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Original Article

The bidirectional association between sleep problems and anxiety symptoms in adolescents: a TRAILS report

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ABSTRACT

Background: Previous studies have suggested a bidirectional association between sleep problems and anxiety symptoms in adolescents. These studies used methods that do not separate between-person effects from within-person effects, and therefore their conclusions may not pertain to within-person mutual influences of sleep and anxiety. We examined bidirectional associations between sleep problems and anxiety during adolescence and young adulthood while differentiating between person effects from within-person effects.

Methods: Data came from the Dutch TRacking Adolescents' Individual Lives Survey (TRAILS), a prospective cohort study including six waves of data spanning 15 years. Young adolescents (N = 2230, mean age at baseline 11.1 years) were followed every 2–3 years until young adulthood (mean age 25.6 years). Sleep problems and anxiety symptoms were measured by the Youth Self-Report, Adult Self-Report and Nottingham Health Profile. Temporal associations between sleep and anxiety were investigated using the random intercept cross-lagged panel model.

Results: Across individuals, sleep problems were significantly associated with ($\beta = 0.60$, $p < 0.001$). At the within-person level, there were significant cross–sectional associations between sleep problems and anxiety symptoms at all waves ($\beta = 0.12–0.34$, $p < 0.001$). In addition, poor sleep predicted greater anxiety symptoms between the first and second, and between the third and fourth assessment wave. The reverse association was not statistically significant.

Conclusions: Within-person associations between sleep problems and anxiety are considerably weaker than between-person associations. Yet, our findings tentatively suggest that poor sleep, especially during early and mid-adolescence, may precede anxiety symptoms, and that anxiety might be prevented by alleviating sleep problems in young adolescents.

1. Introduction

According to the cognitive model of insomnia [1], excessive and uncontrollable worry, anxiety, fear, and intrusive thoughts diminish sleep quality and exacerbate insomnia. Consistent with this theory, research has shown that individuals with high trait worry experience moderate sleep disturbances, and that worry predicts sleep problems [2]. On the other hand, it is also possible that sleep disturbance leads to anxiety symptoms. Several studies proposed potential mechanisms of how sleep disturbance may predict the development of anxiety. For example, in a study by Yoo et al. [3], one night of sleep deprivation led to an increased amygdala response to a negative stimulus and decreased functional connectivity between the amygdala and the medial prefrontal cortex. Decreased brain activation and decreased functional connectivity between brain regions may contribute to a diminished ability to regulate anxiety-related processes [4]. In sum, research suggests that there are bidirectional associations between sleep problems and anxiety symptoms.

Symptoms of sleep problems and anxiety are known to change throughout the lifespan. These symptoms often increase during adolescence [5,6], and the quantity and quality of both symptom domains change further in adults [7]. Adolescence may thus be a

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sensitive period for developing anxiety symptoms and sleep problems [8]. The transition from child to adult is characterized by significant biological, psychological, and social changes, which may result in alterations in emotion regulation and delayed circadian phase (internal clock) [9,10]. Notably, a study from New Zealand showed that approximately one-third of young adolescents (33.4%) reported experiencing at least one sleep problem, and the adolescents who reported sleep problems were more likely to report anxiety symptoms [11]. Another study found that as many as 90% of young people with anxiety experience subjective sleep complaints [12].

Several longitudinal studies have provided evidence that sleep problems predict anxiety symptoms and anxiety disorder across childhood, adolescence, and young adulthood. For instance, Jansen et al. [13], reported that sleep problems in infancy and early toddlerhood were associated with anxiety or depression symptoms at three years. Gregory and O'Connor [14] reported that sleep problems at age four predicted anxiety/depression symptoms in mid-adolescence. Gregory et al. [15], reported that persistent poor sleep at age five, seven, and nine predicted the presence of an anxiety disorder at age 21 and 26. Furthermore, Shanahan et al. [16], found that, in children and adolescents aged 9–16 years, poor sleep predicted increases in the prevalence of generalized anxiety disorder (GAD) and symptoms of depression/GAD one year later. Although many longitudinal studies have found that sleep problems predict subsequent anxiety, less research has focused on associations in the opposite direction [17]. The studies that did test bidirectional associations between sleep problems and anxiety symptoms in children and adolescents yielded mixed results regarding the effect of anxiety on sleep: some found clear evidence of an effect of anxiety on subsequent sleep problems [16,18,19], others did not [13,20] or found only weak indications [21]. None of these studies extended into young adulthood. Hence, the possible bidirectional nature of the association between sleep and anxiety requires further investigation.

In addition to being the first to investigate bidirectional associations between sleep problems and anxiety across adolescence and young adulthood, our study also adds to the existing evidence because our statistical approach made it possible to distinguish between interindividual (between-person) and intra-individual (within-person) differences. Many psychological theories pertain to within-person effects because within–person processes offer the best clues for – personalized – interventions. In practice, however, associations are often tested at the between-person rather than the within-person level. Statements at the between-person level cannot be extrapolated to the within-person level [22]. For example, the fact that adolescents who report many sleep problems are also likely to report many anxiety symptoms does not necessarily imply that individual adolescents will experience less anxiety when they improve their sleep [22]. Only statistical models that separate within-person effects from between-subjects allow one to make valid statements regarding within–person processes; the often-used cross-lagged panel model (CLPM) does not, most of the time. The CLPM assumes that there are no stable intra-individual differences in the variables under study. This is often untrue; in the case of anxiety and sleep, to a certain extent both variables are trait-like and show some stability in between-person rank order. That means that the assumption of the CLPM is not met and that the autoregressive effects in the CLPM, which are supposed to estimate within-person temporal stability of sleep and anxiety, also capture between-person variation in these variables. This hampers straightforward interpretation of the cross-lagged effects of sleep and anxiety, because these effects cannot be understood as the within-person effect of sleep at one assessment, on anxiety at the next assessment wave, and vice versa. Hamaker et al. [23], showed that, depending on the type of model, cross-lagged effects might be overestimated, underestimated, or even reversed if the assumption of the CLPM is not met. In other words, a mixture of within-and between-person variance can lead to incorrect conclusions concerning the within-person mutual influences of sleep and anxiety. The random intercept cross-lagged panel model (RI-CLPM) accounts for time-invariant individual differences by the inclusion of random intercepts and hence yields less biased estimates of the within-person effects than more traditional approaches [23]. Both within-person and between-person effects may be relevant for intervention and prevention; whereas within-person associations indicate possible starting points for treatment, between-person associations can help to identify target populations.

