Associations among early life adversity, sleep disturbances, and depressive symptoms in adolescent females and males: a longitudinal investigation

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Background: Exposure to adversity early in life (ELA) has been associated with elevated risk for depression during adolescence, particularly for females; the mechanisms underlying this association, however, are poorly understood. One potential mechanism linking ELA and sex differences in depressive symptoms is sleep disturbances, which increase during adolescence and are more common in females. Here, we examined whether sleep disturbances mediate the association between ELA and increases in depressive symptoms during adolescence and whether this mediation differs by sex. Methods: 224 (N = 132 females) youth were recruited at age 9–13 years and assessed every 2 years across three timepoints. At the first timepoint, we conducted extensive interviews about stressful events participants experienced; participants provided subjective severity ratings of events and we objectively scored the severity of each event. Self-reported sleep disturbances and depressive symptoms were assessed at all timepoints. We conducted linear mixed models to estimate both initial levels and changes in sleep disturbances and depressive symptoms, and moderated mediation analyses to test whether initial levels and/or changes in sleep disturbances mediated the association of ELA (objective and subjective) with increases in depressive symptoms across adolescence and whether the mediations differed by sex. Results: While higher initial levels and increases in sleep problems were uniquely associated with increases in depressive symptoms for males and females, they were related to ELA differently by sex. For females, greater ELA (both objectively and subjectively rated) was associated with higher initial levels of sleep problems, which in turn were associated with increases in depressive symptoms from early to late adolescence. In contrast, for males, ELA exposure was not associated with either initial levels of, or increases in, sleep problems. Conclusions: These findings highlight the role of sleep disturbances during the transition to adolescence in mediating sex differences in the effects of ELA on depressive symptoms. Keywords: Early adversity; sleep disturbances; depressive symptoms; adolescence; sex differences.

Introduction
Depression is a debilitating disorder that often emerges during adolescence. Adolescent females are disproportionately affected by depression; furthermore, the higher rate of depressive symptoms among female adolescents has been increasing in recent decades (Breslau et al., 2017). Exposure to stressors early in life has been consistently associated with elevated risk for depression during adolescence (LeMoult et al., 2020; Tracy, Salo, Slopen, Udo, & Appleton, 2019), particularly in females (Colich et al., 2017, 2023; LeMoult et al., 2019). The mechanisms by which exposure to early life adversity (ELA) is associated with sex differences in risk for depression, however, are not well understood.

One potential mechanism linking ELA and depressive symptoms during adolescence is increased sleep disturbances. Sleep disturbances, including restricted or prolonged sleep duration, poor sleep quality, variable and irregular sleep times, and problems initiating and maintaining sleep, have been associated with poorer outcomes in multiple domains of health across the lifespan, including depression (Chattu et al., 2019; Matricciani, Paquet, Galland, Short, & Olds, 2019; Medic, Wille, & Hemels, 2017). Sleep disturbances tend to increase during adolescence due to a combination of puberty-related shift in circadian rhythm and psychosocial changes that result in restricted and irregular sleep (Crowley, Wolfson, Tarokh, & Carskadon, 2018). ELA has been associated cross-sectionally with greater sleep disturbances during adolescence (April-Sanders et al., 2021; Chae, Jang, Park, & Jang, 2021; Langevin et al., 2019; McPhie, Weiss, & Wekerle, 2014; Park et al., 2021; Turner et al., 2020; Wang, Raffeld, Slopen, Hale, & Dunn, 2016; Xiao et al., 2020). While few longitudinal studies have been conducted, one prospective, longitudinal study found that ELA is associated with greater sleep disturbances during adolescence, but not during childhood (April-Sanders et al., 2021), suggesting that the normative increases in sleep disturbance during adolescence represent a double hit for individuals with a history of ELA (Fuligni, Chiang, & Tottenham, 2021). Indeed, in a recent review paper, Brown, Rodriguez, Smith, Ricker, and Williamson (2022) suggest that, although the relation between ELA and sleep disturbances during childhood tend to be more mixed, studies on adolescents and adults demonstrate a more robust association between exposure to ELA and greater sleep disturbances.
Sleep disturbances are also more prevalent among females than males (Crockett, Martínez, & Jiménez-Molina, 2020; Meers, Stout-Aguilar, & Nowakowski, 2019). In addition, the association between ELA and sleep disturbances during adolescence differs by sex, making sleep disturbance a candidate mechanism to explain sex differences in adversity-related outcomes. For example, adolescent females who experienced greater childhood maltreatment have been found to report more sleep problems than do adolescent males who experienced similar levels of maltreatment (Wang et al., 2016; Xiao et al., 2020). It is not clear, however, how these adversity-related increases in sleep problems during adolescence are related to depressive symptoms. Furthermore, studies in this area have been cross-sectional, examining sleep disturbances and/or depressive symptoms only at one timepoint. Therefore, we do not know whether ELA is related to longitudinal changes in sleep disturbances and how these changes might contribute to changes in depressive symptoms over adolescence. Sleep is a modifiable health behavior that has downstream effects on the same biological mechanisms that have been found to be involved in ELA and depression and that undergo significant changes during adolescence. Such biological mechanisms include cortical and subcortical brain regions involved in affective processing and regulation, the hypothalamic–pituitary–adrenal (HPA) axis, and the immune system (see Fuligni et al., 2021 for review). Elucidating the longitudinal associations among ELA, sleep disturbance, and depressive symptoms from late childhood/early adolescence through adolescence has the potential to inform etiological models of depression and has important implications for targeted approaches to prevention and intervention.

