A Cognitive Vulnerability Model of Sleep and Mood in Adolescents under Naturalistically Restricted and Extended Sleep Opportunities

Bei Bei, DPsych, PhD[1,2]; Joshua F. Wiley, MA[3,4]; Nicholas B. Allen, PhD[2]; John Trinder, PhD[2]

[1]*School of Psychological Sciences, Faculty of Medicine, Nursing and Health Sciences, Monash University, Victoria, Australia;* [2]*Melbourne School of Psychological Sciences, University of Melbourne, Victoria, Australia;* [3]*Department of Psychology, UCLA, Los Angeles, CA;* [4]*Elkhart Group Ltd., Columbia City, IN*

Study Objectives: School terms and vacations represent naturally occurring periods of restricted and extended sleep opportunities. A cognitive model of the relationships among objective sleep, subjective sleep, and negative mood was tested across these periods, with sleep-specific (i.e., dysfunctional beliefs and attitudes about sleep) and global (i.e., dysfunctional attitudes) cognitive vulnerabilities as moderators.

Design: Longitudinal study over the last week of a school term (Time-E), the following 2-w vacation (Time-V), and the first week of the next term (Time-S).

Setting: General community.

Participants: 146 adolescents, 47.3% male, mean age = 16.2 years (standard deviation ± 1 year).

Interventions: N/A.

Measurements and Results: Objective sleep was measured continuously by actigraphy. Sociodemographics and cognitive vulnerabilities were assessed at Time-E; subjective sleep, negative mood (anxiety and depressive symptoms), and academic stress were measured at each time point. Controlling for academic stress and sex, subjective sleep quality mediated the relationship between objective sleep and negative mood at all time points. During extended (Time-V), but not restricted (Time-E and Time-S) sleep opportunity, this mediation was moderated by global cognitive vulnerability, with the indirect effects stronger with higher vulnerability. Further, at Time-E and Time-V, but not Time-S, greater sleep-specific and global cognitive vulnerabilities were associated with poorer subjective sleep quality and mood, respectively.

Conclusions: Results highlighted the importance of subjective sleep perception in the development of sleep related mood problems, and supported the role of cognitive vulnerabilities as potential mechanisms in the relationships between objective sleep, subjective sleep, and negative mood. Adolescents with higher cognitive vulnerability are more susceptible to perceived poor sleep and sleep related mood problems. These findings have practical implications for interventions.

Keywords: adolescents, anxiety, attitudes, beliefs, cognitive vulnerability, depression, mood, sleep, sleep restriction, vacation

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INTRODUCTION

There is growing recognition that a significant number of adolescents obtain insufficient and poor quality sleep,[1,2] especially during school weekdays.[3] Major contributing factors include maturational processes that produce a progressive delay in the circadian timing of sleep and a reduction in homeostatic drive across adolescence,[4] early school start times,[3] and psychosocial factors such as less parental control over bedtime and the emergence of cultural social interests and obligations.[4,5] Insufficient and poor sleep has been linked to psychosocial and physical consequences such as impaired cognitive performance,[6] obesity,[7] and increased risks for mood problems[8] in adolescents.

The Sleep-Mood Relationship in Adolescents

The adolescent literature on the bidirectional relationship between sleep and negative mood has focused on two areas: sleep differences among adolescents with and without a mood/anxiety disorder, and whether sleep restriction/deprivation affects mood. Sleep can be assessed objectively using polysomnography (PSG) or actigraphy, and subjectively using self-report questionnaires or sleep diary. Depressive[9] or anxiety [10,11] disorders have typically been associated with longer sleep onset latency (SOL), more awakenings, and shorter rapid eye movement latency. In adolescents, lower subjective sleep quality and quantity are cross-sectionally associated with negative mood,[12–14] and longitudinally with increased risk of mood problems.[15,16] Studies that have integrated objective with subjective measurements of sleep are rare, and results are somewhat inconsistent. For example, among community adolescents, subjective sleepiness, but not actigraphy-measured sleep duration or its variability, was related to anxiety/depressive symptoms.[8] Nevertheless, longer PSG-measured SOL during childhood/adolescence predicted adulthood depression,[17] and experimentally restricting sleep in adolescents worsened mood and emotional regulation,[18–21] suggesting an etiological role for sleep in negative mood.

A Cognitive Vulnerability Model of the Sleep-Mood Relationship

From a neurocognitive perspective the prefrontal cortex (PFC), which is important for cognitive control and affect regulation,[22] undergoes ongoing development during adolescence.[23] The negative effects of sleep deprivation on the functioning of the PFC [24] has been proposed as a potential neurocognitive mechanism underlying the affective consequences of inadequate sleep.[25,26]

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Address correspondence to: Bei Bei, DPsych(Clinical), PhD, School of Psychological Sciences, Faculty of Medicine, Nursing and Health Sciences, Building 17 Clayton Campus, Monash University VIC3800; Tel: + 61 3 9905 3903; Email: bei.bei@monash.edu

However, few studies have explored the mechanisms underlying the relationship between sleep and negative mood from a psychological perspective. The stronger relationship between subjective sleep and mood when compared to that between objective sleep and mood[8,27,28] suggests that psychological factors that contribute to personal experiences of sleep might play important roles in the sleep-mood relationship. One such psychological factor is cognitive vulnerability—erroneous beliefs, cognitive biases, or patterns of thought that predispose individuals to a higher likelihood of psychopathology.[29] The importance of these cognitive processes in the development and maintenance of mood problems is supported by strong empirical evidence in both adults[30] and adolescents[31–34] yet they are rarely applied to understand the sleep-mood relationship.

Sleep-Specific Cognitive Vulnerability

When dysfunctional beliefs and attitudes are related to sleep, they are sleep specific, and are most commonly assessed using the Dysfunctional Beliefs and Attitudes about Sleep (DBAS) Scale.[35] The contribution of DBAS as a sleep-specific cognitive vulnerability to sleep complaints is elegantly illustrated in Harvey's cognitive model of insomnia,[36] which proposes that individuals with insomnia tend to be preoccupied by sleep and the daytime consequences of poor sleep. This excessive, negatively toned, cognitive activity triggers selective attention and monitoring of sleep related threat cues, and can lead to overestimation of sleep deficit. Few studies have assessed DBAS among adolescents; however, those that did have found that higher DBAS scores were associated with longer actigraphy-assessed SOL,[37] as well as shorter subjectively assessed nighttime sleep and more regular napping.[38] These findings suggest a link between DBAS and poor sleep in adolescents, and a potential role of DBAS in sleep perception and sleep safety behaviors (e.g., napping).

