent stressful life events were significantly associated with sleep disturbances before and after controlling for anxiety and depression.

Keywords: childhood trauma; stressful life events; sleep patterns; anxiety; depression, adolescence

1. Introduction

Adolescence is a critical transitional period associated with an increase in stress, significant social readjustments [1] and high reactivity to stress [2]. Stress in the form of childhood trauma is common [3] and associated with the development of mental health disorders [4–6], lower school engagement [7] and poor health outcomes [6]. Childhood trauma is also associated with a high suicide rate [5]. Stress in the form of stressful life events is also common in childhood and adolescence, and impact psychological functioning [8,9], mental health symptoms and substance use [10]. Severe stressful events in childhood are associated with anxiety and depression in adolescents [11–14]. Interestingly, in a study that assessed both childhood trauma and stressful life events, childhood trauma but not stressful life events were associated with developing anxiety and depressive symptoms [15,16].

Childhood trauma such as sexual abuse and physical abuse are associated with multiple sleep disturbances such as difficulty falling asleep, staying asleep and increased activity during sleep [17,18]. Similarly, stressful life events are associated with sleep disturbances such as insomnia [19,20].

Higher the number of adverse childhood experiences, higher the sleep disturbances suggesting a graded relationship between stressful life events and sleep [21,22].

Both childhood trauma and stressful life events are associated with the development of mental health disorders in adolescence. Adolescent mental health disorders are common, with 31.9% of adolescents reporting an anxiety disorder and 14% a mood disorder in a national survey of mental health symptoms [23]. Anxiety and depression consistently present with sleep problems that include obtaining less sleep, trouble falling asleep [24,25] and irregular sleep patterns [26]. The directionality of sleep and mental health symptoms is unclear as sleep disturbances are known to precede [27–29] or accompany the appearance of anxiety and depressive symptoms. Although the subjective reports of sleep disturbances are well known, the associated objective correlates of sleep problems are less understood [18]. Dysregulated Hypothalamus – Pituitary – Adrenal (HPA) axis and the altered feedback mechanisms have been identified in anxiety [30], depressive symptoms [26], stressful events [32] and disruption of sleep patterns [33]. However, the exact pathophysiology underlying the comorbid presentation of sleep disturbances in anxiety, depression and stress manifestations are less well understood.

Even though the disruption of sleep patterns in childhood trauma and anxiety and depressive symptoms is known, the independent contribution of childhood trauma and stressful life events on childhood on sleep patterns has not been investigated. Herein, we explored the effects of childhood trauma and stressful events in the past year on sleep patterns after controlling for anxiety and depression. One such study in adults identified that at least one disrupting stressful life event in the past four months was associated with sleep disturbances in depressed adults but not controls [34]. Building upon the current literature of the effects of childhood stress on sleep and anxiety and depressive symptoms, we investigated if childhood trauma and stressful life events are independently associated with altered sleep patterns in adolescence.

2. Materials and Methods

2.1 Participants and Procedures

Seven hundred fifty-two adolescents between the ages of 12 years and 14 years 11 months were recruited from the greater San Antonio area for a longitudinal study to evaluate the development of alcohol use disorders and depressive disorders. Initial screening excluded those with a diagnosis of Autism Spectrum Disorder and those with an IQ less than 80 based on prior testing or estimated. Subjects with floating metallic objects and dental braces were excluded because of the MRI component of the study. The adolescent participant and their guardian were invited to come for an on-site visit to fill out questionnaires assessing sleep patterns, childhood trauma, stressful life events and anxiety and depressive symptoms. We are presenting the analyses from the baseline questionnaires. The study was approved by the Institutional Review Board at University of Texas Health Science Center at San Antonio (Institutional Review Board registered codes IRB00000553, IRB00002691, IRB00002692 and IRB00009608).

2.2 Measures

Sleep patterns: Sleep patterns were extracted from eleven sleep questions in the Dimensions of Temperament Survey (DOTS) and four questions in the Youth Self Report (YSR). Dimensions of Temperament Survey is a widely used instrument developed to measure temperament [35] and the Youth Self Report is a questionnaire commonly used for assessing emotional and behavioral disorders [36]. Sleep questions extracted from the Dimensions of Temperament Survey [35] evaluated the regularity of bedtime, wake time, moving in sleep, moving in bed, and naps—each rated “Usually false” scored “1”, “More false than true” scored “2”, “More true than false” scored “3” and “Usually true” scored “4”. Sleep questions in the Youth Self Report assessed if the adolescents obtained less

sleep, had trouble sleeping, needed more sleep and experienced nightmares—rated “not true” scored “0”, “Sometimes or Somewhat true” scored “1” and “very true” scored “2” (Table 2). Sleep questions from the Youth Self Report and Dimensions of Temperament Survey were used in prior studies for assessing sleep patterns [37–40].