In addition to a lack of longitudinal studies, previous studies examining the association between ELA and sleep during adolescence have mostly relied on self-reported measures to assess ELA (April-Sanders et al., 2021; Chae et al., 2021; McPhie et al., 2014; Park et al., 2021; Turner et al., 2020; Wang et al., 2016; Xiao et al., 2020) as well as utilized a cumulative risk approach where the number of adverse events is summed, regardless of the severity of the events (e.g., April-Sanders et al., 2021; Wang et al., 2016). These methods may not fully capture the multifaceted and complex experience of ELA exposure. Using objective, in addition to subjective, assessments of ELA that integrate both the number and the severity of adverse events will complement and advance our understanding of the effects of ELA on sleep disturbances and other outcomes across development.

In the current longitudinal study, we examined whether sleep disturbances (both during early adolescence and longitudinally across adolescence) mediate the association between ELA and changes in depressive symptoms during adolescence and whether this mediation differs for males and females. We assessed ELA by conducting extensive interviews with participants about the stressful events they have experienced during their childhood. In addition to acquiring participants’ subjective severity ratings of these events, we also derived objective severity of these events by having a panel of trained coders who were blind to the participants’ subjective ratings of these events rate the objective severity of each event. We aggregated the severity ratings across stressor types to compute, separately, the subjective and objective cumulative severity of adverse events for each participant. Thus, this approach takes into account the number and objective severity of a variety of adverse events during childhood. Importantly, we followed these participants longitudinally across adolescence, thereby allowing us to examine the effects of ELA on sleep disturbances and depressive symptoms prospectively across adolescence. Based on previous research, we hypothesized that ELA will be associated with both higher initial levels and increases in sleep disturbances across adolescence, which, in turn, will be related to increases in depressive symptoms across adolescence. Because levels of sleep disturbances and depressive symptoms have been found to be higher in female than in male adolescents, we hypothesized that this mediation will be stronger for females than for males. Furthermore, we also explored possible differences between the subjective and objective severity ratings of early adversity, given research demonstrating differential associations between participants’ subjective and objective experience of maltreatment and psychopathology (e.g., Danese & Widom, 2020).

Methods

Participants

224 participants (N = 132 females) were recruited starting in September 2013, from the San Francisco Bay Area to participate in a longitudinal study examining the effects of ELA on psychobiology over puberty. Participants were recruited using a combination of media and online advertisements posted in local communities around Stanford University. Because the larger study involved a magnetic resonance imaging (MRI) session, criteria for exclusion from the study included factors that would preclude an MRI scan (e.g., metal implants, braces), as well as a history of major neurological or medical illness, severe learning disabilities that would make it difficult to comprehend the study procedures, and, for females, the onset of menses. Inclusion criteria were that children were ages 9–13 years and were proficient in spoken English. Participants were 9.11–13.98 years of age (M = 11.51 years, SD = 1.08) at the first timepoint (T1), 11.15–16.26 years of age (M = 13.39, SD = 1.09) at the second timepoint (T2), and 13.07–17.93 years (M = 15.61 years, SD = 1.12) at the third timepoint (T3). Exposure to early adversity was assessed at T1. Reports of sleep problems (T1: N = 214, T2: N = 167, T3: N = 164) and depressive symptoms (T1: N = 221, T2: N = 167, T3: N = 169) were obtained from as many participants as possible at all timepoints (219 participants had at least one timepoint of sleep problems data and 224 participants had at least one timepoint of data on depressive symptoms). 189 participants provided at least two timepoints of data, and 141
participants provided data at all three timepoints. There were no significant differences between participants who provided data for only one timepoint (N = 35) and participants who provided data for at least two timepoints (N = 189) on any variables at T1 (Table S1). All analyses were conducted with the largest number of participants. A total of 218 participants were included in the final moderated mediation analysis.

**Procedures**

Study procedures were approved by the Stanford University Institutional Review Board and were in accordance with guidelines set forth by the Declaration of Helsinki. After screening participants for inclusion/exclusion criteria (see above), eligible families were invited to attend a laboratory session. Participants and their parents or legal guardians gave informed assent and consent, respectively, for study activities. Children completed measures of sleep disturbances and depressive symptoms and then completed the TESI interview with a trained administrator.

