ORIGINAL ARTICLE

Childhood Sleep Functioning as a Developmental Precursor of Adolescent Adjustment Problems

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Abstract
Sleep has been linked to adjustment difficulties in both children and adolescents; yet little is known about the long-term impact of childhood sleep on subsequent development. This study tested whether childhood sleep problems, sleep quantity, and chronotype predicted internalizing and externalizing problems during adolescence. Latent Growth Modeling using the Czech portion of the European Longitudinal Study of Pregnancy and Childhood ($N = 4393$) was utilized to test the developmental trajectories of sleep characteristics (from 1.5 to 7 years) as predictors of adjustment problems trajectories (from 11 to 18 years). Findings provided evidence that children with higher levels of sleep problems at 1.5 years (and throughout childhood) reported higher levels of internalizing and externalizing problems at age 11. Additionally, greater eveningness at age 1.5 predicted a greater increase in externalizing problems from ages 11 to 18 years. The results emphasize the importance of childhood sleep problems in evaluating the risk of future adjustment difficulties.

Keywords Sleep · Internalizing problems · Externalizing problems · Adolescent adjustment

Sleep patterns, including sleep problems, short sleep, and evening chronotype (i.e., eveningness), have been repeatedly linked to adjustment difficulties, defined as internalizing and externalizing problems [1–3]. Sleep problems have been most commonly operationalized as troubles falling and remaining asleep, having nightmares, and being overtired without good reason [4]. In children, these problems are usually registered and subsequently reported by parents and often include troubles in sleep consolidation, characterized by fragmented sleep (i.e., bedtime resistance and frequent night awakenings) [2]. In adolescents, sleep problems are often related to delayed sleep-phase syndrome (i.e., inability to fall asleep, late sleep onset time, and daytime sleepiness) [5] and can be reported either by parents or adolescents (for

discussion on potential discrepancies between reporters, see the paper by De Los Reyes and Kazdin [6]). Concurrent associations between sleep problems and depression, anxiety, hyperactivity, and conduct problems were found in cross-sectional samples of both children [7, 8] and adolescents [5, 9]. Adjustment difficulties were also found to be associated with a short amount of sleep [1, 10], assessed as sleeping less than other children [11], as the number of hours in bed computed from parent or self-reported bedtimes and wake up times [8], or measured by actigraphy [12]. Lastly, a substantial body of research, albeit predominantly cross-sectional, has provided evidence of a link between eveningness and adjustment problems [13, 14]. Aggression, antisocial behavior, and hyperactivity/inattentiveness were each more prevalent in evening types than in morning types, in both children and adolescents [15, 16]. Moreover, eveningness has been linked to depression, anxiety, and general affective problems in adolescents [14, 16, 17]. With a few exceptions [18, 19], the results of cross-sectional investigations focused on the links between sleep functioning and adjustment have been supported by findings from longitudinal studies. Sleep problems, short sleep, and later bedtimes—an indicator of eveningness—predicted internalizing and externalizing problems in children and adolescents prospectively [20–22].

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A small but growing number of studies examined whether the effects of childhood sleep on later adjustment persisted into adolescence. This line of research has significance for two main reasons. First, if poor sleep in childhood might serve as a risk factor for later impairment, it is important to detect and treat sleep problems in a timely fashion [1], particularly given that adolescence has been described as a period of vulnerability for the development of adjustment difficulties [23]. Second, sleep can serve as an early marker of later psychopathology and thus may enable clinicians to identify at-risk individuals before more serious symptoms develop [2]. Findings from this line of research showed that sleeping less than others as a child predicted a greater likelihood of high aggression in late adolescence [11] and that daytime sleepiness in school age predicted externalizing problems in adolescence [21]. In addition, sleep problems in preschool children predicted anxiety and depression at 9–13 years [24], and similarly, the persistence of insomnia in childhood (measured at 4.5 and 9 years) predicted depression and externalizing problems in adolescence [25]. Lastly, sleep problems at age 4 were found to predict internalizing and externalizing problems 11 years later [26].

Three studies have utilized a developmental trajectory approach to test the associations between poor sleep and adjustment problems. First, Wang and colleagues [4] used a latent class analysis (LCA) to identify latent trajectories of sleep problems in a longitudinal sample of Australian children between ages 5 and 14 years. Sleep problems were assessed by six items from the Child Behavior Checklist (CBCL). Results showed that being a troubled sleeper in childhood was associated with a greater probability of having attention problems and being aggressive in middle adolescence. Second, Wong et al. [27] investigated the relationship between childhood sleep problems, measured by two items from the CBCL, and internalizing and externalizing problems in adolescence, based on a sample of European American children from at-risk families. Results from Latent Growth Modeling (LGM) suggested that sleep problems in childhood predicted initial levels as well as the developmental changes in both internalizing and externalizing problems, from childhood to adolescence. Third, Touchette et al. [28] found that sleep problems assessed by a single item from the CBCL in a sample of French children and adolescents (4–16 years) predicted a greater likelihood of following a trajectory characterized by high levels of internalizing symptoms.