Global Cognitive Vulnerability

When dysfunctional beliefs and attitudes are not focused on a specific behavioral or experiential domain, they are global. Based on Beck's widely studied cognitive model,[39] early adverse events foster negative attitudes and biases about self, world, and future, that are integrated into the cognitive organization in the form of schemas, which become activated by later life stressors that impinge on the specific cognitive vulnerability, leading to systematic negative biases at the core of depression.[40]

There is some evidence that global cognitive vulnerabilities might play a role in the association between sleep complaints and negative mood. For example, in adolescents, sleep problems have been associated with cognitive factors (cognitive errors and control beliefs) that were closely linked to anxiety and depression.[41] Among young female adults,[42] insufficient sleep has been shown to be correlated with melancholic symptoms such as "I thought my life had been a failure" rather than "poor concentration" or "difficulty to get going". Also, a recent study in older adults showed that hopelessness, an aspect of global cognitive vulnerability, partially mediated the effect of insomnia on depressive symptoms.[43]

Restricted and Extended Sleep Opportunities

In adolescents, school days are associated with restricted sleep opportunities[12,44] and vacation periods with extended sleep opportunities.[3] It is important to study the roles of cognitive vulnerability in the sleep-mood relationship during both school and vacation periods because (1) they represent two distinctive sleep-wake patterns common to most adolescents, (2) naturalistic changes in sleep opportunity over school terms and vacation are associated with changes in sleep quality such as SOL[3] that are relevant to mood,[17] and (3) this allows examination of cognitive vulnerabilities under two conditions in which school schedule, an exogenous nonpsychological factor, is the main contributing factor to differences in sleep opportunity.

The Current Study

In this study, a cognitive vulnerability model of the relationships between objective sleep, subjective sleep, and negative mood (see Figure 1) was proposed and tested in a single model during both school terms and vacations. It was hypothesized that:

1. Subjective sleep perception would mediate the relationship between objective sleep and negative mood.
2. Based on the cognitive model of insomnia,[36] higher sleep-specific cognitive vulnerability would be associated with worse subjective sleep, and that the relationship between objective sleep and subjective sleep would be moderated by sleep-specific cognitive vulnerability.
3. Based on the general cognitive model of depression,[39] higher global cognitive vulnerability would be associated with worse mood, and that the relationship between subjective sleep and negative mood would be moderated by global cognitive vulnerability. This part of the model proposes that perceived poor sleep functions as a form of life stress and interacts with biased cognitions in vulnerable individuals to lead to negative mood.

Academic stress and sex were included as covariates as the prior literature has shown that higher academic stress[45,46] and being female[47,48] were associated with mood problems in adolescents. Academic stress was controlled because it was theorized that it is a major non-sleep related contributor to the mood differences between the school and vacation periods.

METHODS

Participants

Participants were 146 adolescents (47.26% males, age mean ± standard deviation = 16.18 ± 1.00 y) enrolled in y 10–12 of Australian secondary colleges, and were primarily of Australian (59.6%) or Asian (26.7%) descent. One female was excluded because the presence of multiple sleep disorders with daily naps, and data from the first week were excluded from one female because of physical illness. A small number of participants reported having a depressive, anxiety, or attention deficit hyperactivity disorder (6.16%), or sleep conditions (11.64%) such as insomnia and bruxism at the time of recruitment (see Bei et al.[3] for details). No significant differences in model fit or parameter estimates were found when the hypothesized model was estimated with or without these participants. Therefore, they were not excluded to retain the representativeness of a community sample.

Procedures

Procedures were approved by the Human Research Ethics Committee of the University of Melbourne. Participants were recruited via flyers in community centers and school e-newsletters with two movie vouchers as incentives. Informed consent was obtained from participants and guardians.

Data were collected over school terms and vacations (typically 2 w in Australia), excluding summer vacations, using an actigraph and online surveys. Participants were asked to register bedtimes and rise times using the actigraph's Event Marker and wear the actigraph on the non-dominant hand continuously for 4 w: the last school term week (Time-E [End]), through the 2-w vacation (Time-V [Vacation]), and the first week of the following term (Time-S [Start]). The measures of subjective sleep, negative mood, and academic stress referred to the preceding week, and were collected over Time-E, Time-V (within the second week of vacation), and Time-S. Demographics and cognitive vulnerability were assessed at Time-E.

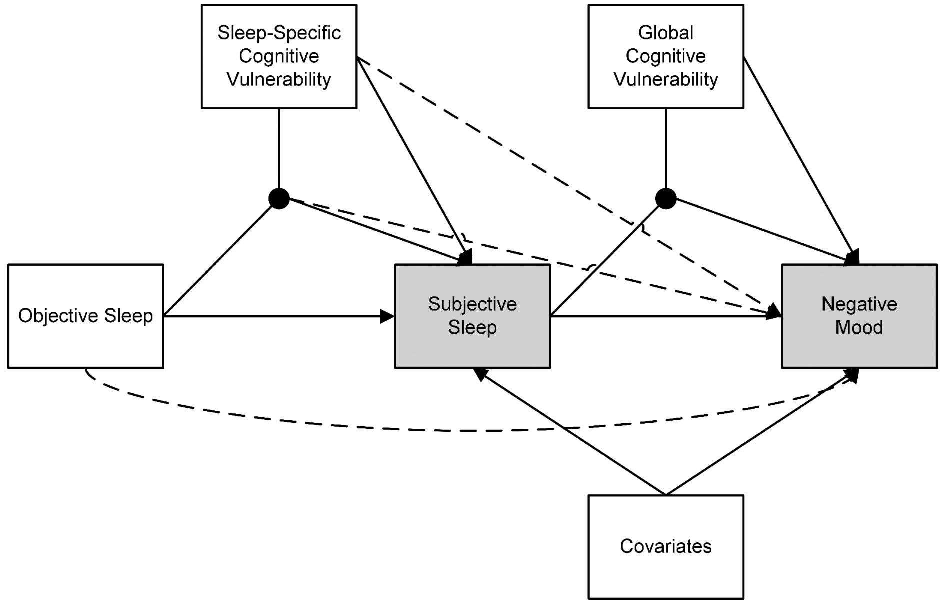

Figure 1—Analytic model of the relationships among objective sleep, subjective sleep, and cognitive vulnerabilities. Gray boxes indicate dependent variables, white boxes indicate independent variables, black dots represent the interaction of variables, lines with arrows represent directional regression paths from one variable to another, dotted lines represent paths that were not specifically hypothesized but were necessary to allow the possibility that effects were not mediated by subjective sleep but rather were direct effects on mood.