**Measures**

**Early life adversity (T1).** A modified version of the Traumatic Events Screening Inventory for Children (TESI-C; Ford et al., 2002) was used to assess more than 30 types of life events, including direct exposure to or witnessing of severe accidents, illness or disaster, family or community conflict or violence, and sexual molestation. The order in which the questions were asked was arranged to review experiences hierarchically in order to help the child tolerate the possible stress of disclosing traumatic experiences by gradually increasing the intimacy of the experiences (e.g., sexual trauma is assessed at the end of the interview). Each type of event endorsed by a participant was followed up with questions to obtain a deeper characterization of the experience. For example, participants were asked if they have “ever been in a really bad accident, like a car accident, a fall, or fire, where you or someone else could have been (or actually was) badly injured or killed.” If this item was endorsed, participants were then asked how many times such an event happened (if multiple times, each event was recorded as a separate event), when the event happened, and whether and how badly they or someone else were really hurt. Participants were then asked to rate how “scared, confused, or helpless” they felt in relation to the event, providing a subjective severity rating. If participants showed signs of distress during the interview, the administrator validated the participants’ feelings (e.g., “thank you for sharing that with me, that must have been hard”), offered them the opportunity to take a break, and reminded them that they could decline to answer any questions. The complete interview took 1–2 h to complete. After the interview, the administrator then presented each event to a panel of three trained coders who, blind to the participants’ subjective severity ratings, used a modified version of the UCLA Life Stress Coding System (Adrian & Hammen, 1993; Rudolph & Hammen, 1999) to rate the objective severity of each event on a scale ranging from 0 (not impactful) to 4 (extremely severe and impactful), with half-point increments (inter-rater ICC = 0.99). If there were any discrepancies among coders in ratings for an event, the coders discussed their ratings to arrive at a consensus score for the event that was then used in analyses. Cumulative adversity severity scores were computed by summing the maximum objective severity scores for each type of stressor endorsed (e.g., Chahal, Kirshenbaum, Ho, Mastroti, & Gotlib, 2021; Chahal, Miller, Yuan, Buthmann, & Gotlib, 2012; King, Graber, Colich, & Gotlib, 2020). Cumulative adversity severity scores were also computed based on participants’ subjective severity ratings for the events. Objective and subjective cumulative adversity severity scores were highly correlated (r = .81, p < .001).

**Sleep disturbances (T1–T3).** Participants completed the Youth Self-Report (YSR; Achenbach & Rescorla, 2001), from which we calculated a sleep problems composite generated from five items assessing sleep quality: “I sleep less than most kids,” “I sleep more than most kids during the day and/or night,” “I have trouble sleeping,” “I have nightmares,” and “I feel overtired.” This sleep composite score has been used in previous research as a measure of overall sleep functioning (e.g., Wang et al., 2016) and has also been shown to correlate highly (r = .61, 95% CI: [0.54, 0.67]) (LIonetti et al., 2021) with the validated Children’s Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000). Each item is rated on a 3-point scale (0 = not true, 1 = somewhat or sometimes, 2 = very true or often true). Response frequencies for each sleep item and the reliabilities (Cronbach’s alpha) for the five-item composite at all timepoints are presented in Table S2. An item analysis indicated that removing the item assessing hyperomnia (i.e., “I sleep more than most kids during the day and/or night”) and the item assessing nightmares (i.e., “I have nightmares”) increased the reliability of the sleep composite. Thus, we removed these two items and computed a sleep problems composite score consisting of the sum of the three other items; we used this new composite score in analyses (range = 0–6), with higher scores indicating more sleep problems. Reliabilities for the sleep problems composite at T1, T2, and T3 are 0.68 (95% CI: [0.61, 0.75]), 0.64 (95% CI: [0.56, 0.72]), and 0.68 (95% CI: [0.61, 0.75]), respectively. These internal reliabilities are consistent with the internal reliabilities of the CSHQ, which was 0.68 for a community sample and 0.78 for a clinical sample (Owens et al., 2000).

**Depressive symptoms (T1–T3).** Participants completed the 10-item short form of the Child Depression Inventory (CDI-S; Kovacs, 2015), a self-report measure of depressive symptoms designed for youth ages 8–17 years. Participants indicated the severity of symptoms of depression they were experiencing over the past 2 weeks on a 3-point scale that ranged from 0 (no symptoms) to 2 (definite symptoms). The CDI-S measures sadness, pessimism, self-deprecation, self-hate, crying spells, irritability, negative body image, loneliness, lack of friends, and feeling unloved. Frequencies of responses and reliabilities are presented in Table S3. On this version of the CDI, sleep disturbances were not included as a symptom of depression. A sum score was calculated to represent depressive symptoms, with higher scores indicating more symptoms. Reliabilities for the depressive symptoms scale at T1, T2, and T3 are 0.75 (95% CI: [0.70, 0.80]), 0.80 (95% CI: [0.76, 0.84]), and 0.85 (95% CI: [0.82, 0.88]), respectively.