The Tracking Adolescents' Individual Lives Survey (TRAILS) is a prospective cohort study in which the participants were followed from early adolescence (11 years of age) to young adulthood (25 years of age). Six waves have been conducted so far, and every wave included measurements of sleep and anxiety [24] adapted to the age of the participants at the time of assessment. This longitudinal study aimed to examine bidirectional associations between sleep problems and anxiety symptoms from adolescence through young adulthood, taking into account within-person and between-person effects.

2. Methods

2.1. Participants

We used data from the longitudinal TRAILS study. TRAILS contributes to the understanding of various determinants of mental and physical health by following Dutch pre-adolescents (11 years old) into adulthood (25 years old). The target sample consisted of adolescents from 135 schools in five municipalities in the North of the Netherlands, including both urban and rural areas. The sampling procedure has been described in more detail elsewhere [25]. Of all participants who were approached (n = 3145), 210 (6.7%) were excluded because of severe mental retardation, severe physical illness, or language limitations. Of the remaining 2935 young adolescents, 76% participated in the study. Initial responders and non-responders did not differ with respect to family composition (ie, the proportion of single-parent families) or teacher-rated mental health problems (including anxious/depressed behaviors). However, the nonresponse group included more boys (61% vs. 47%), children whose parents had a low educational level (44% vs. 33%), and children who received help for learning difficulties (28% vs. 21%) at school. For more details, see De Winter et al., [25]. Of the baseline sample, 11% originated from a non-western country (mostly Morocco, Turkey, Surinam, the Dutch Antilles, and Indonesia), 16% were raised in single-parent families, and 17% lived in families with a disposable annual income up to € 13.620, which is below the at-risk-of-poverty-threshold. Baseline assessment was followed up by five additional waves, with intervals of two to three years, with good retention rates (see Table 1). Compared to

Table 1
Participants in the population of TRAILS across the data collection six waves.

Wave	N (retention rate[a])	Mean age, years (SD)	Females %
1	2230	11.1 (0.6)	51%
2	2149 (96%)	13.6 (0.5)	51%
3	1819 (81%)	16.3 (0.7)	52%
4	1881 (84%)	19.1 (0.6)	52%
5	1782 (80%)	22.3 (0.6)	53%
6	1617 (73%)	25.6 (0.6)	54%

[a] Retention rate refers to the proportion of the baseline sample participating in each subsequent wave.

adolescents who participated up until the sixth assessment waves, those who dropped out before that were more likely to be male (56% versus 47% $\chi 21 = 27.9$, $p < 0.001$), to come from low-SES families (38% versus 22% $\chi 21 = 41.7$, $p < 0.001$); they reported slightly fewer anxiety (0.31 ± 0.29 versus 0.35 ± 0.31, t (df = 2191) = 2.42, p = 0.02) and sleep problems (0.45 ± 0.47 versus 0.50 ± 0.46, t (df = 2194) = 2.02, p = 0.04) at baseline. Of all participants, 28.0% had a lifetime diagnosis of any anxiety disorder, as measured by the Composite International Diagnostic Interview [26], at the fourth assessment wave; 12.4% had a social phobia, 11.5% a specific phobia, 2.9% a generalized anxiety disorder, 3.1% a separation anxiety disorder, 1.6% a panic disorder, and 1.0% an agoraphobia. Overall, the mean age of onset was 8.8 years (SD 4.2). Specific phobias had a mean age of onset of 6.8 years (SD 3.5), separation anxiety disorders of 9.1 years (SD 4.5), social phobia of 10.1 years (SD 3.6), agoraphobia of 11.6 years (SD 4.3), and generalized anxiety disorder and panic disorder of 13.7 years (SD 3.4 and 4.2, respectively). Missing values were handled in two instances. First, in case of missing item scores for anxiety and sleep problems, we used the corrected item mean (CIM) substitution method that replaces missing values by the item mean, which is corrected for the 'ability' of the respondent [27]. Second, in the RI-CLPM, missing data were handled by using the maximum likelihood robust (MLR) estimator. This estimator can handle missing data when participants have valid data at one or more measurement waves. Three participants were excluded because they had missing information on sleep and anxiety at all six waves. Informed consent was obtained from parents and adolescents. Each study wave was approved by the Dutch Central Committee on Research Involving Human Subjects (CCMO) and conducted according to the principles of the Declaration of Helsinki.

2.2. Measures

2.2.1. Anxiety symptoms

At T1, T2, and T3, anxiety symptoms were measured by the Youth Self-Report (YSR), which was developed for 11- to 18-year-old respondents; it containes six items that cover anxiety symptoms according to the DSM-IV [28]. The anxiety items were "I am too dependent on adults", "I am nervous or tense", "I am afraid of certain animals, situation or places other than school", "I am afraid of going to school", "I am too fearful and anxious", and "I worry a lot". Participants reported on their feelings during the past six months. Items were scored on a three-point Likert scale (0 = not true, 1 = somewhat/sometimes true, and 2 = very/often true). The scale scores represent the mean scores of these six items. Cronbach's alphas of these scales ranged from 0.62 to 0.64. Spearman-Brown corrected alphas were 0.74–0.75. At T4, T5, and T6, anxiety was assessed with the Adult Self-Report [29], which is the adult version of the YSR. The ASR Anxiety scale contains seven items for measuring anxiety symptoms in the past six months: "I am afraid of certain animals, situation or places other than school", "I worry a lot", "I am too fearful and anxious, "I am nervous or tense", "I worry about my future", "I worry about my family", and "Heart pounding or racing without known medical cause". As with the YSR, the items were scored on a three-point Likert scale (0 = not true, 1 = somewhat/sometimes true and 2 = very/often true), and the scale scores represent the mean item scores. Cronbach's alphas ranged from 0.75 to 0.80. The concurrent validity of YSR anxiety symptoms has been determined [30]. Based on normative samples, sum scores of YSR and ASR were categorized as falling in the normal (<92nd percentile), borderline (subclinical, 93-97th percentile), and clinical (>97th percentile) range [28].