Equipment and Materials

Actigraphy

Actigraphy is widely used to study sleep patterns in adolescents,[49] and provides estimates of sleep duration and quality close to that of PSG.[50] Actiwatch 2 and Actiwatch-64 (Mini Mitter, Bend, OR, USA) with comparable sleep statistics[51] were used with data collected at 1-min epochs and analysed based on "medium" threshold for sleep/wake detection in Actiware 5.5. The following variables were generated using Actiware software (details on data processing see Bei et al.[3]): total sleep time (TST_{acti}), sleep onset latency (SOL_{acti}), sleep efficiency (SE_{acti}), and percentage of wake after sleep onset ($\%WASO_{acti}$). For Time-E and Time-S with restricted sleep opportunity, data from Monday to Thursday (24-h cycles that started and ended on a school day) were averaged; weekend days with extended sleep opportunity were not included. Data from the Saturdays at the start to the end of the vacation were averaged for Time-V variables.

Questionnaires

Subjective Sleep: The Pittsburgh Sleep Quality Index[52] (PSQI) is well validated[53] and has been applied in the adolescent population to assess sleep problems with good reliability.[14,54] In this study, two subjective component scores were derived using PSQI raw values. First, TST_{psqi} (min) was used as the subjective sleep duration variable. Second, raw values for SOL_{psqi} (min), SE_{psqi} (%), SD_{psqi} (sleep disturbance; sum of items 5b–5j), SQ_{psqi} (sleep quality; item 9), and DD_{psqi} (sleep related daytime dysfunction; item 7) were standardized and summed to be the subjective sleep quality (SSQ) variable. Item 8, "how much of a problem was it for you to keep up enthusiasm to get things done?" was not included to reduce overlap with negative mood.

Negative Mood: Negative mood was assessed using two well-validated scales for depressive (Center for Epidemiological Studies Depression Scale; CES-D[55]) and anxiety (Spence Children's Anxiety Scale; SCAS[56]) symptoms. The CES-D has 20 items, and has been validated for use in adolescents[57]; the 44-item SCAS was designed for assessing various aspects of anxiety in children and adolescents. To reduce overlap between sleep and negative mood, scores on the item "my sleep was restless" was removed from the total score of CES-D. Both scales had excellent internal consistency reliability across all time points (all Cronbach $\alpha \geq 0.89$). Correlations between the total scores of CES-D and SCAS were high across time (r ranged 0.59–0.66). This is consistent with the notion that although depression and anxiety can be reliably distinguished, they have substantial overlap.[58] In this study, overall negative mood was of interest, and scales of depression and anxiety were standardized and summed within each time point to make a composite score (MOOD) where higher values indicate greater negative mood.

Cognitive Vulnerability: Sleep-specific cognitive vulnerability was assessed using the Dysfunctional Beliefs and Attitudes about Sleep Scale-16 (DBAS-16), an abbreviated form of the DBAS Scale that is well validated.[59] Global cognitive vulnerability was assessed using the Dysfunctional Attitude Scale (DAS), a 40-item questionnaire that assesses assumptions and beliefs based on Beck's cognitive model,[60,61] and is

Table 1—Means (standard deviations) of objective sleep, subjective sleep, mood, academic stress, and cognitive vulnerability variables.

Variable	Time-V	Time-S	Time-E
Objective sleep			
BT_{acti}	00:39 (81.42)	23:22 (71.65)	23:14 (61.96)
TST_{acti}	430.15 (48.32)	389.35 (52.75)	398.01 (46.07)
SOL_{acti}	20.33 (12.49)	19.97 (15.71)	15.80 (11.82)
SE_{acti}	79.70 (5.37)	81.11 (5.72)	81.92 (5.14)
$\%WASO_{acti}$	13.70 (4.84)	12.38 (4.57)	12.52 (4.31)
Subjective sleep			
TST_{psqi}	499.38 (88.02)	439.71 (72.15)	443.19 (66.51)
SOL_{psqi}	24.03 (21.54)	27.54 (24.82)	24.40 (20.29)
SE_{psqi}	86.76 (10.84)	89.46 (9.17)	89.29 (8.49)
SD_{psqi}	3.53 (2.81)	3.36 (2.63)	3.26 (2.64)
DD_{psqi}	0.45 (0.58)	0.77 (0.72)	0.72 (0.68)
SQ_{psqi}	1.15 (0.77)	1.30 (0.70)	1.24 (0.66)
PSQI Global [a]	5.62 (2.94)	6.26 (3.29)	5.91 (2.63)
Mood			
CES-D	11.23 (8.40)	12.55 (8.67)	13.21 (9.29)
SCAS	19.08 (13.56)	17.59 (14.00)	23.50 (14.84)
Academic stress	32.51 (10.87)	35.68 (10.66)	39.65 (10.54)
Vulnerabilities			
DBAS	72.02 (26.24)		
DAS	125.82 (32.43)		

[a] Global PSQI scores were provided for reference only, and were not used for any analysis. All variables followed with "acti" in subscript were derived from actigraphy, and all variables followed with "psqi" in subscript were derived from the Pittsburgh Sleep Quality Index (PSQI). n ranged from 136–145 for each variable because of a small amount of missing data. BT, bedtime, CES-D, Center for Epidemiologic Studies Depression Scale; DAS, dysfunctional attitudes scale; DBAS, dysfunctional beliefs and attitudes about sleep; DD, daytime dysfunction; SE, sleep efficiency; SCAS, Spence Children's Anxiety Scale; SD, sleep disturbance; SOL, sleep onset latency; SQ, sleep quality; Time-E, end of term; Time-S, start of term; Time-V, vacation period; TST, total sleep time; %WASO, % wake after sleep onset.

validated for use in adolescents.[62] Higher total scores on both the DBAS-16 and the DAS indicate higher endorsement of dysfunctional beliefs. In this study, Cronbach α was 0.86 for DBAS and 0.92 for DAS.

Academic Stress: Academic stress was measured using 18 academic-specific items (e.g., "struggling to meet your own standards of performance at school") from the 41-item Inventory of High-School Students' Recent Life Experiences.[63] Participants were asked to rate from 1 to 4 how each experience had been a part of his/her life, and the 18 items were summed to create a composite where higher total scores reflect greater academic stress. The academic stress composite had excellent internal consistency reliability across time points (all Cronbach $\alpha \geq 0.90$).

Statistical Analysis

Analytic Plan

The hypothesized model in Figure 1 was tested as a single model in two steps. First, preliminary analyses were conducted using a series of linear regression analyses to determine the specific objective and subjective sleep variables that best represented the objective and subjective concepts. Second, primary model analyses were conducted at all three time points to test the hypothesized model in Figure 1. Sex and academic stress were included as covariates. Age was considered as a covariate, but was excluded after preliminary analyses showed that it shared minimal correlations at all time points (all r's < 0.11, all P > 0.05) with all variables included in the model.