Childhood trauma: Childhood trauma was assessed by the Childhood Trauma Questionnaire (CTQ). The CTQ is a 28-item validated instrument to measure physical, sexual and emotional trauma in childhood [41–43]. CTQ has a high internal consistency ($\alpha = 0.95$; 0.63 – 0.95) and test-retest reliability (Intraclass Correlation Coefficient = 0.88) [43]. The questions assessed components of childhood stress such as physical abuse (i.e., I believe that I was physically abused), sexual abuse (i.e. Someone molested me), emotional abuse (i.e., People in my family said hurtful or insulting things to me), emotional neglect (i.e., I didn’t have enough to eat) and physical neglect. Each question was rated “never true” scored “1”, “rarely true” scored “2”, “sometimes true” scored “3”, “often true” scored “4”, and “very often true” scored “5”. The scores for each of the subscales ranged from 5–25 and were summed to obtain the total score. The cutoff scores for various subscales of abuse were the following: physical abuse, 10 or higher; sexual abuse, 8 or higher; emotional abuse, 13 or higher; emotional neglect, 15 or higher; physical neglect, 10 or higher [42].

Stressful Life Events: Stressful life events in the past year were assessed by the Stressful Life Events Schedule (SLES). SLES is an 80-item stress measure validated to measure objective and subjective stress from life events experienced by adolescents in the past 12 months with a test-retest reliability $k = 0.68$ (95% CI, 0.64–0.72) and inter-rater reliability for objective threat ($k = 0.67$ ranged from 0.58 to 0.89). The stress questions assessed life events at school (i.e., I changed schools), job (i.e., I had problems at my job), family (i.e., My family had money problems), legal (i.e., I was a victim of a crime) and personal events (i.e., I had relationship problems with my boyfriend/girlfriend). Each question was rated “not at all” scored “0”, “a little” scored “1”, “somewhat” scored “2” and “lot” scored “3”. Subjective stress score was obtained from the self-report score, whereas the objective stress score was calculated from the objective threat scores given by neutral raters [44].

Anxiety symptoms: Anxiety symptoms were assessed by Screen for Child Anxiety Related Emotional Disorders (SCARED). The SCARED self-report questionnaire is a 41-item instrument for measuring anxiety symptoms in children and adolescents and has high internal consistency ($\alpha = 0.93$; 0.70 to 0.90) and test-retest reliability (intraclass correlation coefficients = 0.86 0.70 0.90). The scale assesses DSM IV based symptoms of Generalized Anxiety Disorder, Separation Anxiety Disorder, Panic Disorder, Social Phobia and School Phobia and calculates a total anxiety score for the past three months [7]. Each question was rated on a 3-point scale: “almost never” scored “0”, “sometimes” scored “1” and “often” scored “2”. A total score was calculated from summing individual questions. The scores of the SCARED questionnaire have a range from 0–69. A total score of ≥ 25 in clinical samples is suggestive of an anxiety disorder [46].

Depressive symptoms: Depressive symptoms were assessed by the Mood and Feelings Questionnaire Child version (MFQ-C) [38]. The Mood and Feelings Questionnaire is a 34-item instrument that measures depressive symptoms in the prior two weeks in the age group 8–18 years and has a high internal consistency ($\alpha = 0.90$) and test-retest reliability (intraclass correlation coefficient = 0.75). The questions assess depressive symptoms based on DSM III criteria on a three-point scale: “not true” scored “0”, “sometimes true” scored “1” and “true” scored “2”. The depressive symptoms score was calculated after removing the two sleep questions from the Mood and Feelings Questionnaire. The score of the Mood and Feelings questionnaire has a range from 0 – 64. The cutoff scores for MFQ used in previous studies is as follows: MFQ < 20 as low, MFQ 20–34 as medium and MFQ >34 as high for depression. Wood et al identified a cutoff score of 27 that represented Major Depression [49].