2.2.2. Sleep problems

At T1, T2, and T3, sleep problems were measured with the YSR. The YSR sleep problems scale contains four items for measuring sleep problems in the past six months. The items were "I have nightmares," "I sleep less than most kids," "I sleep more than most kids," and "I have trouble sleeping." We excluded "I sleep more than most kids" because we hypothesized that associations between sleep and anxiety are specific for sleeping less than other people, and do not pertain to sleeping more than other people. The items were scored on a three-point Likert scale (0 = not true, 1 = somewhat/sometimes true, and 2 = very/often true) and transformed (0 = not true, 0.5 = somewhat/sometimes true, and 1 = very/often true) to achieve consistency with the scoring of the NHP (see below). The mean score on these three items was used as scale scores. Cronbach's alphas ranged from 0.55 to 0.57. Spearman-Brown corrected alphas were 0.80–0.81.

At T4, T5, and T6, sleep problems were measured with the sleep scale of the Nottingham Health Profile (NHP), a validated questionnaire to identify health problems in adults [31]. The NHP sleep problems scale contains five items that reflect the overall experience of momentary sleep problems. The sleep problems items were "I wake up in the early hours of the morning," "I lie awake for most of the night," "It takes me a long time to get to sleep," "I sleep badly at night" and "I take pills to help me sleep." Items were scored with "yes = 1" or "no = 0". Because sleeping pills may affect the reporting of sleep problems, we excluded 137 adolescents who reported using sleeping pills at one or more of the three waves from the analyses. We computed the mean score on these four items to construct the scale scores. Cronbach's alphas ranged from 0.63 to 0.64. Spearman-Brown corrected alphas were 0.77–0.78.

2.3. Statistical analysis

SPSS 25.0 was used to calculate descriptive statistics. RI-CLPM models were used to test whether sleep problems predicted changes in anxiety symptoms over time and, conversely, whether anxiety symptoms predicted sleep problems. RI-CLPM is an extension of the CLPM that accounts for time-invariant, trait-like stability by the inclusion of random intercepts [23]. Specifically, the variance of the observed score was split into variances due to a between-person stable invariant trait and variance due to within-person fluctuation. First, we calculated intra-class correlations (ICC) for sleep problems and anxiety symptoms. ICC can be defined as the proportion of the variance explained by differences between subjects. Second, we applied a random intercept cross-lagged panel model (RI-CLPM), in which observed sleep and anxiety mean scores were regressed on their own latent factor (each loading constrained at 1). The resulting twelve latent factors were used to identify autoregressive, cross-lagged paths, and cross–sectional associations (T1 correlation and correlated change). The residual variances of the observed variables were constrained at zero, which allowed the latent factor structure to capture the within- and between-person variance. Next, we added two random intercepts (one for sleep problems, the other for anxiety symptoms) with factor loadings constrained at one. These random intercepts represent the stable trait-like differences between individuals with respect to sleep problems and anxiety symptoms. The correlation between the random intercepts reflected how stable between-person differences in sleep problems were linked with stable between-person differences in anxiety symptoms (see Fig. 1). Autoregressive paths were interpreted as to what extent prior differences from their expected scores predicted within-person deviations in sleep problems and anxiety symptoms. The cross-lagged paths reflected to what extent sleep problems and anxiety problems are linked bidirectionally and indicated whether deviations from