Statistical Methods

Primary analyses were estimated in a Bayesian path analysis framework,[64,65] which performs excellently for mediation analysis,[66] using R 3.0[67] and Mplus 7.0[68] via MplusAutomation 0.6-2.[69] Missing data were handled by using all available data, which is more efficient than listwise deletion. Outliers and normality were assessed and one outlier was removed from SOL_{acti} and SOL_{psqi} at Time-V. Further, the Bayesian inference is robust to non-normality. To facilitate interpretation, continuous variables were standardized to have a mean of zero and standard deviation of one.

Minimally informative priors were used for all parameters and convergence was determined using the Gelman scale reduction factor < 1.05 from two independent chains[70] with at least 5,000 iterations. Model fit was assessed using posterior predictive checks,[71] which give a P value for the difference between the estimated and observed covariance matrix. A non-significant value indicates good fit. Parameter estimates are reported as the posterior medians and 95% credible intervals. Two-tailed significance tests were used and P < 0.05 was considered statistically significant.

RESULTS

Descriptive Statistics

Descriptive statistics are shown in Table 1. Differences in objective sleep variables between time points have been reported previously.[3] The data indicate that compared to Time-V with extended sleep opportunity, Time-S and Time-E were associated with substantial sleep restriction with significantly shorter sleep duration, shorter SOL, and more consolidated sleep as measured by actigraphy. Linear mixed models showed that compared to school term, Time-V was associated with significantly shorter TST_{psqi}, higher DD_{psqi}, and lower SE_{psqi}; however, SD_{psqi} and SOL_{psqi} were not significantly different across time points. Depressive symptoms increased significantly from Time-V to Time-E, whereas anxiety symptoms decreased from Time-V to Time-S, but were highest at Time-E. Overall the sample was healthy, with 90.41%, 89.04%, and 84.25% scoring under the clinical cutoff on the CES-D,[72] and 91.78%, 90.41%, and 81.51% within the normal range on the SCAS[56] at Time-V, Time-S, and Time-E respectively.

The rate of missing data on actigraphy was low (91.40% of all daily data were available) and was caused by technical faults, inconvenience of wearing the actigraph during certain activities, potential participant noncompliance, and a lost actigraph. Objective sleep variables based on averaged actigraphy daily values had ≤ 6.20% missing at any time point. The rate

Table 2—Results of the cognitive vulnerability model tested at Time-V, Time-S, and Time-E.

	Time-V		Time-S		Time-E	
	β (SE)	95% CI	β (SE)	95% CI	β (SE)	95% CI
MOOD						
SOL_{acti}	−0.07 (0.08)	−0.21, 0.08	−0.04 (0.07)	−0.18, 0.10	−0.01 (0.06)	−0.12, 0.11
SSQ	0.29 (0.08) [c]	0.14, 0.43	0.42 (0.07) [c]	0.29, 0.57	0.31 (0.06) [c]	0.20, 0.43
DBAS	0.14 (0.07) [a]	0.00, 0.27	0.15 (0.07) [a]	0.02, 0.29	0.18 (0.06) [b]	0.06, 0.30
DAS	0.21 (0.07) [b]	0.06, 0.35	0.04 (0.06)	−0.08, 0.17	0.24 (0.06) [c]	0.12, 0.36
SSQ × DAS	0.12 (0.06) [a]	0.00, 0.24	nonsignificant, dropped from model		nonsignificant, dropped from model	
Female	0.44 (0.13) [b]	0.18, 0.70	0.26 (0.13) [a]	0.00, 0.51	0.28 (0.11) [a]	0.05, 0.50
Academic stress	0.28 (0.07) [c]	0.13, 0.42	0.29 (0.07) [c]	0.15, 0.43	0.33 (0.07) [c]	0.21, 0.46
SSQ						
SOL_{acti}	0.36 (0.08) [c]	0.22, 0.52	0.21 (0.07) [b]	0.06, 0.36	0.21 (0.08) [b]	0.06, 0.36
DBAS	0.16 (0.07) [c]	0.02, 0.32	0.09 (0.08)	−0.06, 0.24	0.30 (0.08) [c]	0.15, 0.46
Female	0.18 (0.15)	−0.11, 0.47	0.29 (0.16)	−0.03, 0.59	0.23 (0.15)	−0.07, 0.53
Academic stress	0.20 (0.07) [b]	0.05, 0.35	0.32 (0.08) [c]	0.15, 0.47	0.18 (0.08) [a]	0.02, 0.34
Indirect effect	significant indirect effect was moderated, see Figure 2		0.09 (0.04) [b]	0.02, 0.17	0.06 (0.03) [b]	0.02, 0.12
Model fit P value	0.347		0.311		0.215	

MOOD and SSQ are dependent variables, other variables are predictors. Standardized estimates and standard errors are reported, with 95% confidence intervals (CI). [a] $P < 0.05$. [b] $P < 0.01$. [c] $P < 0.001$. DAS, dysfunctional attitudes scale; DBAS, dysfunctional attitudes about sleep; MOOD, a composite score based on standardized Center for Epidemiological Studies Depression Scale and Spence Children's Anxiety Scale; SOL_{acti}, actigraphy-assessed sleep onset latency; SSQ, subjective sleep quality (higher is worse), a composite score based on sleep quality subscales of Pittsburgh Sleep Quality Index; Time-E, end of term; Time-S, start of term; Time-V, vacation period.

of missing data for questionnaires was similarly low (≤ 4.14%) across all time points.

Preliminary Analyses

To identify which sleep variables uniquely explained negative mood at each time point, MOOD was simultaneously regressed on SSQ and TST_{psqi}, and on BT_{acti}, TST_{acti}, SOL_{acti}, SE_{acti}, and $\%WASO_{acti}$, controlling for sex and academic stress. SSQ was the only statistically significant subjective sleep variable (all $P < 0.001$), whereas no actigraphy variable was significant (all $P > 0.08$). Next, SSQ was simultaneously regressed on BT_{acti}, TST_{acti}, SOL_{acti}, SE_{acti}, and $\%WASO_{acti}$ to examine whether objective sleep variables uniquely explained SSQ. Across all time points, SOL_{acti} was the only significant explanatory variable (all $P < 0.05$), with higher SOL_{acti} being associated with worse SSQ. Therefore, SOL_{acti} was used for objective sleep and SSQ for subjective sleep.