The existing evidence suggested that sleep functioning in childhood may be an early sign of future adjustment problems [4, 24]; however, several gaps in the research remain unaddressed. First, most previous studies did not test developmental trajectories of sleep characteristics or adjustment as a predictor or outcome; thus, either sleep characteristics and/or adjustment problems were assessed as mean levels only. Although appropriate, such an analytic strategy is unable to address whether a change in sleep patterns over time predicts adjustment. For example, it is plausible that sleep problems in early childhood are a less salient predictor of future problems than their persistence over time. Although several studies partially addressed this limitation [4, 27, 28], they did not model both sleep functioning and adjustment as trajectories and thus did not examine the interplay between developmental changes in both constructs.

Second, the vast majority of previous studies focused solely on sleep problems, including the studies utilizing a trajectory approach to model the sleep—adjustment links [4, 27, 28]. Only two longitudinal studies examined the effect of sleep quantity on adjustment [11, 29], and only one of them tested the association between sleep quantity in childhood and adjustment in adolescence [11]. Similarly, the effect of childhood chronotype on adolescent adjustment remains under-researched, although a large number of cross-sectional studies on the topic exists [15]. Third, many of the previous longitudinal studies employed samples that did not span the entire period of childhood and adolescence [29] or utilized only a limited number of assessments [21, 25].

This study builds upon the existing work in three important ways: First, by testing developmental changes of both sleep problems and adjustment problems, rather than utilizing their mean levels as predictors and outcomes; second, by testing childhood sleep problems as well as quantity and chronotype as predictors of adjustment difficulties; and finally, by using a large longitudinal sample spanning 16.5 years with four assessments of sleep functioning in childhood (T1: 1.5 years, T2: 3 years, T3: 5 years, T4: 7 years) and three assessments of adjustment problems (T5: 11 years, T6: 15 years, T7: 18 years) in adolescence.

Based on previous studies, we hypothesized that: (a) a higher initial level of sleep problems (T1) and their developmental change (T1–T4) would predict a higher initial levels of both internalizing and externalizing problems (T5) and their developmental changes (T5–T7), (b) a lower initial level of sleep quantity and its developmental change would predict a higher initial levels of both internalizing and externalizing problems and their developmental changes, and (c) a greater initial level of eveningness and its developmental change would predict higher initial levels of both internalizing and externalizing problems and their developmental changes.

Methods

Sample

Data for the current study were obtained from the Czech portion of the European Longitudinal Cohort Study of

Pregnancy and Childhood (ELSPAC [30]). Health records about pregnancy and delivery from a total of 7589 children born in two metropolitan areas were collected between March 1, 1991, and June 30, 1992 (96% of all eligible births). Questionnaire data were collected at birth (baseline) from $N=5151$ mothers and $N=4653$ fathers. Follow-up assessments included medical examinations as well as self-reported questionnaires from mothers, their partners, children, and teachers, collected at 13 time points from the prenatal period until 19 years [30]. Informed consent was collected from all participants. Approximately 50% of participants were retained in the study until age 11 while about 20% of participants remained in the study until 19 years of age. The sample included almost exclusively Caucasian, Czech participants as over 99% of the residents in both regions consisted of the Czech ethnic group in years 1991–1992 [30]. All questionnaires were administered in the Czech language. Access to ELSPAC data and their use in the current study was approved by the Institutional Review Board at the University of Kentucky. For the purpose of the current study, data from seven time points were used (T1–T7; 1.5, 3, 5, 7, 11, 15, and 18 years). Only participants who provided answers at least at one time point during the examined time period were included in the analytic sample. The analytic sample consisted of $N=4393$ participants, thus constituted 85.3% of the original number of participants at the baseline ($N=5151$ at birth).

Measures

Reliability coefficients (Cronbach's α) along with descriptive statistics of the scales are summarized in Table 1.

The items part of the scales were mean averaged and coded so that a higher score represented a higher quantity of the assessed construct. See Appendix for the list of items part of the measures.

Control Variables

Sex Sex was coded as *male* (1) or *female* (0).

Family Socioeconomic Status (SES) Family SES was assessed as a total family income in Czech crowns per month at T1.

Family Structure Family structure was coded as *two biological parents* (1) or *other* (0) at T1.