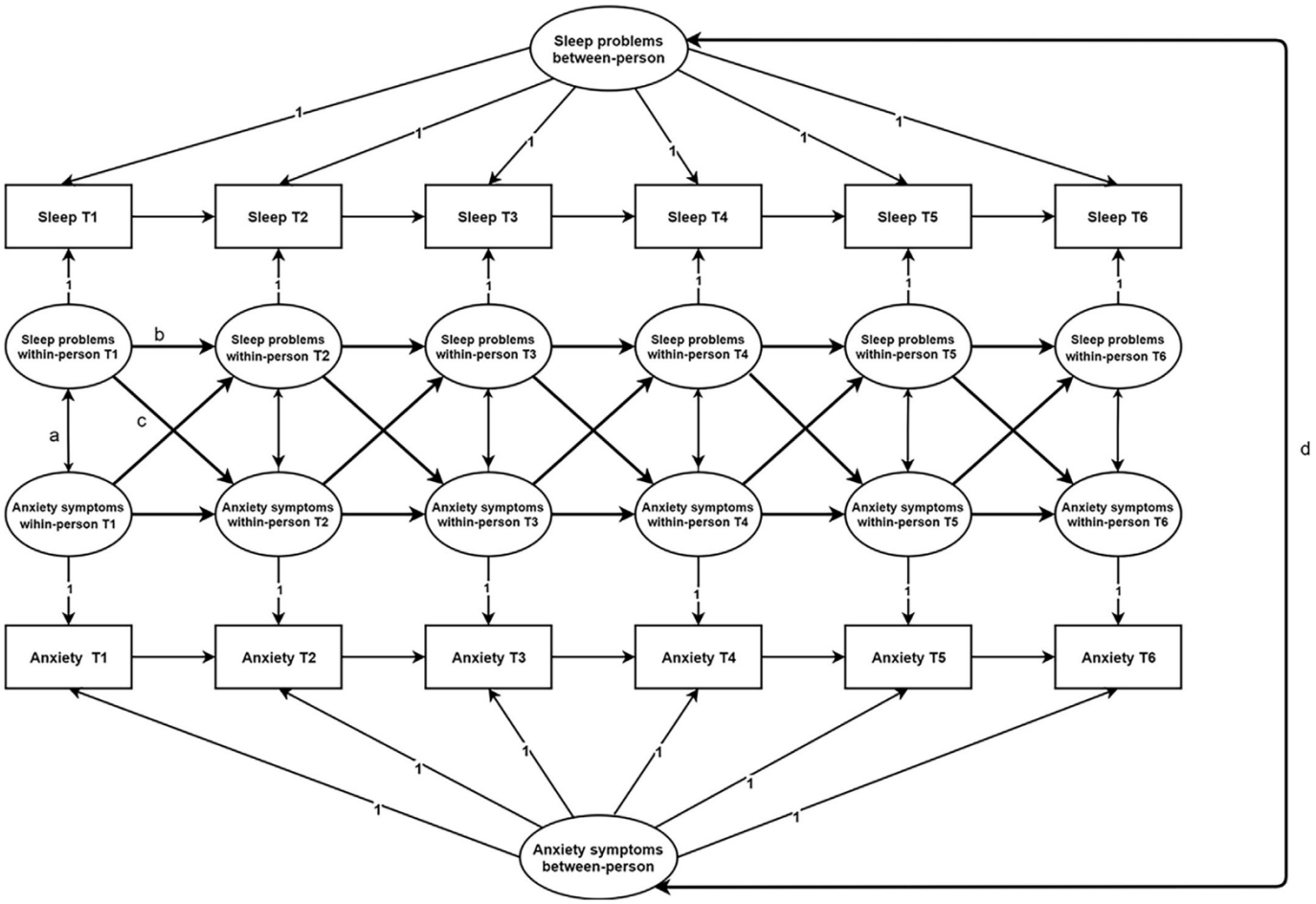

Fig. 1. Six-waves Random Intercept Cross-Lagged Panel Model: (a)- cross-sectional paths, (b)- autoregressive paths, (c) cross-lagged paths), (d) correlation between stable traits of sleep problems and anxiety symptoms at the between-person level. Square denote observed variables; circles represent "latent" variables.

expected scores in sleep problems predicted deviations from expected scores in anxiety symptoms (and vice versa) at the next assessment wave. Cross-sectional paths were interpreted as correlations at T1 and as correlated changes at T2-T6. The correlation at T1 reflected the extent to which a person's deviation of his/her expected score for sleep problems was associated with the deviation of his/her expected score for anxiety symptoms. Correlated changes at T2-T6 reflected whether the within-person changes in sleep problems were linked to the within-person changes in anxiety problems.

In sensitivity analyses, we excluded two anxiety symptoms that were only measured in the YSR or in the ASR, namely, "I am too dependent on adults" from the YSR and "Heart poundings with a known medical cause" from the ASR. Also, we excluded the YSR item on nightmares because the NHP did not include questions on nightmares.

RI-CLPM was tested with Mplus 5.1 using MLR. This method estimates a mean-adjusted χ^2 that is robust to nonnormal distributions [32]. Model fit was evaluated using chi-square (χ^2), the Comparative Fit Index (CFI), and the Root Mean Squared Error of Approximation (RMSEA). A CFI larger than 0.95 and RMSEAs smaller than 0.05 indicate a good model fit [33]. Two-tailed p values smaller than 0.05 were considered statistically significant. All presented results reflect standardized coefficients.

3. Results

3.1. Descriptive statistics

Descriptive results are shown in Table 2. The mean scores of anxiety symptoms were relatively stable during early and middle adolescence and then increased during late adolescence and young adulthood; the percentages of adolescents with anxiety symptoms in the borderline range and clinical range followed the same pattern. More sleep problems were reported at 11 years of age than at 13 and 16 years of age. The mean score of sleep problems sharply decreased from 16 to 19 years of age. This decrease may be due to a different instrument introduced for sleep problems at T4. From 19 to 22 years, the reported sleep problems were stable, and they slightly increased in the years afterward. Correlations between anxiety scores over measurements and sleep scores over measurements are reported in tables A1 and A2.

3.2. Relationship between anxiety symptoms and sleep problems

For anxiety symptoms, the intra-class correlation (ICC) was 0.79. This indicates that differences between adolescents explained 79% of the variance in anxiety symptoms in the six measurement waves, and fluctuations explained the remaining 21% within persons. For sleep problems, the ICC was 0.67, indicating that 67% of the variance

Table 2
Descriptive statistics of anxiety symptoms and sleep problems.

Variable	T1	T2	T3	T4	T5	T6
N valid	2056	1954	1534	1560	1367	1189
Gender (female)	49.8%	50.0%	51.8%	53.4%	55.2%	58.0%
Mean age, SD	11.1 ± 0.55	13.6 ± 0.52	16.2 ± 0.68	19.1 ± 0.58	22.3 ± 0.64	25.6 ± 0.60
Anxiety						
Mean score, SD	0.34 ± 0.30	0.35 ± 0.31	0.32 ± 0.30	0.37 ± 0.35	0.39 ± 0.35	0.47 ± 0.40
Normal n %	1991 (96.8%)	1893 (96.9%)	1490 (97.1%)	1537 (98.5%)	1340 (97.9%)	1147 (96.5%)
Sub-clinical range n %	41 (1.6%)	36 (1.8%)	25 (1.6%)	10 (0.6%)	18 (1.3%)	20 (1.7%)
Clinical range n %	24 (1.2%)	25 (1.3%)	19 (1.2%)	13 (0.8%)	11 (0.8%)	22 (1.9%)
Sleep problems						
Mean score, SD	0.24 ± 0.23	0.18 ± 0.21	0.18 ± 0.21	0.11 ± 0.19	0.11 ± 0.18	0.13 ± 0.20

SD - standard deviation.

in sleep problems was explained by differences between adolescents and 33% by fluctuations within persons.