**Statistical analyses**

Using the lme4 package in R, we first conducted linear mixed effects (LME) models with random intercepts and age slopes to estimate the intercepts and slopes of sleep problems for each participant. LME models make use of all available data across timepoints, even in the presence of missing data, providing an advantage over traditional repeated measures analyses. In LME models, random effects represent individual-level changes in the outcome measure, which can vary in their initial level (i.e., intercept) and rate of change (i.e., slope). We modeled self-reported sleep problems as a function of age and extracted the intercept and slope parameter estimates for each participant. Age was centered at the youngest age in our sample (9.11 years) such that the intercept reflected sleep problems in early adolescence. Model parameters estimating the effects of age thus reflected change in sleep problems from early through late adolescence. We conducted the same linear mixed effects analysis for depressive symptoms to extract estimated intercepts and slopes of depressive symptoms for each participant. This analytic approach has been used in studies that examined...
associations between longitudinal changes in multiple variables during adolescence (e.g., Cooper et al., 2023).

Using the extracted estimated intercepts and slopes for sleep problems and depressive symptoms for each participant, we then conducted moderated mediation analyses using Hayes’ PROCESS macro in R to test whether initial levels (i.e., intercepts) and/or slopes of sleep problems (in parallel) mediated the association between objective severity ratings of ELA and changes in depressive symptoms (i.e., slopes), and whether this mediation was moderated by sex. Sex was tested as a moderator for all paths (a, b, and c) of the mediation model (Model 59). Initial levels of depressive symptoms (i.e., intercepts) were included as a covariate.

In addition to using objective severity ratings of ELA, we also conducted moderated mediation analyses using participants’ subjective severity ratings of ELA as the predictor to explore whether associations differed as a function of rater.

At T3, N = 36 (15%) of the sample was assessed during the COVID-19 pandemic. Although imprecise as a measure of the effects of COVID-19, we created a binary variable indicating whether participants were assessed prior to (i.e., before 17 March 2020) (0) or during (1) the pandemic (i.e., after 17 March 2020) and included this variable as a covariate in analyses.

We also tested the mediation in the reverse direction to assess directionality of effects, with initial levels and slopes of depressive symptoms (in parallel) mediating the association of ELA with changes in sleep problems, controlling for initial levels of sleep problems, and whether this mediation was moderated by sex.

Results
Demographic characteristics and descriptive statistics for the study variables are presented in Table 1. Although males were significantly older than females at all timepoints (ps < .001), the difference was always less than 1 year. There were no sex differences in race (p = .46), socioeconomic status (ps > .10), objective (p = .91) or subjective (p = .22) ELA severity, sleep problems at T1 (p = .58), T2 (p = .72) and T3 (p = .06), or depressive symptoms at T1 (p = .97) and T2 (p = .31); however, females reported higher levels of depressive symptoms at T3 (p = .003). Bivariate correlations among the study variables are presented in Table 2.

Moderated mediation analyses
We tested whether initial levels and/or changes in sleep disturbances in parallel mediated the association between objective severity of ELA and changes in depressive symptoms, and whether the mediations were moderated by sex. Analyses yielded a significant moderated mediation for initial levels of sleep disturbance, over and above parallel mediation by changes in sleep problems (effect = 0.0076, bootstrapped SE = 0.0040, bootstrapped 95% CI: [0.0008, 0.0165]): the indirect effect was significant for females (effect = 0.0082, bootstrapped SE = 0.0035, bootstrapped 95% CI: [0.0024, 0.0160]), but not for males (effect = 0.0005, bootstrapped SE = 0.0021, bootstrapped 95% CI: [−0.0042, 0.0045]) (Figure 1).

Specifically, for females, objective severity of ELA was positively associated with initial levels of sleep problems (b = 0.0352, SE = .0116, t(212) = 3.0476, p = .0026, 95% CI: [0.0124, 0.0580]), which in turn were positively associated with increases in depressive symptoms, over and above the effects of changes in sleep problems (b = 0.2315, SE = .0336, t(208) = 8.6575, p < .001, 95% CI: [1.3695, 2.1772]). Increases in sleep disturbances, over and above initial levels of sleep disturbances, also mediated the association between objective severity of ELA and increases in depressive symptoms for females (indirect effect = 0.0070, SE = 0.0041, 95% CI: [0.0003, 0.0165]): greater ELA was positively associated with increases in sleep problems (b = 0.0040, SE = .0019,