Maternal Internalizing Problems Maternal internalizing problems were assessed by the Edinburgh Postnatal Depression Scale (EPDS), a widely used and validated measure of

Table 1 Descriptive statistics of study variables

Variable	N	Mean	SD	Min/Max	Skewness	Kurtosis	α
Sex[male]	4389	–	–	0/1	–	–	–
Family SES 1.5 years	3318	6526.33	2976.82	0/50,400	3.69	32.70	–
Family type[two-parent] 1.5 years	3569	–	–	0/1	–	–	–
Maternal internalizing 1.5 years	3619	0.63	0.45	0.00/2.50	0.89	0.62	0.85
Maternal alcohol use 1.5 years	3619	0.00	0.89	− 1.63/4.61	0.80	0.77	0.68
Sleep problems 1.5 years	3623	0.74	0.63	0.00/3.00	1.02	0.67	0.79
Sleep problems 3 years	3660	0.68	0.56	0.00/3.00	1.07	1.07	0.76
Sleep problems 5 years	3591	0.56	0.51	0.00/3.00	1.24	1.63	0.75
Sleep problems 7 years	3291	0.45	0.42	0.00/3.00	1.53	3.43	0.69
Sleep quantity 1.5 years	3619	11.38	0.90	6.00/15.00	− 0.39	2.08	–
Sleep quantity 3 years	3642	11.09	0.87	6.00/15.00	− 0.06	0.70	–
Sleep quantity 5 years	3595	10.97	0.80	6.00/15.00	− 0.01	1.26	–
Sleep quantity 7 years	3282	10.72	0.61	6.17/13.50	− 0.20	2.06	–
Chronotype 1.5 years	3618	25.19	0.61	23.00/27.50	0.32	0.68	–
Chronotype 3 years	3644	25.47	0.54	22.00/28.50	0.13	1.44	–
Chronotype 5 years	3597	25.55	0.50	22.00/28.00	0.08	3.14	–
Chronotype 7 years	3281	25.79	0.41	24.08/27.50	0.08	0.54	–
Internalizing problems 11 years	2524	0.60	0.37	0.00/2.00	0.61	0.49	0.66
Internalizing problems 15 years	1635	0.67	0.48	0.00/2.00	0.57	− 0.30	0.71
Internalizing problems 18 years	625	0.72	0.46	0.00/2.00	0.48	− 0.32	0.66
Externalizing problems 11 years	2527	0.49	0.34	0.00/2.00	0.68	0.47	0.67
Externalizing problems 15 years	1635	0.51	0.39	0.00/2.00	0.63	− 0.15	0.69
Externalizing problems 18 years	625	0.50	0.39	0.00/2.00	0.70	0.62	0.68

depression [31]. The measure was translated from English to Czech language and has been previously administered in a Czech sample [32]. Mothers answered ten self-reported items on a four-point Likert-type scale ranging from *never* (0) to *most of the times* (3) at T1 (e.g., "I was anxious or worried for no good reason.").

Maternal Alcohol Use Maternal alcohol use was assessed by two standard epidemiological questions pertaining to amount and frequency of alcohol consumption (e.g., "How much alcohol do you usually consume"). The items, self-reported at T1, were standardized and then mean averaged.

Predictors

Sleep Problems Sleep problems were assessed at four time points (T1–T4) by a Czech translation of the scale originally developed for the purpose of the Avon Longitudinal Study of Parents and Children (ALSPAC) by a research team coordinating the study [33]. The scale has been previously used [34, 35] and is similar in content to other scales commonly utilized to measure sleep problems (such as CBCL) [4]. Seven mother-reported items (e.g., "In the last 6 months, your child had difficulties falling asleep") was answered on a four-point Likert-type scale ranging from *this has never happened* (0) to *this happened and I was very worried about it* (3).

Sleep Quantity Nighttime sleep quantity was computed from bedtimes and wake-up times reported by mothers, consistent with the previous research [8, 33]. Sleep quantity was assessed at four time points (T1–T4).

Chronotype Chronotype was measured at four time points (T1–T4). The midsleep point, a previously validated indicator of chronotype [36, 37] was computed from mother-reported bedtimes and wake-up times as a midpoint between these two values. The midsleep was represented by a linear variable created on a basis of military time, ranging from a value of approximately 22.00 (= 10 pm) to 28.00 (= 4 am). Higher midsleep point represented greater eveningness.

Outcomes

Internalizing Problems Internalizing problems were assessed at three time points (T5–T7) by five adolescent-reported items (e.g., "In the last 6 months, you were sad or depressed.") adapted from the Czech version of the Strength and Difficulties Questionnaire (SDQ [38]), a previously validated measure with good psychometric properties [39]. The items were answered using a four-point Likert-type scale ranging from *never true* (0) to *always true* (3) at T5, and using a three-point Likert-type scale ranging from *false* (0) to *true* (2) at T6 and T7. Linear transformation of answering scale at T5 was used to convert the four-point scale into a three-point one [40].