Primary Model Analyses

The full model shown in Figure 1 was tested at all three time points with good model fit (see results in Table 2). The interaction of SOL_{acti} with DBAS was not a significant predictor of SSQ or MOOD at any time point (all $P > 0.05$) and was therefore dropped in the final models. The interaction of SSQ with DAS did not significantly predict MOOD at Time-S or Time-E, and this path was dropped from the model at Time-S and Time-E. No other paths from the model were dropped.

The Mediating Role of Subjective Sleep (Hypothesis 1)

Across all time points after controlling for academic stress and sex, SOL_{acti} was significantly associated with SSQ, such that if SOL_{acti} was longer by one standard deviation, SSQ was worse by 0.21 to 0.36 standard deviations (all $P < 0.01$). Although SOL_{acti} was not significantly associated with MOOD, worse SSQ was significantly associated with more negative MOOD across all time points (all $P < 0.001$).

There was a significant indirect effect of SOL_{acti} on MOOD via SSQ at Time-S (β = 0.09, $P = 0.002$) and Time-E (β = 0.06, $P = 0.008$), such that longer SOL_{acti} was associated with higher SSQ, which in turn was associated with more negative MOOD. The indirect effect was also significant at Time-V; as this significant mediation effect was qualified by moderation, it is discussed under Hypothesis 3. Therefore, Hypothesis 1, that subjective sleep mediates the relationship between objective sleep and negative mood, was supported at all three time points.

The Role of DBAS (Hypothesis 2)

The direct effect of DBAS on SSQ was significant at Time-V ($P = 0.028$) and Time-E ($P < 0.001$), and higher DBAS was associated with worse SSQ. The direct effect of DBAS on SSQ was not significant at Time-S ($P = 0.23$). The interaction of DBAS and SOL_{acti} on SSQ was not significant at all time points. These results suggest that DBAS did not moderate the relationship between objective and subjective sleep, but made significant direct contributions to subjective sleep at Time-V and Time-E. This partially confirms Hypothesis 2.

The Role of DAS (Hypothesis 3)

The direct effect of DAS on MOOD was significant at Time-V and Time-E ($P < 0.01$), and higher DAS was associated with more negative mood. The direct effect of DAS on MOOD was not significant at Time-S ($P > 0.05$).

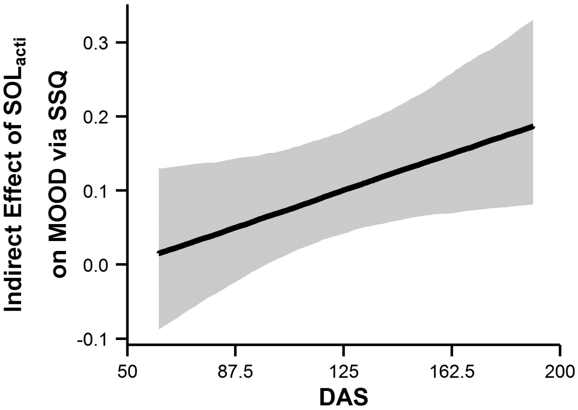

Figure 2—Line represents the indirect effect of SOL_{acti} on MOOD via SSQ at each value of DAS. The shaded region represents 95% credible intervals. When the interval does not include 0, the indirect effect is statistically significant at $P < 0.05$. DAS, dysfunctional attitudes scale; MOOD, a composite score; SOL_{act}, actigraphy-assessed sleep onset latency; SSQ, subjective sleep quality.

At Time-V (but not Time-V or Time-E), there was a significant SSQ by DAS interaction, such that the association between SSQ and MOOD was stronger with higher DAS scores (more vulnerable). Also at Time-V, the significant mediating effect of SSQ between SOL_{acti} and MOOD was moderated by DAS, such that the indirect effect was stronger for individuals with higher vulnerability (higher DAS scores). The indirect effects of SOL_{acti} on MOOD via SSQ across a range of DAS values are shown in Figure 2. The indirect effect is statistically significant for DAS raw scores ≥ 98.22, when the 95% confidence interval does not include zero. In this sample, the range of DAS was from 60 to 221, with 115 participants falling above the 98.22 cutoff on DAS where the indirect effect is significant.

Thus, the hypothesis that global cognitive vulnerability (i.e., DAS) moderates the relationship between sleep perception and negative mood was supported for extended but not restricted sleep opportunity. DAS also made significant direct contributions to negative mood at Time-V and Time-E.

Covariates

At all time points, higher academic stress was significantly associated with worse SSQ (all $P < 0.05$), whereas the effect of sex on SSQ was not significant. Sex and academic stress had moderate and significant effects on MOOD across all time points, such that being female (all $P < 0.05$) and having higher academic stress (all $P < 0.001$) were associated with more negative MOOD.

DISCUSSION

Findings suggest that the cognitive vulnerability model proposed in Figure 1 can be useful in understanding the relationship between sleep and negative mood in adolescents over both restricted and extended sleep opportunities.

Subjective Sleep, Objective Sleep, and Mood

At all time points, actigraphy-measured SOL was the only objective variable that made significant, unique contributions to SSQ. This suggests that the presleep period and ease of sleep onset are key aspects of sleep experience upon which adolescents base their sleep perception, and are critical to their evaluation of overall sleep quality. The finding from the preliminary analysis that SSQ, but not objective sleep, was significantly associated with negative mood at all time points is consistent with the current understanding in both adolescent[8] and adult[27] literature. The finding that during both restricted and extended sleep opportunities, SSQ mediated the relationship between objective sleep and negative mood highlighted an important mechanistic role of perceived sleep quality in sleep related mood problems among adolescents.

Sleep-Specific Cognitive Vulnerability

In this study, DBAS as a sleep-specific cognitive vulnerability was not found to be a moderator between objective and subjective sleep, but a direct contributor to SSQ after controlling for academic stress and sex. The significant association between higher DBAS and worse SSQ at Time-E and Time-V is consistent with findings in adults that individuals with higher DBAS tend to have more sleep complaints.[36,73] Findings in this study suggested that sleep-specific cognitive vulnerability might predispose adolescents to perceive poorer sleep quality during both restricted and extended sleep opportunities.

The effect of DBAS on SSQ was stronger at Time-E compared to Time-V. It is possible that although the effects of academic stress on SSQ was controlled, concerns regarding school-related sleep restriction and its daytime consequences at the end of a school term might have contributed to a stronger effect of DBAS compared to during vacation periods. The absence of a significant effect of DBAS on SSQ at Time-S can be interpreted in light of substantial changes in sleep-wake patterns at the start of a new school term: attitudes and beliefs might play a more important role at Time-V and Time-E when sleep-wake schedules were more stably established, compared to at Time-S when there was an abrupt advance in sleep timing and significant sleep restriction as adolescents transitioned from extended to restricted sleep opportunity.[3] Thus, sleep parameters might be more strongly affected by changes in externally imposed sleep schedules.