### Table 1 Sample characteristics and descriptive statistics by timepoint

<table>
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<tr>
<th>Variable (range)</th>
<th>Males</th>
<th>Females</th>
<th>t or χ²</th>
<th>p</th>
</tr>
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<tr>
<td>N (T1/T2/T3)</td>
<td>93/73/T3</td>
<td>122/93/92</td>
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<td>&lt;.001</td>
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<tr>
<td>Age (T1) (9.11–13.98 years)</td>
<td>11.80 (0.94)</td>
<td>11.02 (1.00)</td>
<td>6.06</td>
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<td>Age (T2) (11.13–16.26)</td>
<td>13.82 (1.02)</td>
<td>13.08 (1.03)</td>
<td>5.17</td>
<td>&lt;.001</td>
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<td>Age (T3) (13.10–18.25)</td>
<td>15.82 (1.00)</td>
<td>15.29 (1.18)</td>
<td>3.39</td>
<td>&lt;.001</td>
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<td>Race (White/African American/Hispanic/Asian/Biracial/Other)</td>
<td>4.92 (1.23)</td>
<td>4.87 (1.36)</td>
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<td>.78</td>
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<td>Parent Education (T1) (1–8)</td>
<td>8.59 (1.72)</td>
<td>8.21 (2.23)</td>
<td>1.64</td>
<td>.10</td>
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<tr>
<td>Parent Income (T1) (1–10)</td>
<td>6.85 (5.00)</td>
<td>6.91 (5.81)</td>
<td>0.11</td>
<td>.91</td>
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<td>Objective Cumulative Severity of Adversity (0–31.5)</td>
<td>5.51 (4.98)</td>
<td>6.42 (5.49)</td>
<td>-1.24</td>
<td>.22</td>
</tr>
<tr>
<td>Subjective Cumulative Severity of Adversity</td>
<td>1.63 (1.47)</td>
<td>1.58 (1.59)</td>
<td>0.56</td>
<td>.58</td>
</tr>
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<td>YSR Sleep Problems (T1) (0–6)</td>
<td>1.66 (1.37)</td>
<td>1.63 (1.75)</td>
<td>0.36</td>
<td>.72</td>
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<tr>
<td>YSR Sleep Problems (T2) (0–6)</td>
<td>1.70 (1.54)</td>
<td>2.17 (2.84)</td>
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<td>.36</td>
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<td>YSR Sleep Problems (T3) (0–6)</td>
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<td>2.16 (2.41)</td>
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<td>.97</td>
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<td>CDI Depressive Symptoms (T1) (0–11)</td>
<td>2.01 (2.36)</td>
<td>2.48 (2.71)</td>
<td>-1.02</td>
<td>.31</td>
</tr>
<tr>
<td>CDI Depressive Symptoms (T2) (0–13)</td>
<td>2.58 (2.82)</td>
<td>4.22 (3.75)</td>
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<td>CDI Depressive Symptoms (T3) (0–14)</td>
<td>12</td>
<td>24</td>
<td>0.89</td>
<td>.35</td>
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</table>

All descriptive statistics are reported in mean (standard deviation) except for race, which are reported as number of participants in each category, and session during COVID. CDI, Child Depression Inventory; YSR, Youth Self Report. Codes for parent education are as follows: 1 = No GED/No High School Diploma; 2 = GED/High School Diploma; 3 = Some College; 4 = 2-year College Degree; 5 = 4-year College Degree; 6 = Master’s Degree; 7 = Professional Degree (MD, JD, DDS, etc.); 8 = Doctorate. Codes for Household Income are as follows: 1 = less than $5,000; 2 = $5,001–$10,000; 3 = $10,001–$15,000; 4 = $15,001–$25,000; 5 = $25,001–$35,000; 6 = $35,001–$50,000; 7 = $50,001–$75,000; 8 = $75,001–$100,000; 9 = $100,001–$150,000; 10 = $150,000 or greater.

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Table 2 Bivariate correlations among variables

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<td>.28***</td>
<td>.19*</td>
<td>.46**</td>
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<td>.0026</td>
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*p < .05, **p < .01, ***p < .001.

Figure 1 Results from moderated mediation analyses. For females, both higher initial levels of and increases in sleep problems uniquely mediated the association between greater cumulative severity of early life adversity (ELA) and increases in depressive symptoms. In contrast, for males, greater ELA was not associated with either initial levels or increases in sleep problems, although both were associated with increases in depressive symptoms across time. Significant effects denoted in bold.

t(212) = 2.1205, p = .0351), which was positively associated with increases in depressive symptoms (b = 1.7733, SE = .2048), t(208) = 8.6575, p < .001. While changes in sleep disturbances did not mediate the association between ELA and increases in depressive symptoms for males (indirect effect = 0.00338 (0.0029), 95% CI: [-0.0011, 0.0103]), the index of moderated mediation was not statistically significant (effect = 0.0033, SE = .0048, 95% CI: [-0.0059, 0.01232]). For males, while initial levels (b = 0.1446, SE = .0453, t(208) = 3.1932; p = .0016, 95% CI: [0.0553, 0.2339]) and changes in sleep problems (b = 1.2869, SE = .2812, t(208) = 4.5770, p < .001, 95% CI: [0.7326, 1.8412]) were both independently positively associated with increases in depressive symptoms, objective severity of ELA was not significantly associated with either initial levels (p = .7997) or changes in sleep problems (p = .2212). Males and females did not differ in the associations of both initial levels and changes in sleep problems with changes in depressive symptoms (sex x initial sleep problems: b = 0.0435, SE = .0278, t(208) = 1.5636, p = .1194; sex x changes in sleep problems: b = 0.2432, SE = .1707, t(208) = 1.4248, p = .1557).