2.3. Statistics

The data was analyzed with IBM Statistical Package for the Social Sciences (SPSS) (Version 26.0). Initially, principal component analysis of the 15 sleep questions was used to extract the sleep factors. Subsequently, General Linear Model Multivariate Analysis of Variance (MANOVA) was utilized to

identify the effects of childhood trauma and stressful life events on sleep factors (dependent variables) after controlling for gender, parental education and psychiatric symptoms (anxiety and depressive symptoms). The effect sizes of the stress measures and psychiatric symptoms on MANOVA's are represented as Partial Eta Squared (η^2) [50]. The estimates of the direction of effect size are represented in t-statistic.

3. Results

The demographics of the sample are in Table 1.

Table 1. Demographics of the sample.

	Female	Male	Total/Average± SD	T test
Number	386	366	752	
Age (years)	13.48 ± 1.01	13.49 ± 1.03	13.48 ± 1.02	t (750) = 0.05, p = 0.95
Pubertal status	3.51 ± 0.98	3.27 ± 0.93	3.39 ± 0.96	t (750) = - 3.35, p = .001
Race White - nonhispanic	194 (50.3 %)	187 (51.1 %)	381 (50.7 %)	
Hispanic	131 (33.9 %)	125 (34.2 %)	256 (34.0 %)	
Black	12 (3.1 %)	13 (3.6 %)	25 (3.3 %)	
Hispanic and White	33 (8.5 %)	22 (6.0 %)	55 (7.3 %)	
Others	16 (4.2 %)	19 (5.1 %)	35 (4.7 %)	
Education				t (750) = 1.28, p = 0.20
Less than 9 th grade	1 (0.3 %)	2 (0.5 %)	3 (0.4 %)	
9 th to 12 th grade (no diploma)	5 (1.3 %)	5 (1.4 %)	10 (1.3 %)	
High School Graduate (including GED)	34 (8.8 %)	35 (9.6 %)	69 (9.2 %)	
Some College, no degree	87 (22.5 %)	59 (16.1 %)	146 (19.4 %)	
Associates Degree	42 (10.9 %)	35 (9.6 %)	77 (10.2 %)	
Bachelor's degree	98 (25.4 %)	105 (28.7 %)	203 (27.0 %)	
Graduate or Professional degree	119 (30.8 %)	125 (34.2%)	244 (32.4 %)	
Adverse Childhood Experiences score (CTQ)	33.33 ± 8.41	33.64 ± 7.32	33.48 ± 7.90	t (750) = 0.54, p = 0.58
Emotional abuse (CTQ)	7.73 ± 3.18	7.24 ± 2.57	7.49 ± 2.91	t (750) = -2.30, p = 0.022*
Physical abuse (CTQ)	6.21 ± 1.83	6.37 ± 1.92	6.29 ± 1.88	t (750) = 1.14, p = 0.255
Sexual abuse (CTQ)	5.27 ± 1.45	5.17 ± .836	5.22 ± 1.19	t (750) = -1.23, p = 0.217
Emotional neglect (CTQ)	8.01. ± 3.47	8.47 ± 3.69	8.23 ± 3.59	t (750) = 1.77, p = 0.076
Physical neglect (CTQ)	6.11 ± 1.92	6.40 ± 1.96	6.25 ± 1.95	t (750) = 2.02, p = 0.043*
Stressful life events subjective score (SLES)	140.76 ± 174.35	84.93 ± 122.66	113.59 ± 153.87	t (750) = - 5.05, p = 0.000***
Stressful life events objective score (SLES)	55.52 ± 59.06	36.84 ± 44.03	46.41 ± 53.05	t (750) = - 4.89, p = 0.000***
Anxiety symptoms (SCARED)	19.38 ± 11.25	14.11 ± 9.76	16.81 ± 10.87	t (750) = - 6.84, p = 0.000***
Depressive symptoms (MFQ)	11.86 ± 10.62	8.90 ± 8.27	10.42 ± 9.66	t (750) = - 4.40, p = 0.000***
Significance levels * - p ≤ .05, ** - p ≤ .001, *** - p ≤ .0001				

Demographic characteristics of the sample

256/752 (34%) of the adolescents were of Hispanic origin. The Hispanic or Latino ethnicity comprises 46% of the population in the San Antonio area. Participants were similarly matched for age, race, and parental education by gender. Females scored significantly higher subjective stress $t(750) = -5.05, p = 0.000$, and objective stress $t(750) = -4.89, p = 0.000$ on SLES and higher anxiety symptoms $t(750) = -6.84, p = 0.000$ and depressive symptoms $t(750) = -4.40, p = 0.000$ than males.