The associations between adolescent anxiety symptoms and sleep problems, divided into within- and between-person effects, are shown in Fig. 2. The overall model fit of the RI-CLPM was good, χ^2 (15) = 156.18, p < 0.001, CFI = 0.97, RMSEA = 0.04. At the between-person level, there was a strong positive association between stable traits of sleep problems and anxiety symptoms (β = 0.60). This indicates that adolescents who had higher scores on sleep problems across the six measurement waves reported higher anxiety symptoms across the 15 years as well. Furthermore, there were significant positive cross–sectional associations (β = 0.12–0.34, p < 0.001) between sleep problems and anxiety symptoms on a within-person level. This means that within-person changes in sleep problems were associated with within-person changes in anxiety symptoms. The autoregressive paths of sleep problems and anxiety symptoms were significant, indicating that within-person deviations from expected scores (ie, the mean) predicted deviations from expected scores in the next wave. Within-person cross-lagged paths from sleep problems to anxiety symptoms were significant at T1-T2 (β = 0.14, 95% CI [0.07, 0.20], p < 0.001) and T3-T4 (β = 0.15, 95% CI [0.08, 0.23], p < 0.001); at those time points, sleep problems predicted anxiety symptoms at the next measurement wave. There were no significant cross-lagged effects from anxiety symptoms to sleep problems.

The overall model fit of the RI-CLPM was still good χ^2 (15) = 150.70, p < 0.001, CFI = 0.97, RMSEA = 0.04, after exclusion of the items: "I am too dependent on adults" and "I have nightmares" from the first three waves, and the item: "Heart pounding or racing without known medical cause" from the last three waves. The results were comparable with those of the previous model (Figure A1).

4. Discussion

We investigated bidirectional associations between sleep problems and anxiety symptoms using data from six waves while distinguishing between within-person and between-person sources of associations. We found that sleep problems and anxiety symptoms strongly correlated across preadolescence and adulthood at a between-person level; in other words, adolescents who reported many sleep problems were likely to report many anxiety symptoms as well. After controlling for these between-person trait effects, consistent cross–sectional associations were found at each measurement wave at a within-person level. Also, sleep problems were associated with later anxiety symptoms at a within-person level at two measurement points. No significant effects were found in the opposite direction.

We found that sleep problems weakly predicted the development of anxiety symptoms in two of the measurement waves. Differences in the measures used to assess sleep and anxiety make it difficult to compare the results of our study to previous reports directly. Despite such methodological differences, our finding that self-reported sleep problems at age 11 years predicted anxiety symptoms at age 13 is consistent with those reported by Kelly and El-Sheikh [21], who found that actigraphy-measured sleep

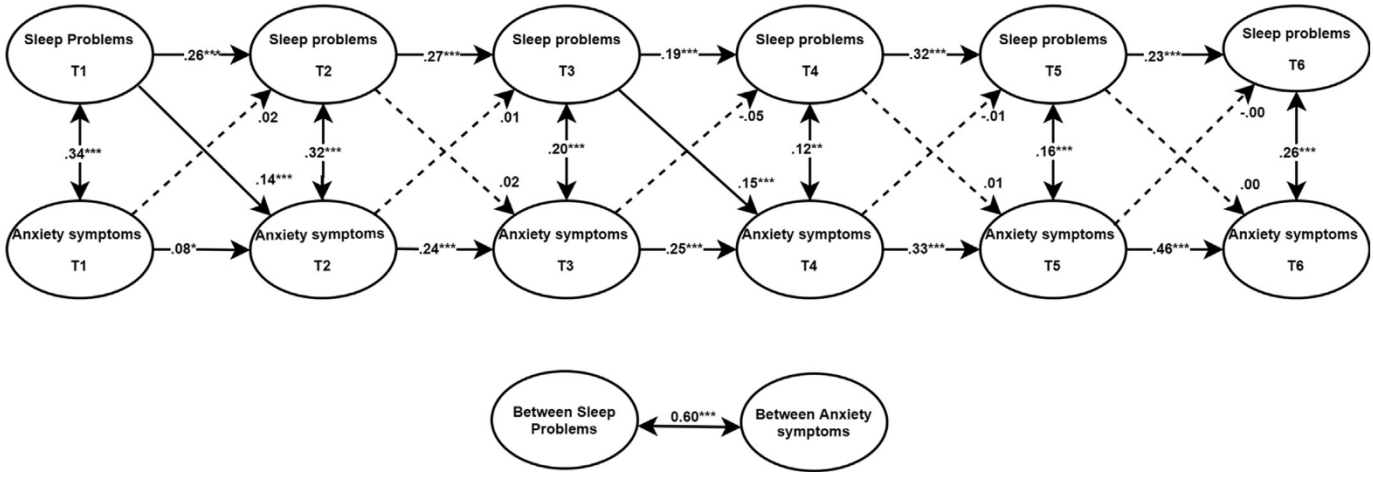

Fig. 2. Six-waves Random Intercept Cross-Lagged Panel Model with Standardized effect (β). Bidirectional association sleep problems and anxiety symptoms. Statistically significance lines are solid, whereas non-significant lines are dotted. *p < 0.05. **p < 0.01. ***p < 0.001.

problems at age 10 predicted greater anxiety at age 13. Furthermore, sleep problems at age 16 predicted anxiety symptoms at 19. This seems to indicate that inadequate sleep might contribute to the development of later anxiety, particularly during early and middle adolescence.

A possible mechanism through which adolescent sleep problems may influence anxiety is a change in circadian rhythms in adolescence; the rhythm shifts towards later bedtime and later [34], found that sleep and wake problems were associated with high levels of emotional problems, including anxiety. The timing of REM sleep is also connected to circadian rhythms, and the amount of REM sleep decreases somewhat during adolescence [35]. REM sleep plays an essential role in memory consolidation and emotion regulation [35]. Furthermore, sleep problems have been found to predict high cortisol reactivity to stress among adolescents [36], which might lead to the development of anxiety symptoms [37].

Despite the plausibility of a pathway from sleep problems to anxiety during adolescence, we prefer not to overinterpret our findings, because only two of the five cross-lagged paths from sleep to anxiety were significant. Even though the p-values were <0.001, this calls for caution. That no significant effects were found during late adolescence and young adulthood could be related to selective attrition: the nature of the sample may have changed in a way that affected the associations during the follow-up period. Although we cannot exclude this possibility, it is not very likely, because the participants that remained in the sample throughout the follow-up period reported more anxiety and sleep problems than the ones who dropped out of the study. The mostly weak cross-lagged effects could also be due to the relatively long time lags between the assessment waves: two to three years. It is very well possible that sleep problems affect anxiety more strongly on a shorter time scale, but that these effects have largely disappeared after two years. That said, although the associations we found were relatively weak and often non-significant, effects might accumulate over time within some of the individuals, potentially leading to clinically relevant effects [16].