Externalizing Problems Externalizing problems were assessed at three time points (T5–T7) by six adolescent-reported items pertaining to hyperactivity, irritability, and conduct problems (e.g., "In the last 6 months, you were angry or irritable."). The measure was adapted from the Czech version of the Strength and Difficulties Questionnaire (SDQ [38]), a previously validated measure with good psychometric properties [39]. The items were answered using a four-point Likert-type scale ranging from *never true* (0) to *always true* (3) at T5, and using a three-point Likert-type scale ranging from *false* (0) to *true* (2) at T6 and T7. Linear transformation of answering scale at age T5 was used to convert the four-point scale into a three-point one [40].

Analytic Procedure

Hypotheses were tested via LGM, suitable for examining the associations between developmental trajectories of constructs [41]. First, developmental trajectories of the main study variables (i.e., sleep problems, sleep quantity, chronotype, internalizing problems, and externalizing problems) were examined by specifying six unconditional linear LGM models. Second, each sleep variable trajectory was entered as a predictor of internalizing and externalizing problems trajectory separately, resulting in a total of six predictive (i.e., growth to growth) models. Specifically, intercepts and slopes of sleep problems were regressed on the intercepts and slopes of the adjustment variables (Fig. 1). To handle missing data, the full information maximum likelihood (FIML) feature in AMOS 23 [42] was implemented.

Demographic variables, specifically sex, family SES, and family structure have been previously found to be associated with sleep functioning in children and adolescents [4, 5, 12, 43]. These demographic variables assessed at T1 were thus added as predictors of both the intercept and slope terms of sleep variables to partial out any effects they might have on the main study findings. Additionally, maternal internalizing problems in models predicting adolescent internalizing problems and maternal alcohol use in models predicting adolescent externalizing problems were added as control variables. Both variables have been found to be associated with childhood sleep [44, 45] and might have influenced reporting of sleep functioning by mothers (e.g., anxious mothers might interpret children's sleep problems as more serious than mothers with low levels of internalizing problems).
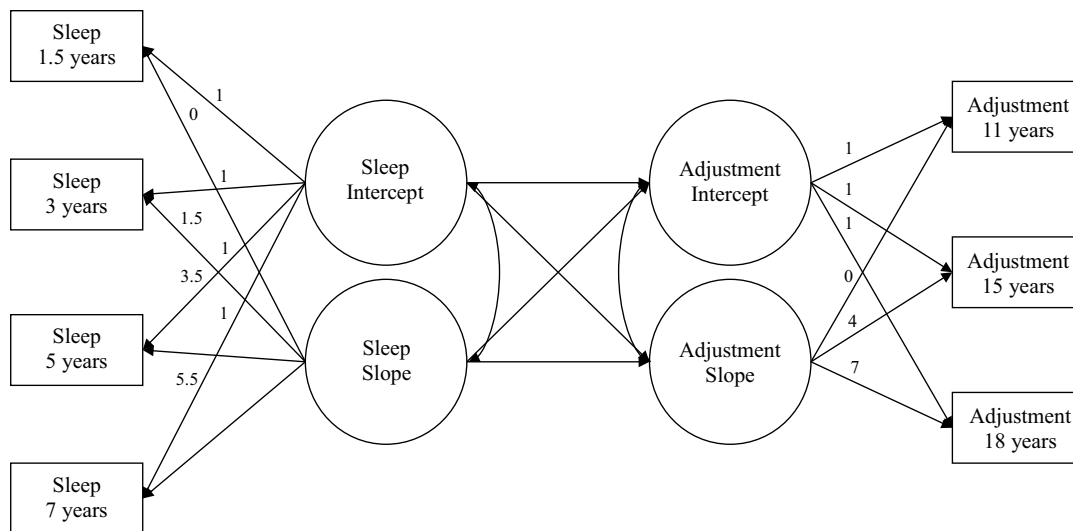
Note: paths from the slope term to the observed scores were fixed to values reflecting the time intervals between each assessment

Fig. 1 Predictive LGM model of sleep characteristics and adjustment problems

Results

Descriptive statistics and bivariate correlations of the study variables are summarized in Tables 1 and 2, respectively.

Approximately half of the sample were boys (51.8%, $n = 2273$) and half were girls (48.2%, $n = 2116$). The median family income at T1 (year 1993) was 6000 Czech crowns per month, which is approximately 265 current U.S. dollars. At T1, 92.2% ($n = 3290$) of the children lived with two biological parents, while 7.8% of children lived in another family arrangement (e.g., single-parent households).

