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Bidirectional Associations Between Child Sleep Problems and Internalizing and Externalizing Difficulties From Preschool to Early Adolescence

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 Supplemental content

IMPORTANCE Although multiple cross-sectional and longitudinal studies have established that sleep problems and behavioral difficulties are associated in children, the directionality of this association and whether sleep problems are differentially associated with different types of childhood behavioral difficulties are unclear. Understanding these associations will inform the focus and timing of interventions.

OBJECTIVE To determine whether longitudinal and reciprocal associations exist between child sleep problems and externalizing, internalizing, or both behavioral difficulties.

DESIGN, SETTING, AND PARTICIPANTS Prospective cohort study using nationally representative data from the first 5 waves (2004, 2006, 2008, 2010, and 2012) of the kindergarten cohort (4983 children aged 4-5 years in 2004) collected for the Longitudinal Study of Australian Children. Associations were evaluated using cross-lagged structural equation model analyses performed from May 25, 2016, to September 20, 2017.

MAIN OUTCOMES AND MEASURES Child sleep problems and internalizing and externalizing behavioral difficulties. Sleep problems were defined using parent-reported child sleep problem severity and specific difficulties (ie, difficulty getting to sleep at night, not happy sleeping alone, waking during the night, and restless sleep) on 4 or more nights of the week. Child behavioral difficulties were defined using the parent-reported Strengths and Difficulties Questionnaire for externalizing difficulties (conduct problems and hyperactivity/inattention subscales) and internalizing difficulties (emotional problems subscale).

RESULTS The 4983 children enrolled in 2004 had a mean (SD) age of 4.7 (0.2) years and comprised a similar percentage of boys (2536 [50.9%]) and girls. In 2012, 3956 children (79.4%) aged 12 to 13 years were retained. Significant bidirectional associations were detected between sleep problems and externalizing difficulties during the elementary school transition period, with greater sleep problems associated with later externalizing behavior and vice versa (cross-lagged path coefficient, 0.04 [95% CI, 0.01-0.08] to 0.09 [95% CI, 0.06-0.13]). Although sleep was a significant driver of later internalizing difficulties (coefficient, 0.10 [95% CI, 0.07-0.14] to 0.16 [95% CI, 0.12-0.19]), the reverse association was not significant. In the final model that included all 3 constructs, the associations were attenuated but remained significant over time.

CONCLUSIONS AND RELEVANCE These results suggest that future studies should investigate whether implementing sleep problem intervention decreases the occurrence of both externalizing and internalizing difficulties. Interventions targeting externalizing, but not internalizing, difficulties may benefit childhood sleep.

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Sleep problems have been estimated to affect up to 2 in 5 children during the elementary school years and are associated with a range of poorer child health and education outcomes as well as parent outcomes.¹ One common association demonstrated in cross-sectional and longitudinal studies is the link between child sleep problems and behavioral difficulties, such as internalizing and externalizing difficulties.² However, the directionality of this association over time and whether there are differences based on the type of behavioral difficulties that children may experience are poorly understood. Addressing this knowledge gap will provide valuable information to inform the focus and timing of interventions aiming to improve children's sleep and behavior during the elementary school years.

Previous cross-sectional and longitudinal research studies have highlighted the need to understand the directionality of the association between child sleep problems and behavior difficulties.²⁻⁶ A growing but limited number of studies have addressed this area to date. Jansen et al⁷ studied 4782 infants and found that parent-reported sleep problems at 2 and 12 months were associated with higher anxiety levels at 3 years as measured by the Child Behavior Checklist but that the reverse association was not present. Williams et al⁸ found a bidirectional association across the infant/preschool years between parent-reported child sleep and emotional regulation assessed using the Short Temperament Scale for Children in 4109 Australian infants and children. In older children, a study of 120 eight-year-olds found sleep problems had a reciprocal association with later depression and anxiety symptoms observed in children up to the age of 13 years. In a study of 270 children with attention-deficit/hyperactivity disorder (ADHD), Mulraney et al⁹ found some evidence of a bidirectional association over a 6-month period between sleep problems as assessed by the Child Sleep Habits Questionnaire and emotional problems but not with conduct problems, with the latter 2 problems measured by the Strengths and Difficulties Questionnaire. In a study of 1420 adolescents, sleep disturbances were associated with an increased prevalence of later generalized anxiety disorder and oppositional defiant disorder, with these conditions also being associated with increases in sleep problems over time.¹⁰ Collectively, these studies suggest that sleep problems may have a reciprocal association with child behavioral difficulties but that there may be variations based on the type of difficulty and the child's age. However, some gaps remain in this evidence.

Studies that further elucidate the longitudinal and bidirectional associations between sleep and internalizing and externalizing difficulties examined at multiple time points over regular intervals and using consistent measures will inform the focus and timing of intervention efforts. If sleep problems are associated with greater internalizing and externalizing difficulties over time, then managing sleep problems may be one way of reducing the burden of mental health problems for children and adolescents. This management is particularly important given that half of all mental health difficulties across a life span present before the adolescent years.¹¹ Conversely, treating internalizing and externalizing problems may help to reduce sleep problems and their associated public health bur-

Key Points

Question Do bidirectional associations exist between child sleep problems and internalizing or externalizing difficulties that span key school transition periods from preschool age through early adolescence?

Findings This cohort study used data obtained every 2 years beginning when 4983 children aged 4 to 5 years were recruited for the Longitudinal Study of Australian Children and found bidirectional associations between sleep problems and externalizing difficulties through ages 12 to 13 years. Although sleep problems were significantly associated with later internalizing difficulties, the reverse was not significant.