Sleep problems may not only lead to the development of anxiety symptoms but also precede other psychiatric problems, including depression, substance abuse disorder, attention-deficit/hyperactivity disorder (ADHD), and suicide in later life [38–40]. A systematic review and a meta-analysis found that cognitive-behavioral sleep interventions among adolescents yielded statistically significant improvements in objective and self-reported sleep measurements, as well as improvements in anxiety and depression [41]. Therefore, interventions focused on sleep in young adolescents could theoretically prevent the onset of a wide range of psychiatric conditions.

Contrary to our expectations, anxiety symptoms did not predict the onset of sleep problems. Kelly and El-Sheikh [21] found that anxiety symptoms at 10 years predicted poor sleep quality (actigraphy) at 13 years. Furthermore, Tochigi et al. [19], found that high anxiety and depression levels delayed later years' bedtime among adolescents aged 12–18 years. This difference between our study and previous studies may be the result of different methods applied by the studies. First, previous research findings combined between-person and within-person effects, however we considered pure within-person effects. Second, Tochigi's study sample was selected from a high school in Tokyo, and their findings might not be generalizable to other adolescent populations from other cultures. Third, the study by Tochigi et al. [19], assessed anxiety utilizing the General Health Questionnaire (GHQ), which includes anxiety items but also includes items on depression and general distress [42]. Alfano et al. [43], found that anxiety was a significant predictor of sleep problems in adolescents under 12 years old. However, among adolescents aged 13–17 years, depression symptoms were a more important predictor of sleep problems. This means that the association between depression and sleep problems may be stronger among older adolescents than the association between anxiety and sleep problems. Kelly and El-Sheikh [21] assessed anxiety symptoms by the Revised Manifest Anxiety Scale (RMAS), which includes many fear items. Our anxiety scales included only a few items on fears. Fear might increase the strength of the association between anxiety and sleep problems, especially in children, because of the generally early age of onset of fear, for example, a specific phobia [44]. Therefore, fears may be more likely to predict sleep problems in children or young adolescents, while distress and worry may be more likely to predict sleep problems in older adolescents.

Sleep problems and anxiety symptoms had significant cross–sectional associations (for T2 to T6 implying correlated changes) in each measurement wave. Thus, within-subjects, when anxiety had increased compared to the previous assessment wave, sleep problems were likely to have increased as well. These results are in line with reports of Quach et al. [45], who found a positive correlation between sleep problems and internalizing symptoms (controlling for externalizing symptoms) at five time points, and of Mulraney et al. [46], who found correlations between sleep problems and internalizing symptoms among children with ADHD. Furthermore, cross-sectional studies found that both state and trait anxiety affected non-rapid eye movement sleep parameters [47] and that anxiety was modestly related to reduced sleep duration [38]. McGowan and colleagues [2] found that day worry predicted increased sleep problems the following night. These results indicate that associations between anxiety symptoms and poor sleep quality may be stronger over short periods than over longer periods.

This study had several strengths. This large longitudinal study included six measurements that allowed us to examine bidirectional associations in sleep problems and anxiety symptoms covering the entire timespan from pre-adolescence (11 years) to young adulthood (25 years), revealing differences in earlier versus later time points. Another important strength was the use of the RI-CLPM model, which splits variance into a within-person level and between-person level, allowing us to study changes over time on a within-person level.

Additionally, there were several limitations. First, the instruments to assess sleep and anxiety did not include the same items in all assessment waves. While on the one hand, a strength of the study was that symptoms were adapted to the participants' developmental stages so that all questions were relevant and age-appropriate, these adaptations also caused some continuity problems. For instance, the YSR that was used to assess sleep at the first three measurements had different response categories than the NHP that was used at the last three assessment waves, and the latter did not include an item about nightmares. Although we modified the scores to make the two questionnaires more consistent, this may still have affected our results. Notably, the autoregressive path of sleep problems was weaker between the third and the fourth wave than at the other time points, and variance might have been artificially attributed to the cross-lagged path as a result. Second, we used self-report questionnaires to study sleep; these tend to be less reliable than objective measures such as actigraphy and polysomnography. Self-reported assessments are subjective, and there is a chance that some adolescents overestimated or underestimated their problems. That said, perceived sleep problems might be as least as relevant as the actual amount of sleep. Third, the internal consistencies of some of the scales used were relatively low. This is not surprising considering the limited number of items and the fact that each of these items covered a different aspect of the different concepts of sleep and anxiety. However, low internal consistencies may have obscured association patterns [48]. Moreover, the validity of the YSR/anxiety scales used in this study is

questionable; Van Lang and colleagues [30], found that the YSR anxiety scale was less strongly associated with DSM-IV anxiety symptoms than anxiety scales of the Revised Child Anxiety and Depression Scale (RCADS). This suggests that our anxiety scale may not be fully comparable to anxiety measures used in other studies. Moreover, how the sleep scales used in this study relate to more standardized measures has not yet been evaluated. The sample included in this study was not fully representative of the population at large. However, non-random drop-out did not result in an overly healthy group with respect to anxiety and sleep. Despite this, the problem levels were still rather low in our community-based sample, and the relative scarcity of severe symptoms precludes generalization to a clinical population.

In sum, our findings show that sleep problems and anxiety problems have a strong association with each other at a between-person level. Within persons, changes in sleep problems and anxiety symptoms were cross-sectionally associated with each other throughout pre-adolescence and young adulthood. Our study further suggests that young adolescents who do not sleep adequately might be at increased risk of developing subsequent anxiety symptoms. No associations were found in either the other direction or in late adolescence and young adulthood. Previous studies, which did not distinguish between within-person and between-person effects, consistently found that sleep problems predicted anxiety symptoms. In contrast, some research that studied bidirectional effects found evidence for the opposite effect as well. Our findings indicate that part of these prior effects may reflect between-person differences rather than processes that occur within individuals.