48/752 (6.2%) of the adolescents met criteria for emotional abuse, 44/752 (5.9%) met criteria for physical abuse, 23/752 (3.1%) met criteria for sexual abuse, 35/752 (4.7%) met criteria for emotional neglect and 58/752 (7.7%) met criteria for physical neglect. 42/752 (5.6%) had a score greater than 27 on Mood and Feelings Questionnaire and 164/752 (21.8%) had a score greater than 25 for anxiety symptoms.

3.1. Principal component analysis of sleep questions

Principal Component Analysis of 15 sleep questions on varimax rotation separated into four factors with an eigenvalue greater than 1 and accounted for 52.09 % of the overall variance (see Table 2).

Table 2: Principal Component Analysis of sleep questions

	Factor 1	Factor 2	Factor 3	Factor 4
	Movement during sleep	Sleep regularity	Sleep disturbances	Sleep pressure
I move a great deal in my sleep (DOTS)	0.825			
I move a lot in bed (DOTS)	0.862			
In the morning I am in the same place as I fell asleep (DOTS)	-0.597			
I don't move around much at all in my sleep (DOTS)	-0.835			
I usually get the same amount of sleep each night (DOTS)		0.546		
I get sleepy just about the same time each night (DOTS)		0.601		
When I am away from home, I wake up at the same time each morning (DOTS)		0.686		
No matter when I go to sleep I wake up at the same time next morning (DOTS)		0.724		
I wake up at the same time on weekends and holidays as on other days of the week (DOTS)		0.673		
I sleep less than most kids (YSR)			0.801	
I have trouble sleeping (YSR)			0.682	
I have nightmares (YSR)			0.409	
I wake up at different times (DOTS)				0.426
I take a nap, rest or break at the same time every day (DOTS)				0.618

I sleep more than most kids during day
and/or night (YSR)

0.742

The coefficients with absolute values less than 0.4 were suppressed. Of the four factors, Factor 1 explained 17.41% of the variance and loaded questions that assessed movement while asleep and movement in bed. Factor 2 explained 15.60% of the variance and loaded questions that assessed regularity of wake-up time, bedtime and regularity of becoming sleepy. Factor 3 explained 10.97% of the variance and loaded questions that assessed sleep disturbances including less sleep, trouble sleeping and nightmares. Factor 4 explained 8.10% of the variance and loaded questions that assessed the need for more sleep, taking naps, and waking at different times (Table 2). The Regression based factor scores of the four sleep factors were used as dependent sleep scores for further analyses.

3.2. Effects of gender, age, race and education on sleep factors

Initially, we identified the individual effects of the demographic variables of gender, age, race, education and pubertal status on the identified sleep factors. In these analyses, female gender was significantly associated with high Factor 1 ($F_{1, 750} = 14.05$, $t = 3.74$, $p = 0.000$, $\eta^2 = 0.018$) and low Factor 2 scores ($F_{1, 750} = 7.40$, $t = -2.72$, $p = 0.007$, $\eta^2 = 0.01$). High parental education was associated with high Factor 2 scores (regularity of sleep) ($F_{1, 750} = 11.12$, $t = 3.33$, $p = 0.001$, $\eta^2 = 0.015$).

Age, race and advanced pubertal status were not significantly associated with any of the sleep factors and were not included in further analyses.

Subsequently, we utilized two models to identify the effects of stress. The first model identified the impact of stress (childhood trauma and stressful life events) on the identified sleep factors after controlling for gender and education of parent. The second model identified the effects of stress (childhood trauma and stressful life events) on the sleep factors after controlling for anxiety and depressive symptoms, gender and education.