Meaning Future studies should determine whether interventions addressing sleep problems improve both internalizing and externalizing difficulties and whether interventions targeting externalizing (but not internalizing) difficulties improve sleep.

den in this population.^{12,13} Furthermore, taking a life-course approach¹⁴ will inform when interventions should be delivered through enhanced understanding of whether the association changes across childhood, especially at key transition periods, such as the start of elementary or high school. Data from the Longitudinal Study of Australian Children (LSAC),¹⁵ with its 5 biennial data collection time points spanning 10 years that started when children are 4 to 5 years old, are well placed to address these gaps. We therefore aimed to elucidate the longitudinal and reciprocal associations between sleep problems and internalizing and externalizing difficulties within a large, nationally representative sample of Australian children from preschool age to early adolescence using LSAC data.

Methods

Study Design and Sample

Data were drawn from the first 5 waves of the LSAC kindergarten cohort. Detailed information on the prospective study design and sample population is described elsewhere.¹⁵ To recruit a nationally representative sample, LSAC used a 2-stage cluster sampling design to enroll the cohort in 2004. In the first stage, Australian postcodes were sampled after stratifying by state and urban vs rural status to ensure proportional geographic representation. In the second stage, children registered on the Australian Medicare database (which included 98% of all children) within each postcode were randomly selected to participate. Follow-up waves occurred biennially (2004, 2006, 2008, 2010, and 2012). The kindergarten cohort spans the preschool to elementary school years. In total, 4983 children aged 4 to 5 years were enrolled in 2004 (wave 1), of whom 3956 (79.4%) remained in the study at wave 5 when aged 12 to 13 years. Retention was marginally lower for children with less highly educated parents and from non-English-speaking backgrounds.¹⁶ Data analyses were conducted from May 25, 2016, to September 20, 2017. The study was approved by the Australian Institute of Family Studies Ethics Committee, and parents provided written informed consent.

Procedures

At each data collection wave, trained research assistants administered an in-person interview with the primary caregiver (usually the mother) in the family home, during which parents reported on their child's sleep and behavior (see the Measures subsection).

Measures Collected at All 5 Waves

Sleep Problems

Child sleep problems were defined by 5 parent-report items modeled as a latent variable. Four items drawn from the Infant Sleep Study¹⁷ asked parents to indicate (yes, 1; no, 0) whether their child usually had “problems on 4 or more nights a week, or more than half the time,” “difficulty getting off to sleep at night,” “not happy to sleep alone,” “waking during the night,” or “restless sleep.” The fifth item asked parents, “How much is your child's sleeping pattern or habits a problem for you (ie, problems going to sleep or waking overnight?).”¹⁸ Parents were required to indicate whether their child's sleeping habits were a large, moderate, or small problem; no problem at all; or “not sure/don't know.” Responses were dichotomized according to previous longitudinal and intervention research, with a sleep problem defined as a large or moderate problem response (coded 1) and no sleep problem defined as a small or no problem response (coded 0).^{1,19,20} “Not sure/don't know” responses were coded as missing. These 5 indicator latent variables for sleep problems fit the data adequately at each wave (comparative fit index [CFI] ≥ 0.97 , root mean square error of approximation [RMSEA] < 0.06 , Tucker-Lewis index ≥ 0.94 , and χ^2 between 2.3 and 80.7; full statistics are available in the eTable in the [Supplement](#)), with most factor loadings at 0.60 or greater. Longitudinal measurement invariance was also tested to ensure that the items were tapping the same construct over time. The criteria for partial scalar longitudinal measurement invariance were met owing to adequate model fit when all factor loadings and most item thresholds were constrained to be equal across time.

Internalizing and Externalizing Difficulties

Child internalizing and externalizing behavioral difficulties were defined using the 25-item Strengths and Difficulties Questionnaire, a validated measure of behavioral and emotional problems for children aged 4 to 16 years.²¹ Specifically, internalizing difficulties were defined using the 5 items from the emotional problems subscale (score range, 0-10; higher scores indicate greater internalizing difficulties), which asked parents to report on the following behaviors over the previous 6 months: “often complains of headaches, stomachaches, or sickness”; “many worries, often seems worried”; “often unhappy, downhearted, or tearful”; “nervous or clingy in new situations, easily loses confidence”; and “many fears, easily scared.” Externalizing difficulties were defined using the 10 items from the conduct and hyperactivity/inattention problems subscales (score range, 0-20; higher scores indicate greater externalizing difficulties). The conduct problems subscale asked parents to indicate whether their child “often loses temper”; “generally well behaved, usually does what adults request”; “often fights with other children or bullies them”; “often lies or cheats”; and “steals from home, school, or else-

where.” The hyperactivity/inattention problems subscale asked about the following behaviors: “restless, overactive, cannot stay still for long”; “constantly fidgeting or squirming”; “easily distracted, concentration wanders”; “thinks things out before acting”; and “good attention span, sees chores or homework through to the end.” These definitions of internalizing and externalizing difficulties have commonly been used in previous population-based and clinical research.²²

Statistical Analysis

A series of 4 longitudinal, structural equation models were developed to examine the reciprocal and longitudinal associations among the variables of interest. A baseline autoregressive model estimated the cross-sectional correlations among the 3 constructs and the autoregressive paths that represent the continuity of each construct over time. Three transactional models were then estimated that included all potential cross-lagged paths among the following: sleep and internalizing problems, sleep and externalizing problems, and sleep and internalizing and externalizing problems together. Estimating this series of models enabled examination of each type of mental health problem independently as well as together, which is important given the complex transactional associations among internalizing and externalizing problems previously documented.^{23,24} Model fit was assessed with RMSEA and CFI scores and interpreted using common thresholds of good fit (RMSEA, < 0.05 ; CFI > 0.95).²⁵ There was no evidence of a lack of fit for any of the presented models. A series of Wald tests was then used to test the statistical differences between pairs of paths of interest, that is, to establish the extent to which sleep-driven or behavioral problem-driven paths were stronger. Each subscale was also independently examined in post hoc analyses (eFigures 1-4 in the [Supplement](#)), and similar patterns of association with the primary behavior constructs were also found in those analyses.