Unconditional Latent Growth Models

The average level of sleep problems at T1 was .745 ($p < .001$) on a scale ranging from 0 to 3 and the trajectory decreased linearly by .053 ($p < .001$) unit per year. The average level of hours slept per night was 11.343 ($p < .001$) at 1.5 years and the trajectory decreased linearly by −.112 h (approximately 7 min; $p < .001$) per year. Lastly, the average midsleep point was 25.241 (approximately 1:15 AM; $p < .001$) at 1.5 years and the trajectory increased linearly by .100 h (i.e., 6 min; $p < .001$) per year.

With regards to adjustment variables, the average level of internalizing problems at T5 was .598 ($p < .001$) on a scale ranging from 0 to 2 and it increased linearly by .018 ($p < .001$) points per year. The average level of externalizing problems at T5 was .492 ($p < .001$) on a scale ranging from 0 to 2, and it increased linearly by .004 ($p = .042$) points per year.

Predictive Latent Growth Models

Predictive Model of Sleep Problems and Internalizing Problems

The predictive, growth to growth LGM model of sleep problems trajectory and internalizing problems trajectory had acceptable fit to the data: $\chi^2 (34) = 256.679$, $p < .001$, CFI = .942, RMSEA = .039 [90% CI = .034, .043], p close = 1.000). The intercept of sleep problems trajectory predicted the intercept of internalizing problems trajectory ($\beta = .409$, $p < .001$). Additionally, the slope of sleep problems trajectory predicted the intercept of internalizing problems trajectory ($\beta = .331$, $p < .001$; Table 3, Model 1).

Predictive Model of Sleep Problems and Externalizing Problems

The model had a good fit to the data: $\chi^2 (34) = 159.222$, $p < .001$, CFI = .963, RMSEA = .029 [90% CI .025, .034], p close = 1.000). The intercept of sleep problems trajectory predicted the intercept of externalizing problems trajectory ($\beta = .506$, $p < .001$). Additionally, the slope of sleep problems trajectory predicted the intercept of externalizing problems trajectory ($\beta = .249$, $p = .002$; Table 3, Model 2).

Table 2 Correlations among study variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
1. Sex male	–																					
2. Fam SES 1.5	.03																					
3. Fam two-parent 1.5	.04*	.27***																				
4. Maternal in. 1.5	–.01	–.09***	–.14***																			
5. Maternal use	.01	–.10***	.01	.03																		
6. Sleep probs 1.5	.04*	–.02	–.04*	.22***	.00																	
7. Sleep probs 3	.02	–.03	–.05**	.21***	.04*	.44***																
8. Sleep probs 5	–.03	–.04*	–.06**	.22***	.06**	.34***	.49***															
9. Sleep probs 7	–.02	–.02	–.03	.23***	.08***	.30***	.42***	.49***														
10. Sleep quant 1.5	–.04*	–.03	–.04*	–.03	.03	–.18***	–.06**	–.01	–.02													
11. Sleep quant 3	–.05**	–.03	–.00	–.04*	–.03	–.08***	–.11***	–.11***	–.06**	.30***												
12. Sleep quant 5	–.01	–.03	–.04	–.06**	–.02	–.09***	–.07***	–.10***	–.06**	.22***	.39***											
13. Sleep quant 7	–.07***	–.09***	–.03	–.05*	–.04	–.04*	–.03	–.05**	–.06**	.24***	.38***	.41***										
14. Chrono 1.5	–.06**	–.01	–.03	.01	–.02	.03	.01	.00	–.00	.06***	.10***	.07***	.11***									
15. Chrono 3	–.01	.01	.01	–.01	.00	.03	.01	.02	.03	–.01	.08***	.04*	.04	.40***								
16. Chrono 5	–.02	.07***	.01	.02	.03	.03	.03	.03	.05**	.01	.02	.19***	.00	.30***	.41***							
17. Chrono 7	–.03	.09***	–.01	.03	.08***	.03	.03	.05**	.05**	.04*	.04*	.03	–.03	.24***	.32***	.46***						
18. Intern 11	–.12***	–.04	–.02	.11***	.00	.07**	.15***	.13***	.15***	–.00	–.02	–.01	–.00	.00	.01	–.02	.02					
19. Intern 15	–.27***	–.03	–.07**	.11***	.01	.06*	.11***	.12***	.12***	.02	.01	.02	.04	.04	.01	.06*	.05*	.28***				
20. Intern 18	–.22***	–.02	–.04	.06	–.07	.05	.15***	.06	.12**	.06	.04	.00	–.05	–.03	.04	–.01	–.03	.17***	.46***			