Author note

This paper used data from the Tracking Adolescents' Individual Lives Survey (TRAILS). Participating centers of TRAILS include the University Medical Center and the University of Groningen, the University of Utrecht, the Radboud Medical Center Nijmegen, and the Parnassia Bavo group, all in the Netherlands. TRAILS has been financially supported by grants from Netherlands Organization for Scientific Research NWO (Medical Research Council program; ZonMW Brainpower program; ZonMw Risk Behaviour and Dependence program; ZonMw Culture and Health program; Social Sciences Council medium-sized investment program; Social Sciences Council projects; Large-size investments program; Longitudinal Survey and Panel funding; Vici program; Gravitation program); Dutch Ministry of Justice (WODC), the European Science Foundation (EuroSTRESS program); European Research Council; European Research Council; Biobanking and Biomolecular Resources Research Infrastructure BBMRI-NL; Gratama Foundation; Jan Dekker Foundation, the participating universities, and Accare Centre for Child and Adolescent Psychiatry. More information about the TRAILS can be found at www.trails.nl.

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Conflict of interest

The authors declare no conflict of interests.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2019.10.018.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2019.10.018.

References

[1] Harvey AG. A cognitive model of insomnia. Behav Res Ther 2002;40:869–93. https://doi.org/10.1016/S0005-7967(01)00061-4.
[2] McGowan SK, Behar E, Luhmann M. Examining the relationship between worry and sleep: a daily process approach. Behav Ther 2016;47:460–73. https://doi.org/10.1016/j.beth.2015.12.003.
[3] Yoo S, Gujar N, Hu P, et al. The human emotional brain without sleep – a prefrontal-amygdala disconnect. Curr Biol 2007;17:1–8. https://doi.org/10.1016/j.cub.2007.08.007.
[4] Cox RC, Olatunji BO. A systematic review of sleep disturbance in anxiety and related disorders. J Anxiety Disord 2016;37:104–29. https://doi.org/10.1016/j.janxdis.2015.12.001.
[5] Van Oort FVA, Greaves-Lord K, Verhulst FC, et al. The developmental course of anxiety symptoms during adolescence: the TRAILS study. J Child Psychol Psychiatry Allied Discip 2009;50:1209–17. https://doi.org/10.1111/j.1469-7610.2009.02092.x.
[6] Maslowsky J, Ozer EJ. Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. J Adolesc Health 2014;54:691–7. https://doi.org/10.1016/j.jadohealth.2013.10.201.
[7] Gadie A, Shafto M, Leng Y. Cam-CAN, Kievit RA, Cam-CAN. How are age-related differences in sleep quality associated with health outcomes? An epidemiological investigation in a UK cohort of 2406 adults. BMJ Open 2017;7:e014920. https://doi.org/10.1136/bmjopen-2016-014920.
[8] McMakin DL, Alfano CA. Sleep and anxiety in late childhood and early adolescence. Curr Opin Psychiatr 2015;28:483–9. https://doi.org/10.1016/j.bbamem.2015.02.010.Cationic.
[9] Crowley SJ, Cain SW, Burns AC, et al. Increased sensitivity of the circadian system to light in early/mid-puberty. J Clin Endocrinol Metab 2015;100:4067–73. https://doi.org/10.1210/jc.2015-2775.
[10] Dahl RE, Lewin DS. Pathways to adolescent health: sleep regulation and behavior. J Adolesc Health 2002;31:175–84. https://doi.org/10.1016/S1054-139X(02)00506-2.
[11] Morrison DN, McGee R, Stanton WR. Sleep problems in adolescence. J Am Acad Child Adolesc Psychiatry 1992;31:94–9. https://doi.org/10.1097/00004583-199201000-00014.
[12] Alfano CA, Ginsburg GS, Kingery JN. Sleep-related problems among children and adolescents with anxiety disorders. J Am Acad Child Adolesc Psychiatry 2007;46:224–32. https://doi.org/10.1097/01.chi.0000242233.06011.8e.
[13] Jansen PW, Saridjan NS, Hofman A, et al. Does disturbed sleeping precede symptoms of anxiety or depression in toddlers? The generation R study. Psychosom Med 2011;73:242–9. https://doi.org/10.1097/PSY.0b013e31820a4abb.
[14] Gregory AM, O'Connor TG. Sleep problems in childhood: a longitudinal study of developmental change and association with behavioral problems. J Am Acad Child Adolesc Psychiatry 2002;41:964–71. https://doi.org/10.1097/00004583-200208000-00015.
[15] Gregory AM, Caspi A, Eley TC, et al. Prospective longitudinal associations between persistent sleep problems in childhood and anxiety and depression disorders in adulthood. J Abnorm Child Psychol 2005;33:157–63. https://doi.org/10.1007/s10802-005-1824-0.
[16] Shanahan L, Copeland WE, Angold A, et al. Sleep problems predict and are predicted by generalized anxiety/depression and oppositional defiant disorder. J Am Acad Child Adolesc Psychiatry 2014;53:550–8. https://doi.org/10.1016/j.jaac.2013.12.029.
[17] Leahy E, Gradisar M. Dismantling the bidirectional relationship between paediatric sleep and anxiety. Clin Psychol 2012;16:44–56. https://doi.org/10.1111/j.1742-9552.2012.00039.x.
[18] Geng F, Liu X, Liang Y, et al. Prospective associations between sleep problems and subtypes of anxiety symptoms among disaster-exposed adolescents. Sleep Med 2018;50:7–13. https://doi.org/10.1016/j.sleep.2018.05.017.
[19] Tochigi M, Usami S, Matamura M, et al. Annual longitudinal survey at up to five time points reveals reciprocal effects of bedtime delay and depression/anxiety in adolescents. Sleep Med 2016;17:81–6. https://doi.org/10.1016/j.sleep.2015.08.024.
[20] Roberts RE, Duong HT. Is there an association between short sleep duration and adolescent anxiety disorders? Sleep Med 2017;30:82–7. https://doi.org/10.1016/j.sleep.2016.02.007.
[21] Kelly RJ, El-Sheikh M. Reciprocal relations between children's sleep and their adjustment over time. Dev Psychol 2014;50:1137–47. https://doi.org/10.1037/a0034501.
[22] Hamaker EL. Why researchers should think "within-person": a paradigmatic rationale. Handbook of research methods for studying daily life. New York: Guilford; 2012.
[23] Hamaker EL, Kuiper RM, Grasman RPPP. A critique of the cross-lagged panel model. Psychol Methods 2015;20:102–16. https://doi.org/10.1037/a0038889.
[24] Oldehinkel AJ, Rosmalen JGM, Buitelaar JK, et al. Cohort profile update: the tracking adolescents' individual lives survey (TRAILS). Int J Epidemiol 2015;44:76. https://doi.org/10.1093/ije/dyu225. 76n.