To handle study attrition and missing values in sleep, internalizing, and externalizing problems over the 5 time points, multiple imputation was conducted under a missing-at-random assumption to create 40 data sets with pooled results across the data sets presented in the Results section. Sample weights were not used to account for the study design because the statistical software package used, Mplus, does not allow them to be included in multiple imputation analysis and because the available weights account only for absence from entire waves but not for values missing from individual study items. Findings from data with and without multiple imputations were similar; thus, results using multiple imputation are presented herein.

Multiple imputation was performed using Stata, version 14.1 (StataCorp). All other analyses were conducted using Mplus, version 7.4 (Muthén and Muthén). Two-sided *P* values $< .01$ were considered statistically significant.

Results

Study Demographics

The 4983 enrolled children had a mean (SD) age of 4.7 (0.2) years and comprised a similar proportion of boys (2536 [50.9%])

Table. Demographic Characteristics

Characteristic	Total (N = 4983)
Child	
Male, No. (%)	2536 (50.9)
Aboriginal or Torres Strait Islander, No. (%)	187 (3.8)
Age, mean (SD), mo	
Wave 1	56.9 (2.6)
Wave 2	81.9 (3.0)
Wave 3	105.6 (2.9)
Wave 4	129.9 (3.5)
Wave 5	155.2 (3.8)
Maternal (Wave 1)	
Age, mean (SD), y	34.6 (5.3)
Educational level, No. (%)	
Did not complete high school	1894 (38.0)
Completed high school only	1624 (32.6)
Completed college degree	1470 (29.5)
Main language spoken at home is English, No. (%)	4168 (83.6)
Country of birth is Australia, No. (%)	3709 (74.4)
Family (Wave 1)	
No. of siblings in the household, median (IQR)	1.0 (1.0-2.0)
Socioeconomic position, mean (SD) ^a	0 (1.0)
Sole parent family, No. (%)	697 (14.0)

Abbreviation: IQR, interquartile range.

^aSocioeconomic position quintile is a composite Longitudinal Study of Australian Children measure derived from standardized scores for combined annual household income, years of parent education, and parent occupation.²²

and girls. Primary caregivers had a mean (SD) age of 34.6 (5.3) years, 3709 (74.4%) were born in Australia, 4168 (83.6%) spoke English as the main language at home, 1624 (32.6%) completed only high school, 1470 (29.5%) completed a college degree, and 4286 (86.0%) were 2-parent households (Table).

Missing data ranged from 30 (0.06%) for sleep problems at 4 to 5 years to 1194 (24%) for externalizing problems at 8 to 9 years. Sleep problems were observed for 4980 children (99.9%) in wave 1, 4461 (89.5%) in wave 2, 4330 (88.9%) in wave 3, 4155 (83.4%) in wave 4, and 3908 (78.4%) in wave 5. Internalizing problems were observed for 4968 children (99.7%) in wave 1, 4341 (87.1%) in wave 2, 3802 (76.3%) in wave 3, 4116 (82.6%) in wave 4, and 3853 (77.3%) in wave 5. Externalizing problems were observed for 4969 children (99.7%) in wave 1, 4340 (87.1%) in wave 2, 3799 (76.2%) in wave 3, 4116 (82.6%) in wave 4, and 3853 (77.3%) in wave 5.

Baseline Autoregressive Model

The path estimates showed moderate to high levels of stability in each construct that generally increased over time (Figure 1). Cross-sectional correlations among the constructs indicated positive correlations between sleep problems and internalizing problems as well as between sleep problems and externalizing problems at each wave. The model accounted for 72.2% of variance in sleep problems, 59.1% of variance in internalizing problems, and 71.8% of variance in externalizing problems in adolescents aged 12 to 13 years.

Transactional Model of Sleep Problems and Internalizing Difficulties

Path estimates showed that sleep problems consistently contributed to increased internalizing problems across the period (Figure 2). The reverse was not true, with only 1 significant cross-lag path from internalizing problems at 6 to 7 years old to sleep problems at 8 to 9 years old. The model accounted for 68.9% of variance in sleep problems and 51.2% of variance in internalizing problems in adolescents aged 12 to 13 years.

Transactional Model of Sleep Problems and Externalizing Difficulties

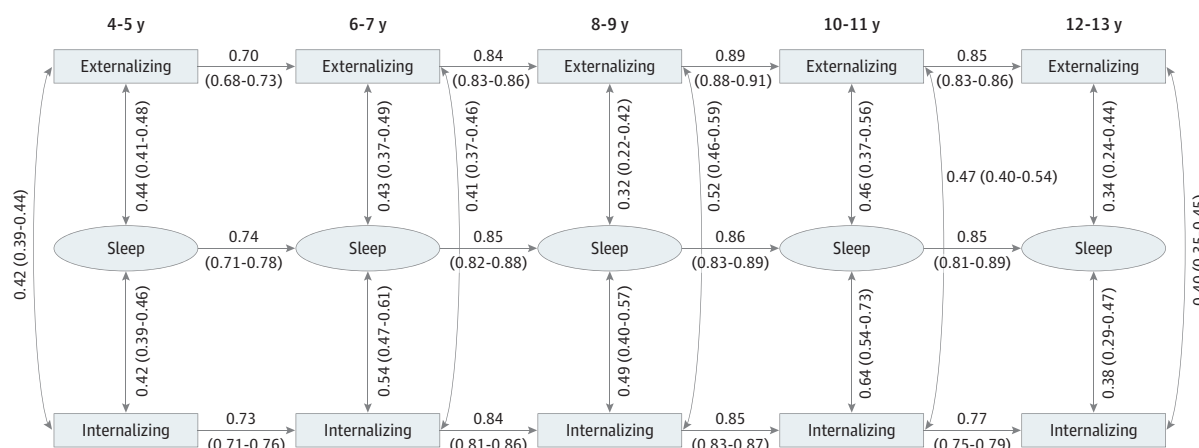
Path estimates showed that sleep problems in children 6 to 7 years old contributed to increased externalizing difficulties at 8 to 9 years but not at other time points (Figure 3). Externalizing problems at each wave were also associated with increased sleep problems at the subsequent wave across the period with the exception of 8 to 9 years to 10 to 11 years. The model accounted for 69.5% of variance in sleep problems and 71.8% of variance in externalizing problems in adolescents aged 12 to 13 years.