Global Cognitive Vulnerability

Consistent with Beck's cognitive model,[39] after controlling for SSQ and covariates, higher dysfunctional attitudes were associated with more negative mood at Time-E and Time-V. Similar to the findings for DBAS and SSQ, the absence of a significant effect of DAS on MOOD at Time-S might be caused by other factors associated with the transition from extended to restricted sleep opportunity having greater effect on mood than dysfunctional beliefs.

During extended (Time-V) but not restricted (Time-S or Time-E) sleep opportunity, DAS moderated the relationship between SSQ and negative mood. In addition, DAS moderated the significant indirect effects of SOL_{acti} on negative mood via SSQ, such that greater endorsement on dysfunctional attitudes was associated with a significantly stronger relationship between SSQ and negative mood, as well as a stronger mediating effect of SSQ. In other words, when sleep opportunity is unconstrained, subjective sleep perception is of particular relevance to negative mood among cognitively vulnerable adolescents, and they were more likely to experience negative mood upon perceiving poor sleep. Adolescents with higher global cognitive vulnerability were more likely to engage in unhelpful thinking processes. Extended sleep opportunity may be permissive of these processes during time in bed, leading to perceived poor sleep, as well as facilitating associations amongst bedtime, poor sleep, and negative emotional experiences; in contrast, restricted sleep opportunity and subsequently shortened SOL during the school term[3] might mitigate the effect of DAS on the sleep-mood association.

In this study, SSQ mediated the relationship between objective sleep and negative mood in nearly 80% of the sample with higher DAS, suggesting that for the majority of adolescents, global cognitive vulnerability might play a role in the etiology of sleep related mood problems.

Covariates

Consistent with the existing literature, at all time points higher academic stress[45,46] and being female[47,48] were associated with negative mood after controlling for SSQ; higher academic stress was also associated with poorer SSQ. These results highlight that multiple factors, including both sleep and non-sleep related factors, collectively contribute to adolescents' psychological well-being during school terms and vacations.

Limitations

First, the relations among variables within each time point were cross-sectional, limiting the strength of causal inference. Second, potential overestimation of wakefulness by actigraphy has recently been noted in adolescents.[74] However, if this were to be present, it would contribute to the absolute values of some actigraphy variables, and be less likely to affect their association with other measures. Third, the lack of normative data in adolescents impeded the computation of a global score for PSQI that represented overall sleep quality. This was overcome by using self-report TST in minutes, and summing standardized raw subscale scores to quantify overall sleep quality. Fourth, only one aspect of global cognitive vulnerability, dysfunctional attitudes, was assessed, and other factors, such as attributional style[75] and coping strategies[76] were not examined. In addition, other psychological factors that might be relevant to adolescents' sleep and mood, such as positive affect[77] and presleep arousal[78] were not examined. Fifth, participants being older adolescents who are relatively healthy raises the caveat that results might not be generalizable to younger adolescents or a clinical population.

Strengths

This is, to the best of our knowledge, the first study to have tested a cognitive vulnerability model of the relationships among objective sleep, subjective sleep, and negative mood in adolescents under both restricted and extended sleep conditions. Conceptually, the integration of theories and empirical evidence from both sleep and psychological sciences helped examine not just the association between sleep and negative mood, but also its underlying mechanisms. Methodologically, a naturalistic design and an unselected community sample suggest that findings in this study are likely to reflect adolescents' everyday experiences with good generalizability. Repeated measures conducted across school terms and vacations allowed for the examination of the cognitive vulnerability model in two main parts of an academic year with distinct sleep-wake patterns. Appropriate statistical modelling also strengthened testing of the hypothesized model.

Implications

By examining cognitive vulnerabilities as important moderators of the links between sleep and negative mood, this study helped better understand the psychological processes underlying sleep related mood problems. Findings raise the possibility that cognitive vulnerability might be a shared risk factor for the development of both sleep problems and emotional disorders.

There are several practical implications: (1) Compared to actual sleep duration, perceived sleep quality played a more important role in sleep related mood problems. A balanced attitude toward sleep, integrating the importance of adequate sleep, as well as normalizing some degrees of sleep restriction without depicting sleep loss as necessarily being a threat to well-being, might be helpful and appropriate in adolescents, particularly those who have sleep onset difficulties. (2) The mediating role of perceived sleep quality provides support to the notion that sleep complaints may be a risk factor,[79] as well as play a maintaining role[80] in the development of emotional disorders. Interventions that aim to improve sleep, particularly the subjective experience of sleep, might have beneficial effects on existing mood symptoms,[14,81] as well as preventive effects on the development of future mood problems. (3) This study provides empirical support for therapeutically targeting cognitive vulnerability as a risk factor for sleep complaints and sleep related mood problems. Identifying and targeting individuals who are vulnerable to sleep related mood problems (e.g., existing sleep onset difficulties, high cognitive vulnerability) might enhance effectiveness of sleep interventions in adolescents.

ABBREVIATIONS

BT, bedtime
CES-D, Center for Epidemiologic Studies Depression Scale
DAS, dysfunctional attitudes scale
DBAS, Dysfunctional Beliefs and Attitudes about Sleep
DD, daytime dysfunction
MOOD, a composite score based on standardized Center for Epidemiological Studies Depression Scale and Spence Children's Anxiety Scale
PFC, prefrontal cortex
PSG, polysomnography
PSQI, Pittsburgh Sleep Quality Index
SCAS, Spence Children's Anxiety Scale
SD, sleep disturbance
SE, sleep efficiency
SOL, sleep onset latency
SQ, sleep quality
SSQ, subjective sleep quality
Time-E, end of term
Time-S, start of term
Time-V, vacation period