3.3. First model to identify the effects of childhood trauma and stressful life events on sleep patterns after controlling for gender and parent education

Table 3: Childhood trauma and stressful life events effects on sleep patterns

	Factor 1 Movement during sleep	Factor 2 Sleep regularity	Factor 3 Sleep disturbances	Factor 4 Sleep pressure
Gender	11.15 (p = 0.001***)	6.57 (p = 0.011*)	.437 (p = 0.509)	0.160 (p = 0.689)
Education	1.41 (p = 0.235)	7.60 (p = 0.006**)	1.77 (p = 0.184)	3.36 (p = 0.067)
Childhood Adversity (CTQ Score)	1.53 (p = 0.216)	10.09 (p = 0.002**)	52.81 (p = 0.000***)	0.003 (p = 0.957)
Stressful Life Events (SLES Score)	5.29 (p = 0.022*)	0.148 (p = 0.700)	28.99 (p = 0.000***)	4.16 (p = 0.042)

Significance levels * - $p \leq .05$, ** - $p \leq .001$, *** - $p \leq .0001$

The corrected model was significant for Factor 1 ($F_{4, 750} = 6.0$, $p = 0.000$, $\eta^2 = 0.031$), Factor 2 ($F_{4, 750} = 7.42$, $p = 0.000$, $\eta^2 = 0.038$) and Factor 3 ($F_{4, 750} = 27.65$, $p = 0.000$, $\eta^2 = 0.129$). Factor 4 was not significant ($F_{4, 750} = 2.15$, $p = 0.072$, $\eta^2 = 0.011$).

In this model, high childhood trauma was significantly associated with high Factor 3 scores ($F_{1, 750} = 52.81$, $t = 7.26$, $p = 0.000$, $\eta^2 = 0.066$) and low Factor 2 scores ($F_{1, 750} = 10.09$, $t = -3.17$, $p = 0.002$, $\eta^2 = 0.013$). Similarly, a high stressful life events score was significantly associated with high Factor 3 scores ($F_{1, 750} = 28.99$, $t = 5.38$, $p = 0.000$, $\eta^2 = 0.037$), high Factor 1 scores ($F_{1, 750} = 5.29$, $t = 2.30$, $p =$

0.022, $\eta^2 = 0.007$) and high Factor 4 scores ($F_{1, 750} = 4.16$, $t = 2.04$, $p = 0.042$, $\eta^2 = 0.006$). The stress measures were not significantly associated with any of the other factors (Table 3).

Female gender in this model was associated with high Factor 1 scores ($F_{1, 750} = 11.15$, $t = 3.34$, $p = 0.001$, $\eta^2 = 0.015$) and low Factor 2 scores ($F_{1, 750} = 6.57$, $t = -2.56$, $p = 0.011$, $\eta^2 = 0.009$). High parental education was associated with high Factor 2 scores ($F_{1, 750} = 7.60$, $t = 2.75$, $p = 0.006$, $\eta^2 = 0.01$). Gender and education were not significantly associated with any of the other factors (Table 3).

3.4. Second model to identify the effects of childhood trauma and stressful life events on sleep factors after controlling for anxiety and depressive symptoms and gender and education

Table 4: Childhood trauma, stressful life events and mental health symptoms effects on sleep patterns

	Factor 1 Movement during sleep	Factor 2 Sleep regularity	Factor 3 Sleep disturbances	Factor 4 Sleep pressure
Gender	5.69 (p = 0.017*)	8.09 (p = 0.005**)	1.84 (p = 0.175)	0.112 (p = 0.737)
Education	1.42 (p = 0.234)	7.62 (p = 0.006)	1.85 (p = 0.173)	3.46 (p = 0.063)
Childhood Adversity (CTQ Score)	0.029 (p = 0.864)	9.43 (p = 0.002**)	10.90 (p = 0.001**)	1.13 (p = 0.288)
Stressful Life Events (SLES Score)	1.36 (p = 0.243)	0.541 (p = 0.462)	7.76 (p = 0.005**)	1.13 (p = 0.287)
Anxiety symptoms score	10.04 (p = 0.002**)	2.29 (p = 0.130)	17.30 (p = 0.000***)	4.34 (p = 0.038)
Depressive symptoms score	0.272 (p = 0.602)	0.082 (p = 0.775)	31.09 (p = 0.000***)	1.20 (p = 0.273)

Significance levels * - $p \leq .05$, ** - $p \leq .001$, *** - $p \leq .0001$

The corrected model was significant for all the sleep factors: Factor 1 ($F_{6, 750} = 7.05$, $p = 0.000$, $\eta^2 = 0.054$), Factor 2 ($F_{6, 750} = 5.41$, $p = 0.001$, $\eta^2 = 0.042$), Factor 3 ($F_{6, 750} = 39.18$, $p = 0.000$, $\eta^2 = 0.240$) and Factor 4 ($F_{6, 750} = 3.42$, $p = 0.002$, $\eta^2 = 0.027$).