Transactional Model of Sleep Problems and Both Internalizing and Externalizing Difficulties

Path estimates reflected those in the prior 2 models, with sleep consistently contributing to both externalizing and internalizing problems across time (Figure 4). However, the contribution to externalizing problems was attenuated from 6 to 7 years owing to the consistently stronger association between sleep problems and internalizing problems. Externalizing problems were relatively consistently associated with subsequent sleep problems and internalizing problems across time. Internalizing problems were not associated with subsequent sleep or externalizing problems across waves with the exception of internalizing problems at 6 to 7 years old contributing to increased sleep problems at 8 to 9 years. The model accounted for 69.5% of variance in sleep problems, 51.7% of variance in internalizing problems, and 71.8% of externalizing problems in adolescents aged 12 to 13 years.

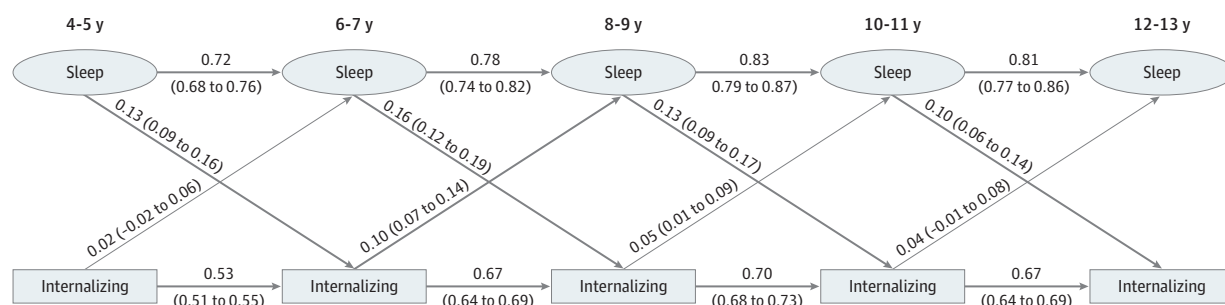
Pairs of paths were sequentially constrained, and Wald tests were used to test the relative strength of bidirectional associations among constructs at each time lag. The association between externalizing problems and sleep 2 years later and between sleep problems and externalizing problems 2 years later were relatively equal in magnitude at each period with the exception of 6 to 7 years to 8 to 9 years. During that period, the contribution of externalizing problems at 6 to 7 years to sleep problems 2 years later was stronger than the association between sleep problems at 6 to 7 years on later externalizing problems ($P = .03$, Wald test). For sleep problems and internalizing problems, the association from sleep problems at one time point to internalizing problems 2 years later was significantly stronger (P values $< .01$, Wald test) at each period with the exception of ages 10 to 11 years to 12 to 13 years, in which the estimates did not significantly differ in magnitude. Sleep-driven paths were stronger in magnitude in relation to later internalizing problems than externalizing problems from ages

Figure 1. Autoregressive and Cross-sectional Correlation Model for Sleep and Internalizing and Externalizing Problems



Fit indices: $\chi^2_{513} = 2700$; root mean square error of approximation = 0.03; comparative fit index = 0.95; and Tucker-Lewis index = 0.94. Standardized estimates (SEs) are shown. Factor loadings for the 5 sleep problem indicator variables are not shown.

Figure 2. Transactional Model for Sleep and Internalizing Problems



Fit indices: $\chi^2_{359} = 1460$; root mean square error of approximation = 0.03; comparative fit index = 0.97; and Tucker-Lewis index = 0.96. Standardized estimates (SEs) are shown. Thick lines indicate significant paths at $P < .01$.

Cross-sectional correlations among constructs were estimated but are not shown here. Factor loadings for the 5 problem indicator variables are not shown.

6 to 7 years to 10 to 11 years but were not significantly different from ages 4 to 5 years to 6 to 7 years or from ages 10 to 11 years to 12 to 13 years.

Discussion

Principal Findings

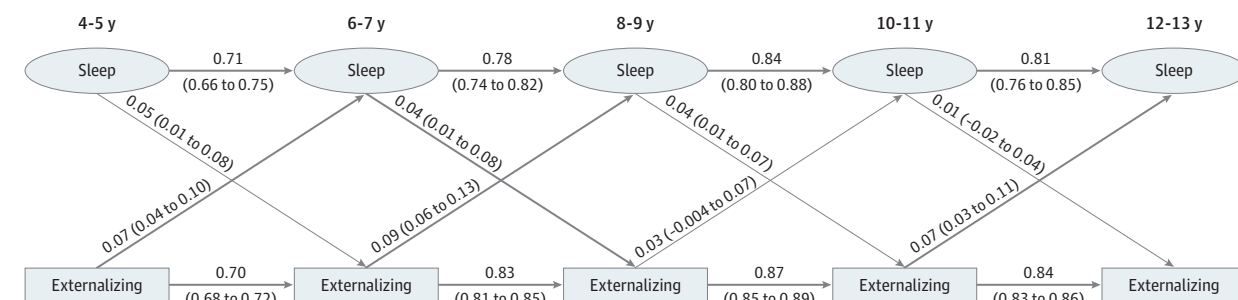
To our knowledge, this is the first study to examine the bidirectional association of sleep problems with internalizing and externalizing difficulties in children from the preschool to early adolescent years. Our findings demonstrated a bidirectional association between sleep problems and externalizing difficulties at some ages when measured at 5 time points between ages 4 to 5 years and 12 to 13 years. By contrast, no reciprocal association was detected between sleep problems and internalizing difficulties, with sleep problems being associated with later internalizing difficulties but not vice versa. Although the associations attenuated, these overall patterns remained even when both types of behavioral difficulties were examined si-

multaneously. These findings demonstrate the differences in the associations of sleep problems with internalizing and externalizing difficulties.