Table 2 (continued)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
21. Extern 11	.14***	−.03	−.03	.10***	.00	.09***	.14***	.12***	.15***	.01	−.03	−.02	.00	−.01	−.04	−.02	.00	.41***	.09***	.11**		
22. Extern 15	−.08**	−.03	−.07**	.11***	−.03	.07**	.12***	.11***	.10***	.03	.01	.00	.04	.02	.02	.06*	.04	.18***	.64***	.34***	.21***	
23. Extern 18	−.02	.03	−.02	.06	−.04	.08	.15***	.08*	.11**	.02	.01	−.02	.02	−.03	.10*	−.03	.00	.10*	.32***	.60***	.19***	.44***

Fam family, *probs* problems, *quant* quantity, *chrono* chronotype, *Intern* internalizing problems, *Extern* externalizing problems

*$p < .05$ **$p < .01$ ***$p < .001$

Predictive Model of Sleep Quantity and Internalizing Problems

The model had poor fit to the data: $\chi^2 (34) = 364.130$, $p < .001$, CFI = .867, RMSEA = .036 [90% CI .033, .039], p close = 1.000). As some authors [46, 47] suggested that traditional fit indices might not perform well in complex LGM models, we examined the model estimates despite the suboptimal model fit. The sleep quantity trajectory did not significantly predict the trajectory of internalizing problems (Table 3, Model 3).

Predictive Model of Sleep Quantity and Externalizing Problems

The predictive model had an acceptable fit to the data: $\chi^2 (34) = 247.560$, $p < .001$, CFI = .905, RMSEA = .029 [90% CI .025, .032], p close = 1.000). The sleep quantity trajectory did not significantly predict the trajectory of externalizing problems (Table 3, Model 4).

Predictive Model of Chronotype and Internalizing Problems

The model had poor fit to the data: $\chi^2 (34) = 452.936$, $p < .001$, CFI = .852, RMSEA = .053 [90% CI .049, .057], p close = .126). The chronotype trajectory did not significantly predict the trajectory of internalizing problems (Table 3, Model 5).

Predictive Model of Chronotype and Externalizing Problems

The model had poor fit to the data: $\chi^2 (34) = 452.936$, $p < .001$, CFI = .852, RMSEA = .053 [90% CI .049, .057], p close = .126). The intercept of chronotype trajectory predicted the slope of externalizing problems trajectory ($\beta = .151$, $p = .049$; Table 3, Model 6).

Discussion

The aim of the current study was to test developmental trajectories of sleep characteristics in childhood as predictors of adjustment problems in adolescence. Results provided partial support for hypothesis 1—a higher level of sleep problems at T1 (1.5 years) predicted a higher level of both internalizing and externalizing problems at T5 (11 years). Additionally, a slower decline of sleep problems (i.e., their persistence over time) predicted a higher level of internalizing and externalizing problems at T5 (11 years). The association between childhood sleep problems and the measures of adolescent adjustment has been reported previously [21, 24, 26]; however, this study adds an important piece of evidence

Table 3 Results of predictive, growth to growth LGM models

	Model 1		Model 2	
	Internalizing problems		Externalizing problems	
	Intercept	Slope	Intercept	Slope
Sleep problems				
Intercept	.409***	.053	.506***	−.001
Slope	.331***	.067	.249**	−.033
	Sleep problems		Sleep problems	
	Intercept	Slope	Intercept	Slope
Control variables				
Maternal internalizing	.303***	−.098**	–	–
Maternal alcohol use	–	–	.020	.073*
Sex[male]	.058**	−.146***	.049*	−.093**
Family SES	.004	−.012	−.015	−.008
Family type[two-parent]	−.033	.039	−.071**	.055
	Model 3		Model 4	
	Internalizing problems		Externalizing problems	
	Intercept	Slope	Intercept	Slope
Sleep quantity				
Intercept	−.014	.092	−.015	.103
Slope	.021	−.130	.030	.012
	Sleep quantity		Sleep quantity	
	Intercept	Slope	Intercept	Slope
Control variables				
Maternal internalizing	−.064*	−.007	–	–
Maternal alcohol use	–	–	.021	−.074*
Sex[male]	−.077**	.024	−.063**	< .001
Family SES	−.040	−.066	−.039	−.058
Family type[two-parent]	−.047	.031	−.035	.024
	Model 5		Model 6	
	Internalizing problems		Externalizing problems	
	Intercept	Slope	Intercept	Slope
Chronotype				
Intercept	.021	.074	−.045	.151*
Slope	.036	.008	.064	.006
	Chronotype		Chronotype	
	Intercept	Slope	Intercept	Slope
Control variables				
Maternal internalizing	−.012	.055*	–	–
Maternal alcohol use	–	–	−.026	.095***
Sex[male]	−.046*	.015	−.049*	.023
Family SES	< .001	.103***	.005	.087**
Family type[two-parent]	−.017	.007	−.016	.001