TST, total sleep time
WASO, wake after sleep onset

DISCLOSURE STATEMENT

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REFERENCES

1. Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. Sleep Med 2011;12:110–8.
2. Roberts RE, Roberts CR, Xing Y. Restricted sleep among adolescents: prevalence, incidence, persistence, and associated factors. Behav Sleep Med 2011;9:18–30.
3. Bei B, Allen NB, Nicholas CL, Dudgeon P, Murray G, Trinder J. Actigraphy-assessed sleep during school and vacation periods: a naturalistic study of restricted and extended sleep opportunities in adolescents. J Sleep Res 2014;23:107–17.
4. Carskadon MA. Factors influencing sleep patterns of adolescents. In: Carskadon MA, ed. Adolescent Sleep Patterns: Biological, Social, and Psychological Influences. New York: Cambridge University Press, 2002:4–26.
5. van den Bulck J. Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up. Sleep 2007;30:1220–3.
6. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. Child Dev 1998;69:875–87.
7. Spruyt K, Molfese DL, Gozal D. Sleep duration, sleep regularity, body weight, and metabolic homeostasis in school-aged children. Pediatrics 2011;127:e345–52.
8. Moore M, Kirchner HL, Drotar D, et al. Relationships among sleepiness, sleep time, and psychological functioning in adolescents. J Pediatr Psychol 2009;34:1175–83.
9. Rao U, Dahl RE, Ryan N, et al. Heterogeneity in EEG sleep findings in adolescent depression: unipolar versus bipolar clinical course. J Affect Disord 2002;70:273–80.
10. Rapoport J, Elkins R, Langer DH, et al. Childhood obsessive-compulsive disorder. Am J Psychiatry 1981;138:1545–54.
11. 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.
12. Short MA, Gradisar M, Lack LC, Wright HR, Dohnt H. The sleep patterns and well-being of Australian adolescents. J Adolesc 2013;36:103–10.
13. Gangwisch JE, Babiss LA, Malaspina D, Turner JB, Zammit GK, Posner K. Earlier parental set bedtimes as a protective factor against depression and suicidal ideation. Sleep 2010;33:97–106.
14. Bei B, Byrne ML, Ivens C, et al. Pilot study of a mindfulness-based, multi-component, in-school group sleep intervention in adolescent girls. Early Interv Psychiatry 2013;7:213–20.
15. Roberts RE, Duong HT. The prospective association between sleep deprivation and depression among adolescents. Sleep 2014;37:239–44.
16. Glozier N, Martiniuk A, Patton PG, et al. Short sleep duration in prevalent and persistent psychological distress in young adults: the DRIVE study. Sleep 2010;33:1139–45.
17. Goetz RR, Wolk SI, Coplan JD, Ryan ND, Weissman MM. Premorbid polysomnographic signs in depressed adolescents: a reanalysis of EEG sleep after longitudinal follow-up in adulthood. Biol Psychiatry 2001;49:930–42.
18. Dagys N, McGlinchey EL, Talbot LS, Kaplan KA, Dahl RE, Harvey AG. Double trouble? The effects of sleep deprivation and chronotype on adolescent affect. J Child Psychol Psychiatry 2012;53:660–7.
19. McGlinchey EL, Talbot LS, Chang K-H, Kaplan KA, Dahl RE, Harvey AG. The effect of sleep deprivation on vocal expression of emotion in adolescents and adults. Sleep 2011;34:1233–41.
20. Talbot LS, McGlinchey EL, Kaplan KA, Dahl RE, Harvey AG. Sleep deprivation in adolescents and adults: changes in affect. Emotion 2010;10:831–41.
21. Baum KT, Desai A, Field J, Miller LE, Rausch J, Beebe DW. Sleep restriction worsens mood and emotion regulation in adolescents. J Child Psychol Psychiatry 2013;55:180–90.
22. Davidson RJ. Anxiety and affective style: role of prefrontal cortex and amygdala. Biol Psychiatry 2002;51:68–80.
23. Giedd JN. Structural magnetic resonance imaging of the adolescent brain. Ann N Y Acad Sci 2004;1021:77–85.
24. Yoo S-S, Gujar N, Hu P, Jolesz FA, Walker MP. The human emotional brain without sleep — a prefrontal amygdala disconnect. Curr Biol 2007;17:R877–8.
25. Telzer EH, Fuligni AJ, Lieberman MD, Galván A. The effects of poor quality sleep on brain function and risk taking in adolescence. Neuroimage 2013;71:275–83.
26. Silk JS, Vanderbilt-Adriance E, Shaw DS, et al. Resilience among children and adolescents at risk for depression: mediation and moderation across social and neurobiological contexts. Dev Psychopathol 2007;19:841–65.
27. Bei B, Milgrom J, Ericksen J, Trinder J. Subjective perception of sleep, but not its objective quality, is associated with immediate postpartum mood disturbances in healthy women. Sleep 2010;33:531–8.
28. Baker FC, Sassoon SA, Kahan T, et al. Perceived poor sleep quality in the absence of polysomnographic sleep disturbance in women with severe premenstrual syndrome. J Sleep Res 2012;21:535–45.
29. Freeman A, Felgoise S. Encyclopedia of Cognitive Behavior Therapy. New York: Springer, 2005.
30. Scher CD, Scher CD, Ingram RE, Ingram RE, Segal ZV. Cognitive reactivity and vulnerability: empirical evaluation of construct activation and cognitive diatheses in unipolar depression. Clin Psychol Rev 2005;25:487–510.
31. Lewinsohn PM, Clarke GN, Seeley JR, Rohde P. Major depression in community adolescents: age at onset, episode duration, and time to recurrence. J Am Acad Child Adolesc Psychiatry 1994;33:809–18.
32. Lewinsohn PM, Joiner TE, Rohde P. Evaluation of cognitive diathesis-stress models in predicting major depressive disorder in adolescents. J Abnorm Psychol 2001;110:203–15.
33. Abela JRZ, Sullivan C. A test of Beck's cognitive diathesis-stress theory of depression in early adolescents. J Early Adolesc 2003;23:384–404.
34. Lakdawalla Z, Hankin BL, Mermelstein R. Cognitive theories of depression in children and adolescents: a conceptual and quantitative review. Clin Child Fam Psychol Rev 2007;10:1–24.
35. Morin CM. Dysfunctional beliefs and attitudes about sleep: preliminary scale development and description. The Behavior Therapist 1994;Summer:163–4.
36. Harvey AG. A cognitive model of insomnia. Behav Res Ther 2002;40:869–93.
37. Ng AS, Ng AS, Dodd HF, et al. The relationship between parent and child dysfunctional beliefs about sleep and child sleep. J Child Fam Stud 2012;22:827–35.
38. Gradisar M, Dohnt H, Wright H, et al. Adolescent napping behavior: dysfunctional cognitions and negative affect. Sleep Biol Rhythms 2008;6:260–3.
39. Beck AT. Cognitive models of depression. J Cogn Psychother 1987;1:5–37.
40. Beck AT. The evolution of the cognitive model of depression and its neurobiological correlates. Am J Psychiatry 2008;165:969–77.
41. Alfano CA, Zakem AH, Costa NM, Taylor LK, Weems CF. Sleep problems and their relation to cognitive factors, anxiety, and depressive symptoms in children and adolescents. Depress Anxiety 2009;26:503–12.
42. Regestein Q, Natarajan V, Pavlova M, Kawasaki S, Gleason R, Koff E. Sleep debt and depression in female college students. Psychiatry Res 2010;176:34–9.
43. Sadler P, Sadler P, McLaren S, McLaren S, Jenkins M, Jenkins M. A psychological pathway from insomnia to depression among older adults. Int Psychogeriatr 2013;25:1375–83.
44. Olds T, Maher C, Blunden S, Matricciani L. Normative data on the sleep habits of Australian children and adolescents. Sleep 2010;33:1381–8.
45. Ang RP, Huan VS. Relationship between academic stress and suicidal ideation: testing for depression as a mediator using multiple regression. Child Psychiatry Hum Dev 2006;37:133–43.
46. Spangler G, Pekrun R, Kramer K, Hofmann H. Students' emotions, physiological reactions, and coping in academic exams. Anxiety Stress Coping 2002;15:413–32.