Interpretation in Light of Other Study Findings

Previous research has been conducted to examine the stability of sleep and internalizing and externalizing difficulties across childhood,^{20,26} and longitudinal studies have examined unidirectional associations, such as whether sleep problems are associated with later behavioral difficulties or vice versa.²⁻⁵ A growing body of research suggests that there is a bidirectional association between sleep problems and behavioral difficulties, with main findings to date obtained in infant populations.^{7,8} Our novel results, using data from 5 time points spanning the preschool and early adolescent years, demonstrated that the association both differed by type of behavioral difficulty and remained relatively stable across transition periods. We found evidence that sleep problems were associated with later externalizing difficulties, and the reverse association of externalizing difficulties being associ-

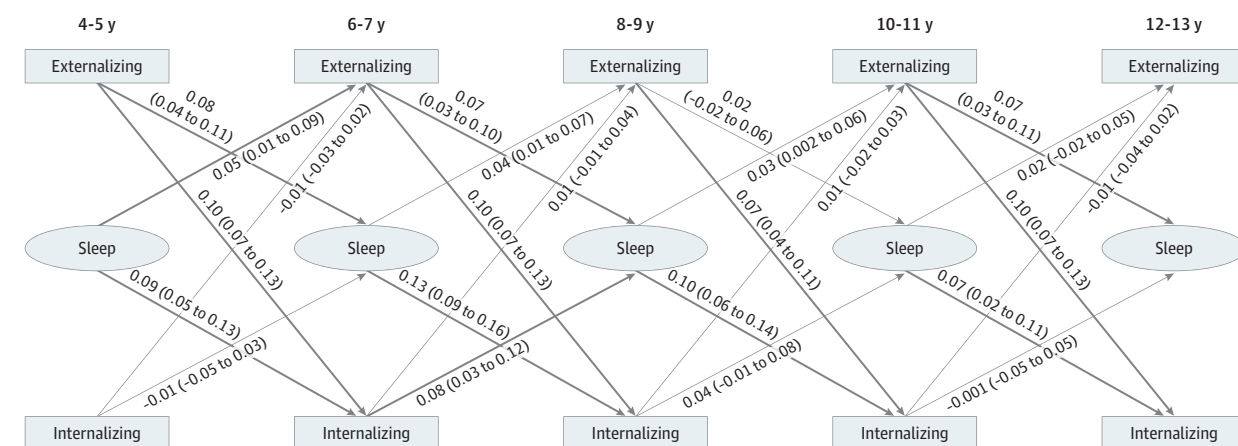
Figure 3. Transactional Model for Sleep and Externalizing Problems



Fit indices: $\chi^2_{359} = 1233$; root mean square error of approximation = 0.02; comparative fit index = 0.98; and Tucker-Lewis index = 0.97. Standardized estimates (SEs) are shown. Thick lines indicate significant paths at $P < .01$.

Cross-sectional correlations among constructs were estimated but are not shown here. Factor loadings for the 5 sleep problem indicator variables are not shown.

Figure 4. Transactional Model for Sleep and Internalizing and Externalizing Problems



Fit indices: $\chi^2_{489} = 1772$; root mean square error of approximation = 0.02; comparative fit index = 0.97; and Tucker-Lewis index = 0.96. Standardized estimates (SEs) are shown. Thick lines indicate significant paths at $P < .01$.

Autoregressive paths and cross-sectional correlations among constructs were estimated but are not shown here. Factor loadings for the 5 sleep problem indicator variables are not shown.

ated with later sleep problems was also present. However, internalizing difficulties were not associated with later sleep problems, although sleep problems were associated with later internalizing difficulties. These findings collectively strengthen the hypothesis that sleep problems contribute to the development of behavioral difficulties in children.^{3,20} However, it also highlights that children with externalizing difficulties are likely to have later sleep problems.

A few mechanisms may underpin our findings, especially the differences observed between internalizing and externalizing difficulties. For instance, studies with children from infancy have shown sleep problems to be reciprocally associated with parent-reported emotional dysregulation across early childhood, with early emotional dysregulation often exhibited through externalizing behaviors.⁸ In turn, early emotional regulation abilities are implicated in the later development of both internalizing and externalizing problems.^{27,28} The present study's findings also reflect those of prior studies that have suggested that externalizing problems contribute to internalizing problems over time.^{23,24} However, the unique

model presented here extends these findings by documenting both the direct contribution of externalizing problems to internalizing problems and also the indirect contribution through sleep problems. Thus, the findings of the present study along with those from studies assessing earlier childhood suggest a mutually exacerbating process of early sleep problems and externalizing behavior that both contribute to later internalizing problems.⁸

Implications for Clinicians and Policymakers

This study has multiple implications for clinical practice. First, the findings demonstrated the stability of externalizing, internalizing, and sleep problems over time, indicating the need for early intervention approaches to manage these common childhood problems. The evidence from this study suggests a developmental pathway through which sleep problems contribute to internalizing and externalizing problems. Externalizing difficulties appear to have both a direct contribution to internalizing problems (but not vice versa) and an indirect contribution through sleep problems. There was robust evidence

of a bidirectional association between externalizing and sleep problems from childhood to adolescence, which suggests that interventions focused on sleep should benefit externalizing behavior and, similarly, interventions focused on externalizing behavior should improve sleep. For example, data from a randomized clinical trial focused on the management of sleep problems in 244 children with ADHD found improved ADHD symptom severity and conduct problems for those in the intervention group compared with those receiving standard clinical care.¹⁹ Given the complex associations between mental health and sleep, it is essential that both are routinely assessed and managed in clinical practice.