Standardized regression estimates are shown

*$p < .05$ **$p < .01$ ***$p < .001$

to the existing scholarship. Not only the mean level of sleep problems in early childhood predicted future adjustment difficulties but also the persistence of sleep problems emerged as a predictor of adolescent adjustment. In other words, toddlers with a high level of sleep problems reported higher levels of internalizing and externalizing problems 9.5 years later. Also, children who showed a lower rate of developmentally normative decreases in sleep problems were at greater risk for future adjustment problems. This finding has practical implications as it can help practitioners identify children who might be at greater risk for future adjustment difficulties. The children would greatly benefit from a timely treatment of sleep problems, for example, focused on behavioral sleep problems (i.e., bedtime resistance, delayed sleep onset, and prolonged night awakenings). Such interventions may not only ameliorate sleep problems but also contribute to lowering both internalizing and externalizing problems during adolescence.

Findings from testing hypothesis 2 did not support the link between sleep quantity and adjustment problems reported in previous studies [1, 11, 20, 29]. This discrepancy might be related to several factors. First, most previous studies, although longitudinal in nature, were focused solely on children [1, 20] or on adolescents [29]. It is possible that while short sleep has been found to prospectively predict adjustment difficulties, this effect might not persist over long periods of time. A study by Asarnow et al. [48] provided some support for this assertion. The authors did not find an effect of sleep duration on emotional adjustment 6–8 years later. The only study which focused on the association between childhood sleep quantity and adolescent adjustment found that sleeping less than others in childhood predicted a greater likelihood of high aggression in late adolescence [11]. However, it is possible that the effect of short sleep might be less robust when it is assessed as the number of hours slept instead of a parental evaluation of sleep quantity as compared to other children.

Second, the lack of association between sleep quantity and adjustment problems in the current study might also be related to methodological limitations. The measure of sleep problems might have captured some aspects of short sleep better than a simple question about bedtime and wake up time. For example, fragmented sleep, a common childhood problem [49], is reflected in decreased sleep quantity but is typically assessed by measures of sleep problems (item "Your child wakes up during the night"). Additionally, bedtimes and wake up times used to calculate sleep quantity were mother-reported only which could have affected the reliability of the measure.

Hypothesis 3 was partially supported by the findings. The trajectory of chronotype in childhood did not significantly predict the trajectory of internalizing problems; however, greater eveningness at 1.5 years predicted a greater increase

in externalizing problems during adolescence. An association between chronotype and externalizing problems has been reported in a number of cross-sectional studies [15]. Longitudinally, late bedtimes during adolescence were associated with greater emotional distress almost a decade later in a study by Asarnow et al. [48]. The current study provided one of the first tests of the associations between childhood chronotype and adolescent adjustment, and it suggested that chronotype might play an important role in the developmental course of externalizing problems later in life. However, given the extent of support for the eveningness-adjustment link, it might be unexpected that the current study only found partial support for the association. It is plausible that even though eveningness has been linked to adjustment problems cross-sectionally, the effect of childhood chronotype might not persist into adolescence, particularly if the evening preference changes during an individual's lifespan. Additionally, chronotype computed from mother-reported bedtimes and wake up times in early childhood might not only reflect a child's sleep preferences, but also parental routines that might not be predictive of children's later adjustment.

In sum, childhood sleep patterns characterized by sleep problems (including their persistence throughout childhood) and to a lesser extent by eveningness, can serve as indicators of future adjustment problems. Sleep problems emerged as a more salient predictor of later adjustment difficulties than sleep quantity and chronotype. These findings support the conclusions of previous studies that measures of subjective sleep functioning appear to be stronger predictors of adjustment than objective characteristics, such as sleep duration [1]. Low sleep quantity and evening chronotype do not have to automatically translate into adjustment difficulties. First, a quadratic relationship was found between sleep quantity and poor adjustment [8, 50], providing evidence that too much sleep might be equally problematic as a short sleep; second, short sleep and evening preference might be an unproblematic individual preference rather than a reason for concern, particularly when not extreme. This was illustrated, for example, in a two-year longitudinal study of young adults concluding that evening types showed lower intrapersonal adjustment than morning types only if they belonged to a group reporting poor sleep in addition to eveningness [51].

Limitations

Several limitations of the study need to be addressed. First, the assessment of sleep was based on mother-reported data and the measure of sleep problems was worded in a way that it captured not only the frequency of children's sleep problem but also worries of their mothers about children's sleep problems. As a result, the measure of sleep problems might partially reflect maternal internalizing problems (i.e., anxiety) and potentially obscure the true associations between

sleep problems and adjustment. Objective measurement of sleep duration, efficiency, and the midpoint of sleep, for example via actigraphy, would greatly increase the validity of sleep assessment, as would utilizing multiple informants of sleep problems.