Childhood trauma score continued to be significantly associated with high Factor 3 scores ($F_{1, 750} = 10.90$, $t = 3.30$, $p = 0.001$, $\eta^2 = 0.014$) and low Factor 2 scores ($F_{1, 750} = 9.43$, $t = -3.07$, $p = 0.002$, $\eta^2 = 0.013$). The Stressful life events score was significantly associated with high Factor 3 scores ($F_{1, 750} = 7.76$, $t = 2.78$, $p = 0.005$, $\eta^2 = 0.01$) and was not associated with the other sleep factors.. The effect sizes of stress measures were lower in this model with the inclusion of psychiatric symptoms (Table 4)

High anxiety symptoms in this model were significantly associated with high Factor 3 scores ($F_{1, 750} = 17.30$, $t = 4.16$, $p = 0.000$, $\eta^2 = 0.023$), high Factor 1 scores ($F_{1, 750} = 10.04$, $t = 3.17$, $p = 0.002$, $\eta^2 = 0.013$) and high Factor 4 scores ($F_{1, 750} = 4.34$, $t = 2.08$, $p = 0.038$, $\eta^2 = 0.006$). High depressive symptom score was significantly associated with high Factor 3 scores ($F_{1, 750} = 31.09$, $t = 5.57$, $p = 0.000$, $\eta^2 = 0.040$). Anxiety and depressive symptoms were not significantly associated with the other sleep factors (Table 4).

Female gender in the combined model continued to be significantly associated with low Factor 2 scores ($F_{1, 750} = 8.09$, $t = -2.84$, $p = 0.005$, $\eta^2 = 0.011$) and high Factor 1 scores ($F_{1, 750} = 5.69$, $t = 2.38$, $p = 0.017$, $\eta^2 = 0.008$). High parental education continued to be significantly associated with high Factor 2 scores ($F_{1, 750} = 7.62$, $t = 2.76$, $p = 0.006$, $\eta^2 = 0.010$). Gender and education were not significantly associated with any of the other sleep factors (Table 4).

3.5. Correlations between childhood trauma, stressful life events and anxiety and depressive symptom scores

Childhood trauma score was significantly correlated with anxiety symptoms score ($r(752) = 0.245$, $p = 0.000$) and depressive symptoms score ($r(752) = 0.457$, $p = 0.000$). Stressful life events score had a significant correlation with anxiety symptoms score ($r(752) = 0.323$, $p = 0.000$) and depressive symptoms score ($r(752) = 0.334$, $p = 0.000$). Childhood trauma score and stressful life events score were correlated ($r(752) = 0.242$, $p = 0.000$) and anxiety symptoms score was highly correlated with depressive symptoms score ($r(752) = 0.634$, $p = 0.000$).

4. Discussion

We evaluated the role of childhood trauma and stressful life events on sleep patterns. We identified four sleep factors—the movement during sleep, the regularity of sleep, sleep disturbances and sleep pressure. Movement during sleep (Factor 1) originated from questions related to moving in bed and moving during sleep; regularity of sleep (Factor 2) from regularity of bedtime and wake time; sleep disturbances (Factor 3) from questions on sleeping less, trouble sleeping and nightmares; and sleep pressure (Factor 4) from questions on sleeping more, needing naps and waking up at different times. Sleep movement [51,52], regularity of sleep [53,54], sleep disturbances [18] and sleep pressure [55] were used in sleep research to evaluate sleep patterns.

Childhood trauma was significantly associated with Factor 3 (sleep disturbances) after controlling for anxiety and depressive symptoms scores. Factor 3 score originated from questions related to nightmares, sleeping less and difficulty sleeping which commonly arise [56] and may persist after the traumatic event. It is interesting to note that the effect size of childhood trauma on sleep disturbances (Factor 3) decreased after anxiety and depressive symptoms were included. It is likely that common mechanisms of sleep disruption underlie trauma and mental health symptoms. Our results are similar to the findings of Noll et al. where female adolescents who suffered sexual abuse had disturbed sleep after controlling for PTSD and depression [57]. It is pertinent to note that childhood trauma scores in this sample were comparable to a community sample [58] and were lower than an adolescent psychiatric inpatient population [41], suggesting the effects of childhood trauma on sleep manifest even at lower levels of trauma.