Strengths and Limitations

The strengths of this study lie in its large population-representative sample, rigorous approach to longitudinal measurement invariance testing of the sleep problem factor, and the complex cross-lagged model design. These models are useful in understanding the longitudinal and reciprocal associations among constructs and, because they account for continuity in the constructs over time, can be considered optimal yet conservative tests of development processes and directions of associations.²⁹ The study is limited by the use of only

parent-reported data. However, for sleep problems, parent-reported questionnaires correlate well with objective measures of sleep problems.³⁰ In addition, statisticians have noted that common method bias may not routinely inflate associations found among variables, as is commonly thought.³¹ Still, further studies should seek to replicate these findings with variables collected from different informants (ie, child and parent) as well as with both objective and subjective measures. Studies that collect data at shorter intervals than the biannual periods reported here would also be useful in better understanding the pathways among sleep and behavior problems across time.

Conclusions

Overall, our findings suggest that interventions addressing sleep problems may have the dual benefit of reducing child externalizing and internalizing difficulties during the early years of elementary school. Interventions targeting externalizing difficulties may benefit childhood sleep, but the same is unlikely to be true for interventions targeting internalizing difficulties.

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Author Contributions: Drs Nguyen and Williams had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: All authors.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: All authors.

Critical revision of the manuscript for important intellectual content: All authors.

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Supplementary Online Content

Quach JL, Nguyen CD, Williams KE, Sciberras E. Bidirectional associations between child sleep problems and internalizing and externalizing difficulties from preschool to early adolescence. *JAMA Pediatr*. Published online December 4, 2017. doi:10.1001/jamapediatrics.2017.4363

eTable. Confirmatory Factor Analyses for Sleep Measures: Standardised Factor Loadings and Model Fit Indices (Chi-square Test, RMSE, CFI, and TLI)

eFigure 1. Autoregressive and Cross-sectional Correlations Model for Sleep, Internalizing, Hyperactivity and Conduct Problems

eFigure 2. Transactional Model for Sleep and Hyperactivity

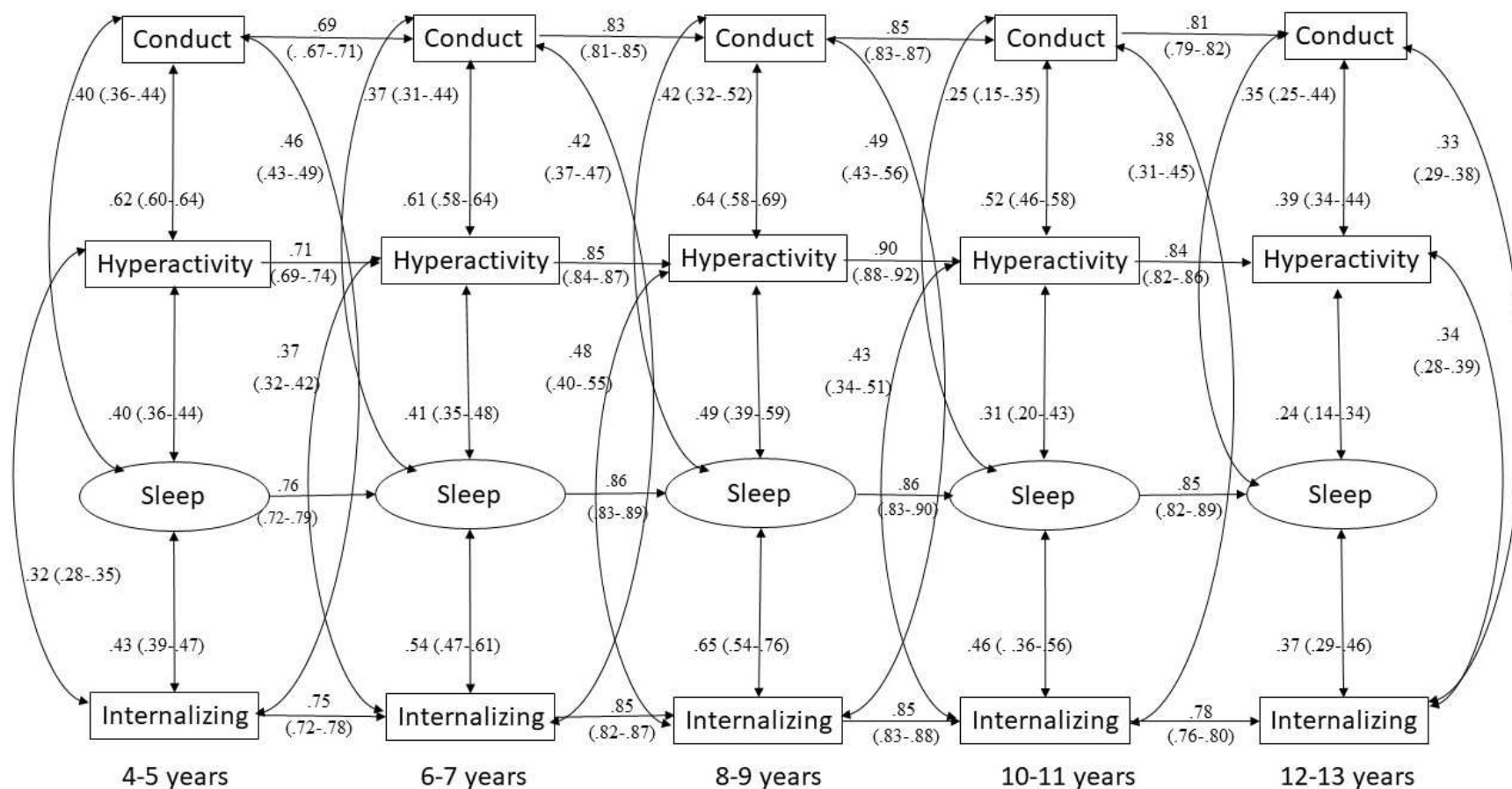
eFigure 3. Transactional Model for Sleep and Conduct Problems

eFigure 4. Transactional Model for Sleep, Internalizing, Hyperactivity, and Conduct Problems

This supplementary material has been provided by the authors to give readers additional information about their work.