Similar results were obtained using subjective severity measures of ELA: initial levels of sleep problems independently mediated the association between subjective severity of ELA and increases in depressive symptoms for females (effect = 0.011, SE = .004, 95% CI: [0.005, 0.019]), but not for males (effect = 0.0037, SE = .0022, 95% CI: [-0.0027, 0.0071]); however, the index of moderated mediation was marginally significant (index of moderated mediation = 0.0074, SE = .004, 94.9% CI: [0.000018, 0.0167], 95% CI: [-0.0002, 0.0167]) (Figure S1). Specifically, for females, greater subjective severity of ELA was associated with higher initial levels of sleep problems (b = 0.048, SE = .011, t (207) = 4.19, p < .001), which in turn were associated with greater increases in depressive symptoms (b = 0.23, SE = .036, t(203) = 6.56, p < .001). Subjective severity of ELA was not associated with initial levels of or changes in sleep problems in males (sleep intercept: b = 0.026, SE = .015, p = .085; sleep slope: b = 0.002, SE = .003, p = .52). Subjective severity of ELA was also not associated with changes in sleep problems in females (b = 0.0034, SE = .002, p = .078). Thus, increases in sleep problems, over
and above initial levels of sleep problems, did not mediate the association between subjective severity of ELA and changes in depressive symptoms for either females ($b = 0.0066$, SE = 0.0013, 95% CI: [0.0006, 0.0015]) or males ($b = 0.0021$, SE = 0.0024, 95% CI: [-0.0027, 0.0071]).

We also tested the mediation in the reverse direction, with initial levels and changes in depressive symptoms, in parallel, mediating the association between ELA (objective or subjective) and increases in sleep problems across adolescence. While increases in depressive symptoms were associated with increases in sleep problems ($b = 0.1887$, SE = 0.0195, $t(211) = 9.66$, p < .001), initial levels of depressive symptoms were not related to increases in sleep problems ($b = 0.0061$, SE = 0.009, $t(211) = 0.71$, p = .48). Neither initial levels (objective ELA: indirect effect = 0.0002, SE = 0.0003, 95% CI: [-0.0005, 0.0010]; subjective ELA: indirect effect = 0.0002, SE = 0.0003, 95% CI: [-0.003, 0.0008]) nor changes in depressive symptoms (objective ELA: indirect effect = 0.0004, SE = 0.0009, 95% CI: [-0.0014, 0.0023]; subjective ELA: indirect effect = 0.0008, SE = 0.0010, 95% CI: [-0.0011, 0.0028]) mediated the association between ELA and increases in sleep problems. The mediations were not moderated by sex (index of moderated mediation for increases in sleep problems ($b = 0.1887$, SE = 0.0195, $t(211) = 9.66$, p < .001), initial levels of depressive symptoms were not related to increases in sleep problems ($b = 0.0061$, SE = 0.009, $t(211) = 0.71$, p = .48).

## Discussion

In the current study, we tested whether longitudinal increases in sleep disturbances during adolescence is a mechanism by which ELA is associated with increases in depressive symptoms, and also helps to explain sex differences in risk for depression. Previous research examining the association between ELA and sleep problems during childhood and adolescence has relied primarily on retrospective self-reported measures and cumulative risk approaches, we found that, while higher levels of sleep problems during early adolescence and increases in sleep problems were each uniquely related to increases in depressive symptoms, there were differential associations of ELA with sleep disturbances as a function of sex. For females, greater cumulative severity of ELA exposure during childhood (measured objectively and subjectively) was associated with higher levels of sleep problems during early adolescence, which in turn were associated with increases in depressive symptoms from early to late adolescence; this mediation was significant over and above the effects of increases in sleep problems on increases in depressive symptoms across adolescence. In contrast, for males, ELA exposure was not associated with either initial levels of, or increases in, sleep problems.

Consistent with previous research (e.g., Langewin et al., 2019; Wang et al., 2016), we found that ELA is associated with greater sleep problems in female than in male adolescents during early adolescence. Epidemiological research shows that sex differences in sleep disturbances emerge around 11–14 years (Camhi, Morgan, Pernisco, & Quan, 2000), and in females after the onset of menses (Johnson, Roth, Schultz, & Breslau, 2006), implicating hormonal changes during puberty in the increased risk for sleep disturbances in females across the lifespan (Mong & Cusmano, 2016). Thus, it is possible that exposure to ELA interacts with sex and pubertal processes to alter biological processes that are important for sleep regulation, such as the hypothalamic–pituitary–adrenal (HPA) axis, immune function, and the brain (Gunnar, 2020).