Second, the rating scales of adjustment problems at T5 had to be transformed to match response scales at T6 and T7. It is important to keep in mind that the results might reflect potential biases related to suboptimal or inconsistent measurement in addition to the observed true effects between the variables. Third, as the entire data collection spanned more than 18 years, there has been considerable attrition of the sample. Lastly, the sample included almost exclusively Caucasian, Czech participants. Although the results largely corroborated findings from work completed on different populations in other countries, including Norway [5], Israel [14], and China [10], some authors found effects of race or ethnicity on the association between sleep and adjustment [12]. Thus, the study findings need to be interpreted with these limitations in mind.

Summary

The aim of the current study was to test the developmental trajectories of sleep characteristics (sleep problems, sleep quantity, and chronotype) during childhood as predictors of adjustment problems (internalizing and externalizing problems) during adolescence. Findings provided evidence that children with greater sleep problems at age 1.5 years and throughout the childhood reported higher levels of internalizing and externalizing problems at age 11. Additionally, greater eveningness at age 1.5 predicted a greater increase in externalizing problems from age 11 to 18. No effects of sleep quantity on the subsequent adjustment problems were found.

Sleep problems emerged as a more salient predictor of future adjustment problems than chronotype and sleep quantity assessed as the number of hours slept per night. These findings have significance for clinical practice. Children with
a high level of sleep problems as well as children whose sleep problems do not improve throughout childhood might be at increased risk for future internalizing and externalizing problems. Recognizing and treating sleep problems during childhood would be important not only to improve sleep problems but also to prevent adjustment difficulties later in life.

Future studies are needed to better understand the mechanisms underlying the sleep functioning-adjustment link. Despite the fact that several potential linkages have been suggested (e.g., altered physiological functioning or temperamental risk factors), it is still unclear how childhood sleep translates into adjustment difficulties later in life and to what extent these pathways are due to genetic and/or environmental factors. For example, a considerable amount of variance in the overlap between sleep functioning and adjustment difficulties has been explained by shared genetic etiology, and thus, it is possible that childhood sleep functioning and adolescent adjustment problems are in fact manifestation of the same underlying genetic traits expressed differently at different developmental ages. Understanding the links between sleep functioning and adjustment problems would greatly enhance efforts to intervene through prevention and intervention strategies.

Compliance with Ethical Standards

Conflict of interest The authors declare no conflict of interest.

Ethical Approval All study procedures were performed in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix

Maternal internalizing problems

In the past 7 days:

1. I was able to laugh and see the funny side of things. (R)
2. I looked forward with enjoyment to things. (R)
3. I blamed myself unnecessarily when things went wrong.
4. I was anxious or worried for no good reason.
5. I felt scared or panicky for no very good reason.
6. Things have been getting on top of me.
7. I was so unhappy that I had difficulty sleeping.
8. I felt sad or miserable.
9. I was so unhappy that I was crying.
10. The thought of harming myself occurred to me.

0…never
1…not very often
2…often
3…most of the time

Maternal alcohol use

1. How much alcohol do you usually consume?

1…do not drink alcohol
2…rarely (less than once a week)
3…sometimes (at least once a week)
4…1 to 2 glasses almost every day
5…3 to 4 glasses every day
6…at least 10 glasses every day

2. On how many days during the last months have you consumed more than two units of alcohol at one occasion (2 beers/glasses of wine/shots)?

1…every day
2…more than 10 days
3…5 to 10 days
4…3 to 4 days
5…1 to 2 days
6…none

Sleep problems

In the last year, your child:

1. Refused to go to bed.
2. Woke up very early.
3. Had difficulties falling asleep.
4. Had nightmares.
5. Kept getting up after he/she was put in bed.
6. Woke up during the night.
7. Woke up after only few hours of sleep.

0…it did not happen
1…it happened but I was not worried about it
2…it happened and I was worried a bit
3…it happened and I was worried a great deal

Internalizing problems

In the last 6 months, you:

1. Had headaches, stomach aches, or felt sick in general.
2. Were worried about many things.
3. Were sad or depressed.
4. Were anxious in new situations and was losing confidence easily.
5. Got anxious or afraid easily.

At age 11 reported on the following scale:

0…false
1…rarely true
2…often true
3…always true
9…do not know

At ages 15 and 18 reported on the following scale:

0…false
1…somewhat true
2…true

Externalizing problems

In the last 6 months, you:

1. Were restless, hyperactive, and could not stay still.
2. Were angry or irritable.
3. Were aggressive towards other children or were fighting with them.
4. Had troubles concentrating and staying focused.
5. Lied or made up things that were not true.
6. Stole something at home, school, or elsewhere.

At age 11 reported on the following scale:

0…false
1…rarely true
2…often true
3…always true
9…do not know

At ages 15, and 18 reported on the following scale:

0…false
1…somewhat true
2…true

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