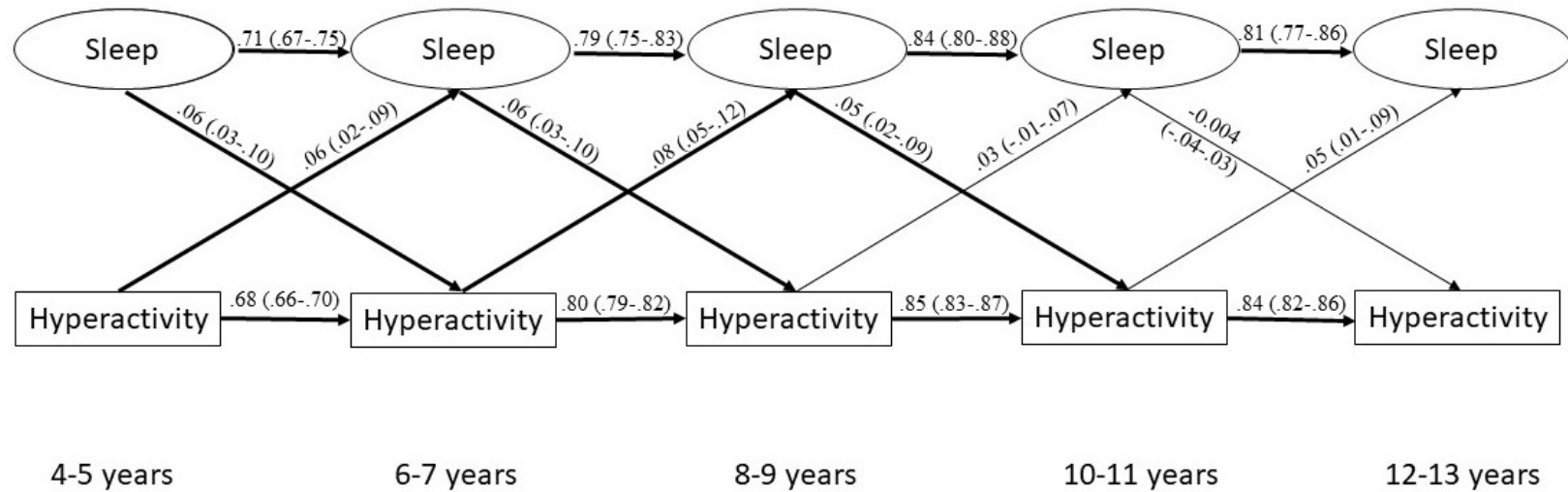
eTable. Confirmatory Factor Analyses for Sleep Measures: Standardised Factor Loadings And Model Fit Indices (Chi-square Test, RMSE, CFI, and TLI)

	Wave 1 4/5 years	Wave 2 6/7 years	Wave 3 8/9 years	Wave 4 10/11 years	Wave 5 12/13 years
Sleep problem					
Difficulty getting off to sleep	0.71	0.74	0.78	0.80	0.81
Not happy to sleep alone	0.64	0.66	0.65	0.63	0.49
Waking during the night	0.64	0.67	0.68	0.71	0.69
Seeming tired in the morning	0.60	0.67	0.76	0.70	0.76
How much is child's sleeping pattern or habits a problem?	0.91	0.88	0.89	0.88	0.82
Model fit indices					
χ^2 (degrees of freedom)	68.525 (5)	80.730 (5)	56.660 (5)	53.010 (5)	2.345 (5)
RMSEA	0.051	0.058	0.049	0.048	0.000
CFI	0.982	0.970	0.983	0.983	1.000
TLI	0.964	0.940	0.966	0.965	1.002



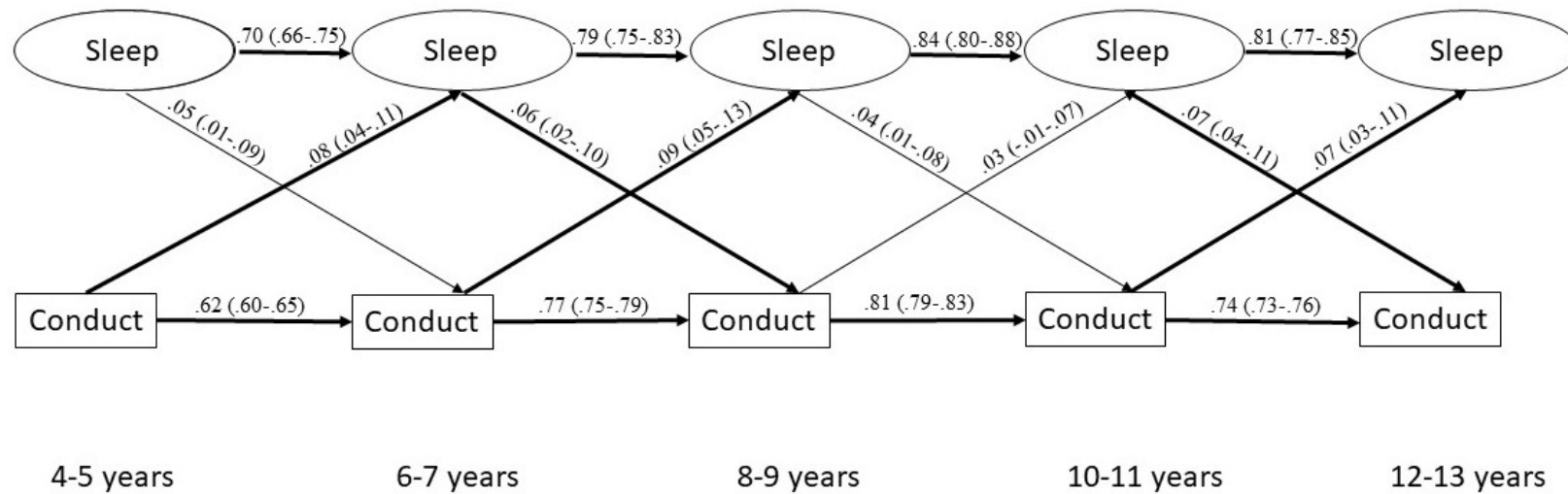
eFigure 1. Autoregressive and Cross-sectional Correlations Model for Sleep, Internalizing, Hyperactivity and Conduct Problems.