47. Lewinsohn PM, Gotlib IH, Lewinsohn M, Seeley JR, Allen NB. Gender differences in anxiety disorders and anxiety symptoms in adolescents. J Abnorm Psychol 1998;107:109–17.
48. Nolen-Hoeksema S, Girgus JS. The emergence of gender differences in depression during adolescence. Psychol Bull 1994;115:424–43.
49. Sadeh A. The role and validity of actigraphy in sleep medicine: an update. Sleep Med Rev 2011;15:259–67.
50. Meltzer L, Walsh C, Traylor J. Direct comparison of two new actigraphs and polysomnography in children and adolescents. Sleep 2012;35:159–66.
51. Philips Respironics. Equivalence of activity recordings and derived sleep statistics [Internet]. minimitter.com. 2008. [cited 2012 Apr 8]. Available from: http://www.minimitter.com/downloads/researchreports.pdf.
52. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193–213.
53. Carpenter JS, Andrykowski MA. Psychometric evaluation of the Pittsburgh Sleep Quality Index. J Psychosom Res 1998;45:5–13.
54. Zhou H-Q, Shi W-B, Wang X-F, et al. An epidemiological study of sleep quality in adolescents in South China: a school-based study. Child Care Health Dev 2012;38:581–7.
55. Radloff LS. The CES-D Scale: a self-report depression scale for research in the general population. Appl Psyc Meas 1977;1:385–401.
56. Spence SH. A measure of anxiety symptoms among children. Behav Res Ther 1998;36:545–66.
57. Radloff LS. The use of the center for epidemiologic studies depression scale in adolescent and young adults. J Youth Adolesc 1991;20:149–66.
58. Clark LA, Watson D. Tripartite model of anxiety and depression: psychometric evidence and taxonomic implications. J Abnorm Psychol 1991;100:316–36.
59. Morin CM, Vallières A, Ivers H. Dysfunctional beliefs and attitudes about sleep (DBAS): validation of a brief version (DBAS-16). Sleep 2007;30:1547–54.
60. Weissman AN, Beck AT. Development and validation of the Dysfunctional Attitude Scale: a preliminary investigation. Paper presented at the meeting of the Association for the Advancement of Behavior Therapy, Chicago, 1978.
61. Weissman AN. The Dysfunctional Attitude Scale: a validation study. Diss Abstr Int 1979;40:1389B–90B.
62. Prenoveau JM, Zinbarg RE, Craske MG, Mineka S, Griffith JW, Rose RD. Evaluating the invariance and validity of the structure of dysfunctional attitudes in an adolescent population. Assessment 2009;16:258–73.
63. Kohn PM, Milrose JA. The inventory of high-school students recent life experiences: a decontaminated measure of adolescents hassles. J Youth Adolesc 1993;22:43–55.
64. Christensen R, Johnson W, Branscum A, Hanson TE. Bayesian Ideas and Data Analysis. Boca Raton, FL: Chapman & Hall/CRC Press, 2011.
65. Muthén BO, Asparouhov T. Bayesian structural equation modeling: a more flexible representation of substantive theory. Psychol Methods 2012;17:313–35.
66. Yuan Y, MacKinnon DP. Bayesian mediation analysis. Psychol Methods 2009;14:301.
67. R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing, 2014. Retrieved from http://www.R-project.org/.
68. Muthén LK, Muthén BO. Mplus User's Guide. 7th ed. Los Angeles, CA: Muthén & Muthén, 2013.
69. Hallquist M, Wiley JF. MplusAutomation: Automating Mplus Model Estimation and Interpretation (Version 0.6-2). 2013. Retrieved from http://cran.r project.org/package=MplusAutomation.
70. Brooks SP, Gelman A. General methods for monitoring convergence of iterative simulations. J Comput Graph Stat 1998;7:434–55.
71. Gelman A, Meng X-L, Stern H. Posterior predictive assessment of model fitness via realized discrepancies. Statistica Sinica 1996;6:733–60.
72. Roberts RE, Lewinsohn PM, Seeley JR. Screening for adolescent depression: a comparison of depression scales. J Am Acad Child Adolesc Psychiatry 1991;30:58–66.
73. Morin CM, Stone J, Stone J, et al. Dysfunctional beliefs and attitudes about sleep among older adults with and without insomnia complaints. Psychol Aging 1993;8:463–7.
74. Short MA, Gradisar M, Lack LC, Wright H, Carskadon MA. The discrepancy between actigraphic and sleep diary measures of sleep in adolescents. Sleep Med 2012;13:378–84.
75. Calvete E, Villardón L, Estévez A. Attributional style and depressive symptoms in adolescents: an examination of the role of various indicators of cognitive vulnerability. Behav Res Ther 2008;46:944–53.
76. Sadeh A, Keinan G, Daon K. Effects of stress on sleep: the moderating role of coping style. Health Psychol 2004;23:542–5.
77. Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and good sleep. J Psychosom Res 2008;64:409–15.
78. Gregory AM, Willis TA, Wiggs L, Harvey AG; STEPS Team. Presleep arousal and sleep disturbances in children. Sleep 2008;31:1745–7.
79. Johnson EO, Roth T, Breslau N. The association of insomnia with anxiety disorders and depression: exploration of the direction of risk. J Psychiatr Res 2006;40:700–8.
80. Alvaro PK, Roberts RM, Harris JK. A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. Sleep 2013;36:1059–68.
81. Manber R, Edinger JD, Gress JL, San Pedro-Salcedo MG, Kuo TF, Kalista T. Cognitive behavioral therapy for insomnia enhances depression outcome in patients with comorbid major depressive disorder and insomnia. Sleep 2008;31:489–95.