Similar to childhood trauma, stressful life events in the past year were significantly associated with high Factor 3 scores (sleep disturbances) that persist after controlling for anxiety and depressive symptoms. These findings are in line with research that identified stressful life events are associated with sleep disturbances [19,20]. The effect size of stressful life events on sleep disturbances was lower than childhood trauma, suggesting the severity of stress plays a critical role in the severity of sleep disturbances. The co-occurrence of childhood trauma and stressful life events was reported in some studies and not in others [15]. The effect of stress, both childhood trauma and stressful life events, albeit varied may present through a maladaptive Hypothalamus – Pituitary – Adrenal (HPA) system. Childhood trauma and stressful life events activate the limbic system that, in turn, activate the HPA axis through its projections into the hypothalamus and release the hormones corticotropin-releasing hormone (CRH) and adrenocorticotrophic hormone (ACTH). CRH activates the fast acting sympathetic-adrenal-medullary system and releases epinephrine in the prefrontal cortex known to increase attention and vigilance, and adrenocorticotrophic hormone (ACTH) releases glucocorticoids from the adrenal cortex. Heightened vigilance and arousal after stress may contribute to sleep disturbance. Laboratory studies have shown that maltreated children and adolescents continue to have increased hypervigilance as they respond to perceived potential social threats [59].

Additionally, anxiety symptoms were significantly associated with high Factor 1 (sleep movement), high Factor 3 (sleep disturbances), high Factor 4 (sleep need) and depressive symptoms associated with high Factor 3 (sleep disturbances). In previous studies, anxiety and depression symptoms are associated with sleep disturbances in adolescents [18,60]. Evidence suggests that sleep problems and anxiety may manifest together in early adolescence [61] and high movement during sleep was observed in studies of anxiety [62]. The above-proposed model of dysregulation of the HPA axis, including the sympathetic system and high glucocorticoids, is implicated in the

pathophysiology of insomnia [63], anxiety [30] and depressive symptoms [31]. Future studies should explore the common biological pathways underlying the HPA axis and their variability between stress, sleep, anxiety and depressive symptoms need to be further explored [18,64].

Female gender is significantly associated with increased movement during sleep and decreased regularity of sleep. The gender-specific finding of increased disruption of sleep in female adolescents in this study is likely related to the advanced pubertal status of female adolescents when compared to males in this study. Previous studies have shown female specific increases in sleep problems in adolescents with advanced pubertal status [65]. High parental education was significantly associated with high regularity of sleep. High parental education is associated with earlier bedtime schedules for children [66]. Parentally established bedtimes [67] improve the regularity of sleep by creating regular sleep schedules for adolescents.

This analysis is a secondary analysis of cross-sectional self-reports and has important limitations. We did not have objective measures for sleep and used self-report questionnaires. The four identified sleep factors assessing sleep movement, sleep regularity, sleep disturbance and sleep pressure were unique. Some degree of association exists between the sleep factors, as sleep habits influence the quality of sleep [68], and poor sleep quality and irregular sleep patterns are associated with increased sleep pressure [69,70]. The temporal associations between the sleep factors cannot be identified in this analysis because of the cross-sectional nature of the observations. Also, collinearity, although not approaching a high correlation, was observed for stress and anxiety and depressive symptoms, suggesting associations between the answers on reported questionnaires. Future research that includes objective measures of stress may help reduce the associations observed in self-report measures. Lastly, we do not have information about the circadian preferences of the adolescents in our sample, which may be relevant given that adolescents with evening type sleep preferences have increased depressive and anxiety symptoms [71].

In summary, we identified that childhood trauma and stressful life events are independently associated with sleep disturbances, and these effects persist after controlling for anxiety and depressive symptoms in a large cohort of adolescents. Future research should include objective measures to identify the complex relationships between stress, anxiety, depression and sleep while focusing on circadian, neurobiological and social factors [18]. Understanding the common cognitive and physiological pathways and their variability in stress, psychiatric and sleep symptoms can lead to improved understanding of the development of sleep disturbances in adolescents with stress and affective problems.

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