Fit indices: $\chi^2(df) = 3442 (679)$; RMSEA = .03; CFI = .95; TLI = .94. Standardized estimates (standard errors) are shown. Factor loadings for the five sleep problem indicator variables are not shown.



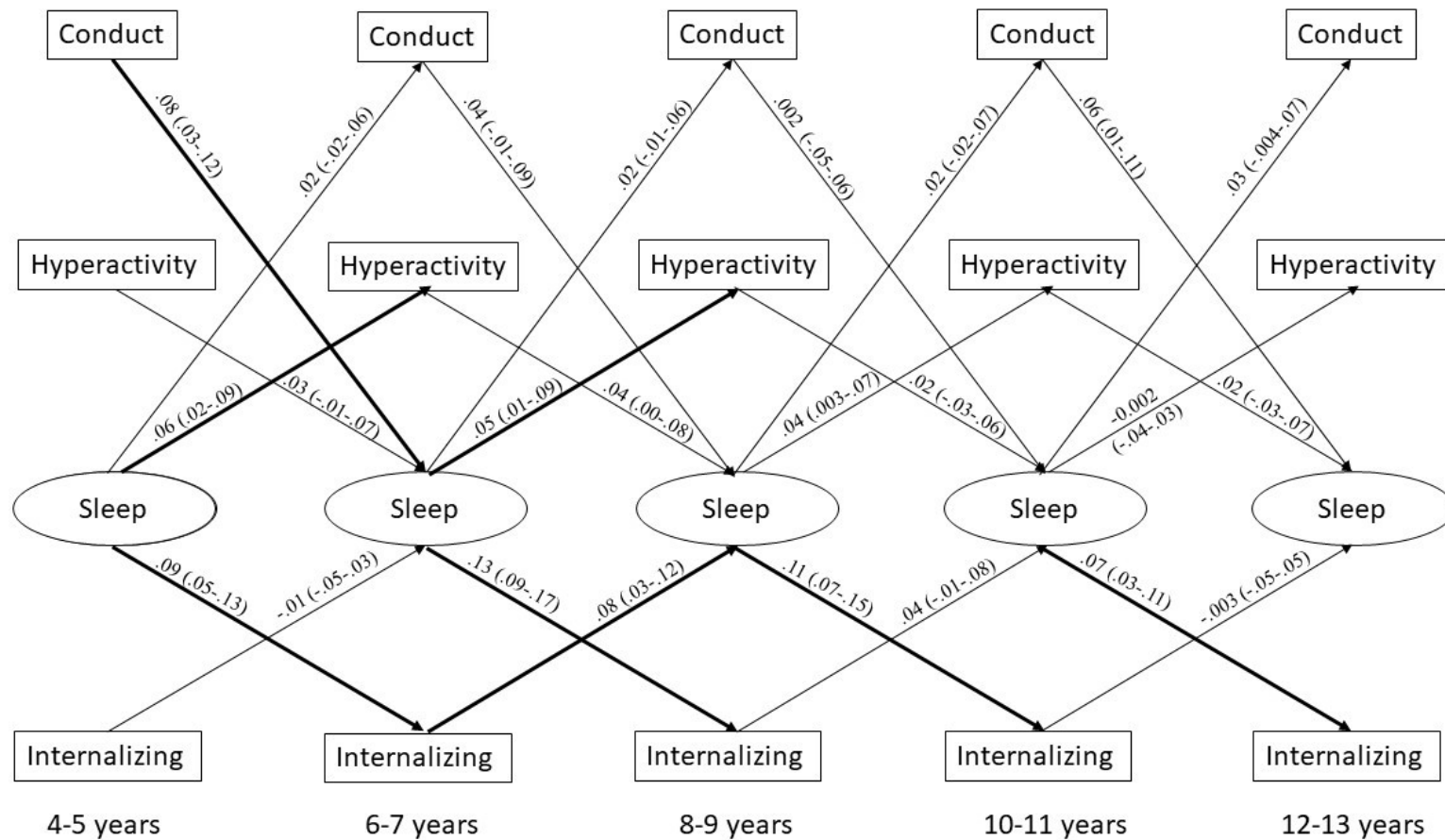
eFigure 2. Transactional Model for Sleep and Hyperactivity.

Fit indices: $\chi^2(df) = 1220(359)$; RMSEA = .02, CFI = .98, TLI = .97. Standardized estimates (standard errors) are shown. Thick lines indicate significant paths at $p < 0.01$. Cross-sectional correlations among constructs were estimated but are not shown here. Factor loadings for the five sleep problem indicator variables are not shown.



eFigure 3. Transactional Model for Sleep and Conduct Problems.

Fit indices: $\chi^2(df) = 1404 (359)$; RMSEA = .02; CFI = .97; TLI = .97. Standardized estimates (standard errors) are shown. Thick lines indicate significant paths at $p < 0.01$. Cross-sectional correlations among constructs were estimated but are not shown here. Factor loadings for the five sleep problem indicator variables are not shown.



eFigure 4. Transactional Model for Sleep, Internalizing, Hyperactivity, and Conduct Problems.

Fit indices: $\chi^2(df=2201)$ (631); RMSEA = .02; CFI = .97; TLI = .96. Standardized estimates (standard errors) are shown. Thick lines indicate significant paths at $p < 0.01$. Autoregressive paths, cross-sectional correlations among constructs, and cross-lagged paths between internalizing, hyperactivity and conduct problems were estimated but are not shown here. Factor loadings for the five sleep problem indicator variables are not shown.