[25] De Winter AF, Oldehinkel AJ, Veenstra R, et al. Evaluation of non-response bias in mental health determinants and outcomes in a large sample of pre-adolescents. Eur J Epidemiol 2005;20:173–81. https://doi.org/10.1007/s10654-004-4948-6.
[26] Kessler RC, Üstün TB. The world mental health (WMH) survey initiative version of the world health organization (WHO) composite international diagnostic Interview (CIDI). Int J Methods Psychiatr Res 2004:13.
[27] Huisman M. Imputation of missing item responses: some simple techniques. Qual Quantity 2000;34:331–51. https://doi.org/10.1023/A:1004782230065.
[28] Achenbach TM, Dumenci L, Rescorla LA. Ratings of relations between DSM-IV diagnostic categories and items of the CBCL/6-18, TRF, and YSR. Vermont Res 2001:1–9.
[29] Achenback TM, Rescorla LA. Reliability, Internal Consistency, et al. ASEBA sch -age forms profiles. 2003. p. 99–107.
[30] Van Lang NDJ, Ferdinand RF, Oldehinkel AJ, et al. Concurrent validity of the DSM-IV scales affective problems and anxiety problems of the Youth self-report. Behav Res Ther 2005;43:1485–94. https://doi.org/10.1016/j.brat.2004.11.005.
[31] Hunt SM, McKenna SP, McEwen J, et al. A quantitative approach to perceived health status. A validation study. J Epidemiol Community Health 1990;34:281–6.
[32] Muthén LK, Muthén BO. S. 2007. p. 1–13. https://doi.org/10.1111/j.1600-0447.2011.01711.x.
[33] Brown T a, Moore MT. Confirmatory factor analysis. New York: Guilford Publications; 2012. https://doi.org/10.1093/acprof:oso/9780195339888.001.0001.
[34] Giannotti F, Cortesi F, Sebastiani T, et al. Circadian preference, sleep and daytime behaviour in adolescence. J Sleep Res 2002;11:191–9. https://doi.org/10.1046/j.1365-2869.2002.00302.x.
[35] Blake MJ, Trinder JA, Allen NB. Mechanisms underlying the association between insomnia, anxiety, and depression in adolescence: implications for behavioral sleep interventions. Clin Psychol Rev 2018;63:25–40. https://doi.org/10.1016/j.cpr.2018.05.006.
[36] Mrug S, Tyson A, Turan B, et al. Sleep problems predict cortisol reactivity to stress in urban adolescents. Physiol Behav 2016;155:95–101. https://doi.org/10.1016/j.physbeh.2015.12.003.
[37] Greaves-Lord K, Ferdinand RF, Oldehinkel AJ, et al. Higher cortisol awakening response in young adolescents with persistent anxiety problems. Acta Psychiatr Scand 2007;116:137–44. https://doi.org/10.1111/j.1600-0447.2007.01001.x.
[38] Sarchiapone M, Mandelli L, Carli V, et al. Hours of sleep in adolescents and its association with anxiety, emotional concerns, and suicidal ideation. Sleep Med 2014;15:248–54. https://doi.org/10.1016/j.sleep.2013.11.780.
[39] Forbes EE, Bertocci MA, Gregory AM, et al. Objective sleep in pediatric anxiety disorders and major depressive disorder. J Am Acad Child Adolesc Psychiatry 2008;47:148–55. https://doi.org/10.1097/chi.0b013e31815cd9bc.
[40] Miller MB, Janssen T, Jackson KM. The prospective association between sleep and initiation of substance use in young adolescents. J Adolesc Health 2017;60:154–60. https://doi.org/10.1016/j.jadohealth.2016.08.019.
[41] Blake MJ, Sheeber LB, Youssef GJ, et al. Systematic review and meta-analysis of adolescent cognitive – behavioral sleep interventions. Clin Child Fam Psychol Rev 2017;20:227–49. https://doi.org/10.1007/s10567-017-0234-5.
[42] Goldberg DP, Hillier VF. A scaled version of the general health questionnaire. Psychol Med 1979;9:139–45. https://doi.org/10.1017/S0033291700021644.
[43] Alfano CA, Zakem AH, Costa NM, et al. Sleep problems and their relation to cognitive factors, anxiety, and depressive symptoms in children and adolescents. Depress Anxiety 2009;26:503–12. https://doi.org/10.1002/da.20443.
[44] Kessler RC, Berglund P, Demler O, et al. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. Arch Gen Psychiatry 2005;62:593–602. https://doi.org/10.1001/archpsyc.62.6.593.
[45] Quach JL, Nguyen CD, Williams KE, et al. Bidirectional associations between child sleep problems and internalizing and externalizing difficulties from preschool to early adolescence. JAMA Pediatr 2018;172:1–8. https://doi.org/10.1001/jamapediatrics.2017.4363.
[46] Mulraney M, Giallo R, Lycett K, et al. The bidirectional relationship between sleep problems and internalizing and externalizing problems in children with ADHD: a prospective cohort study. Sleep Med 2016;17:45–51. https://doi.org/10.1016/j.sleep.2015.09.019.
[47] Horváth A, Montana X, Lanquart JP, et al. Effects of state and trait anxiety on sleep structure: a polysomnographic study in 1083 subjects. Psychiatry Res 2016;244:279–83. https://doi.org/10.1016/j.psychres.2016.03.001.
[48] Tavakol M, Dennick R. Making sense of Cronbach's alpha. Int J Med Educ 2011;2:53–5. https://doi.org/10.5116/ijme.4dfb.8dfd.