Basal activity of the HPA axis is largely regulated by the internal circadian clock and exhibits a diurnal rhythm, characterized by peak activity (i.e., cortisol levels) upon wake and decreasing throughout the day until reaching a trough at the beginning of the sleeping period. Indeed, the initiation of sleep occurs when cortisol level is lowest (Buckley & Schatzberg, 2005). The HPA axis also responds to stress, initiating a cascade of events that lead to the release of cortisol, which also feeds back to the HPA axis to attenuate the stress response and maintain homeostasis. Dysfunction of the HPA axis, therefore, leads to increased sleep fragmentation and shortened sleep time, undermining sleep quality. Sleep disturbances, in turn, alter HPA axis functioning, resulting in a cycle of poor stress and sleep regulation (Buckley & Schatzberg, 2005). Research in rodent models and humans have found sex differences in how the HPA axis responds to stress (Heck & Handa, 2019); however, the magnitude and direction of these effects have been inconsistent (Rubinow & Schmidt, 2019). HPA axis activity can also shape immune functioning and neurobiological
development, particularly in regions that are rich in glucocorticoid receptors and implicated in stress regulation (Koss & Gunnar, 2018). Both immune and neural processes, uniquely and in interaction, have been found to have bidirectional associations with sleep (Irwin, 2015, 2019; Irwin & Opp, 2017) as well as sex differences in their functioning (Moieni et al., 2015; Rubinow & Schmidt, 2019). Extensive research has documented that ELA alters HPA axis functioning across development (Koss & Gunnar, 2018), suggesting that HPA axis dysfunction and its downstream effects are one pathway by which ELA is associated with sleep disturbances (in a sex-dependent manner) during adolescence.

We also found that, regardless of exposure to ELA, greater sleep problems during early adolescence as well as greater increases in sleep problems across adolescence were uniquely associated with greater increases in depressive symptoms for both males and females. These findings are consistent with research showing positive associations between sleep disturbances and depressive symptoms during adolescence (e.g., Palmer, Oosterhoff, Bower, Kaplow, & Nar, 2023), suggesting that HPA axis dysfunction and its downstream effects are one pathway by which ELA is associated with sleep disturbances (in a sex-dependent manner) during adolescence. We also found that, regardless of exposure to ELA, greater sleep problems during early adolescence as well as greater increases in sleep problems across adolescence were uniquely associated with greater increases in depressive symptoms for both males and females. These findings are consistent with research showing positive associations between sleep disturbances and depressive symptoms during adolescence (e.g., Palmer, Oosterhoff, Bower, Kaplow, & Nar, 2023), suggesting that HPA axis dysfunction and its downstream effects are one pathway by which ELA is associated with sleep disturbances (in a sex-dependent manner) during adolescence.

In this study, sex did not moderate the associations between initial levels or increases in sleep problems and increases in depressive symptoms (Raniti et al., 2017), emerging research suggests that it is more likely that sleep disturbances precede depression in adolescents than vice versa (Lovato & Gradisar, 2014). Indeed, several experimental and longitudinal studies have found that sleep disturbances causally affect several risk factors for depression in adolescents, including decreases in positive affect (Short, Booth, Omar, Ostlundh, & Arora, 2020), increases in negative affect (Short et al., 2020), and a diminished ability to effectively regulation emotions (Baum et al., 2014; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010; Vriend et al., 2013). In the current study, we found that increases in depressive symptoms across adolescence, but not initial levels of depressive symptoms during early adolescence, were related to increases in sleep problems. These findings, together with extant research, suggest that sleep disturbances precede depressive symptoms during adolescence.

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ELA and sleep problems across the timepoints (Table 2). That is, adolescents exposed to ELA have more sleep problems earlier in development that remain persistently elevated across adolescence. For males and females whose sleep problems are not related to exposure to ELA, increases in sleep problems across adolescence could be due to normative changes in homeostatic sleep pressure, circadian rhythm timing, and social behaviors during adolescence (Crowley et al., 2018). Although normative, these increases in sleep problems increase risk for depressive symptoms during adolescence regardless of ELA exposure. Taken together, these findings highlight the potential importance of sleep interventions to ameliorate sleep disturbances and depressive symptoms in adolescence; furthermore, for children exposed to ELA, interventions should be targeted during the transition to adolescence.

Although we showed that adversity exposure during childhood affects the development of sleep and depressive symptoms across adolescence, it is likely that different types of ELA may have differential associations with sleep (e.g., Desch, Bakour, Mansuri, Tran, & Schwartz, 2023; Qu et al., 2023; Wang et al., 2016). For example, adolescents who experienced maltreatment, parental divorce, or who have family members who have mental health disorders, were incarcerated, or were victims of domestic violence were more likely to report poorer sleep quality than those who experienced financial hardships, with adolescents who reported experiencing emotional abuse having the highest risk of poor sleep quality (Qu et al., 2023). Additionally, exposure to interpersonal violence during childhood conferred higher risk for insomnia than experiencing accidents/injuries or witnessing adverse events, although almost all event types were significantly associated with insomnia symptoms (Wang et al., 2016). In addition to the characteristics/features of adversity exposure, research has also found that posttraumatic stress symptoms related to adversity exposure mediated the association between exposure to traumatic events and increases in sleep problems among youth in foster care (Lehmann, Gärtner Askeland, & Hysing, 2021). Posttraumatic stress symptoms are also related to greater depressive symptoms in adolescents who experienced trauma, and sleep problems have been found to predict greater posttraumatic stress symptoms, thus creating a feedback loop that may precipitate and amplify depressive symptoms across time (Geng et al., 2019; Giannakopoulos & Kolaitis, 2021). These findings suggest that, over and above the specific features (e.g., type, timing, chronicity) of adverse events, experience of posttraumatic stress symptoms is a strong predictor of sleep disturbance and depressive symptoms in youth who have experienced trauma. Indeed, in a sample of children treated for injuries after road traffic accidents, those who experienced posttraumatic stress had higher and
more persistent sleep problems after 6 months of hospitalization than those who did not (Wittmann, Zehnder, Jenni, & Landolt, 2012). Finally, it is possible that new and ongoing stressors and reactivity to those stressors during adolescence also contribute to our findings. Indeed, research has shown that adolescent females not only reported more stressors (especially interpersonal stressors) than do adolescent males, they are also more reactive to those stressors in the form of higher levels of depressive symptoms (e.g., Hankin, Mermelstein, & Roesch, 2007). Given that exposure to stressors is both ubiquitous and inevitable, it will be important for future research to examine both how ELA interacts with ongoing stressors during adolescence to affect the developmental sequela of sleep and depressive symptoms, and whether there are differential effects as a function of the features of adversity, posttraumatic stress symptoms, sex, and other individual differences.

We should note that in this study adolescents reported on their own sleep problems, which can be biased. Furthermore, we do not have information about participants’ sleep behaviors (e.g., sleep duration, timing, efficiency); therefore, we cannot distinguish the effects of sleep problems from consequences of sleep behaviors. It is important to note, however, that our findings converge with those of several studies that have reported associations between exposure to ELA and increased sleep disturbances in youth assessed through case manager reports (Cecil, Viding, ELA, and increased sleep disturbances in youth that have reported associations between exposure to that our findings converge with those of several studies of sleep behaviors. It is important to note, however, to those stressors in the form of higher levels of depressive symptoms (e.g., Hankin, Mermelstein, & Roesch, 2007). Given that exposure to stressors is both ubiquitous and inevitable, it will be important for future research to examine both how ELA interacts with ongoing stressors during adolescence to affect the developmental sequela of sleep and depressive symptoms, and whether there are differential effects as a function of the features of adversity, posttraumatic stress symptoms, sex, and other individual differences.

The current longitudinal study demonstrated that greater cumulative adversity exposure is associated with more sleep disturbances earlier in development that, in females, remain persistently elevated across adolescence. Higher initial levels (i.e., during early adolescence) and greater increases in sleep disturbances across adolescence were associated with greater increases in depressive symptoms across adolescence for both males and females. These findings highlight the potential importance of sleep interventions to ameliorate sleep disturbances and depressive symptoms in adolescence; furthermore, for children exposed to ELA, interventions should be targeted during the transition to adolescence.

Supporting information
Additional supporting information may be found online in the Supporting Information section at the end of the article:

Figure S1. Results from the moderated mediation analysis testing conditional indirect effects of subjective cumulative severity ratings of early life adversity and changes in depressive symptoms through initial levels of and changes in sleep problems (in parallel).

Table S1. Comparison of demographic and study variables between participants who provided only one timepoint of data (N = 35) compared to participants who provided more than one timepoint of data (N = 189).

Table S2. Response frequencies and reliabilities for sleep-related items on Youth Self Report (YSR) at T1, T2, and T3. 0 = Not True, 1 = Somewhat or Sometimes, 2 = Very True or Often True.

Table S3. Response frequencies and reliabilities for Child Depression Inventory (CDI) depressive symptoms scale.

Acknowledgements
This work was supported by the National Institute of Mental Health (F32MH135657 to JPU and R37MH101495 to IHG). The authors have declared that they have no competing or potential conflicts of interest.

Data availability statement
Data will be available on request.

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Key points
- Exposure to early adversity (ELA) is associated with longitudinal increases in depressive symptoms across adolescence.
- Greater sleep disturbances during early adolescence mediate ELA-related increases in depressive symptoms for females, but not for males.
- For both males and females, higher initial levels (i.e., during early adolescence) and greater increases in sleep disturbances (across 4 years) were associated with greater increases in depressive symptoms.
- These findings highlight the potential importance of sleep interventions to ameliorate sleep disturbances and depressive symptoms in adolescence, especially for females and youth who have experienced ELA.
References


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Accepted for publication: 9 November 2023

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