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The interplay between sleep and mood in predicting academic functioning, physical health and psychological health: A longitudinal study

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ABSTRACT

Objectives: Existing studies on sleep and behavioral outcomes are mostly correlational. Longitudinal data is limited. The current longitudinal study assessed how sleep duration and sleep quality may be causally linked to daytime functions, including physical health (physical well-being and daytime sleepiness), psychological health (mood and self-esteem) and academic functioning (school grades and study effort). The mediation role of mood in the relationship between sleep quality, sleep duration and these daytime functions is also assessed.

Methods: A sample of 930 Chinese students (aged 18–25) from Hong Kong/Macau completed self-reported questionnaires online across three academic semesters. Sleep behaviors are assessed by the Sleep Timing Questionnaire (for sleep duration and weekday/weekend sleep discrepancy) and the Pittsburgh Sleep Quality Index (sleep quality); physical health by the World Health Organization Quality of Life Scale—Brief Version (physical well-being) and Epworth Sleepiness Scale (daytime sleepiness); psychological health by the Depression Anxiety Stress Scale (mood) and Rosenberg Self-esteem Scale (self-esteem) and academic functioning by grade-point-average and the College Student Expectation Questionnaire (study effort).

Results: Structural equation modeling with a bootstrap resample of 5000 showed that after controlling for demographics and participants' daytime functions at baseline, academic functions, physical and psychological health were predicted by the duration and quality of sleep. While some sleep behaviors directly predicted daytime functions, others had an indirect effect on daytime functions through negative mood, such as anxiety.

Conclusion: Sleep duration and quality have direct and indirect (via mood) effects on college students' academic function, physical and psychological health. Our findings underscore the importance of healthy sleep patterns for better adjustment in college years.

Introduction

College students face multiple challenges, such as intellectual demands and identity formation. Furthermore, their sleep behaviors have been characterized by sleep deprivation, poor sleep quality and excessive daytime sleepiness [1]. Growing evidence suggests poor sleep patterns are related to impaired academic performance [2], physical health [3] and psychological well-being [4]. Yet, the temporal relationships among sleep and these functional outcomes are unclear.

Sleep and psychological well-being

The relationship between sleep, mood and other psychological functions has lately become a rapidly developing research area. While negative mood, such as depression and anxiety, has long been identified as harming nighttime sleep, recent findings show that the relationship between sleep and mood is bi-directional [5]. Neuropsychological evidences suggest that both quality and quantity of sleep are vital to the optimal functioning of brain activity in regulating our emotions [5]. Fredriksen and coworkers [4] provided longitudinal data to show that among adolescents, sleep loss was a significant predictor of increased depressive feeling and self-esteem. In fact, Walker and Harvey [6] argued that while sleep and mood are unquestionably linked, future studies should assess how exactly they are related and the outcomes of such interaction/relation.

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Sleep, mood and academic functioning

Sleep and mood also affect school performance. Kelly, Kelly and Clanton [7] found a positive correlation between hours of sleep and school grades. Students with ≥8 h of sleep reported an average grade-point-average (GPA) of 3.24 compared to an average GPA of 2.74 for those with <7 h of sleep. Psycho-physiological research indicated that sleep is crucial for the consolidation and reactivation of memory [8]. Sleep-deprived participants have greater difficulty than healthy controls in recalling learned materials [9]. Good sleep quality was also associated with higher learning motivation and school performance. Gomes, Tavares and de Azevedo [10] recently demonstrated that both sleep duration and quality are significant predictors of school grades among undergraduates. While other evidence suggests that mood is related to school grades and motivation [11], how mood mediates the relationship between sleep behaviors and academic functioning remains to be determined.

Sleep, mood and physical health

A healthy sleep pattern has been shown to relate to desirable health conditions. Sleep duration and quality are suggested to closely relate to daytime sleepiness which reflects one's inability to sustain attention [1]. Daytime sleepiness has been used as an indicator of the health status in both patient and healthy population. For instance, excessive daytime sleepiness is seen as a cardinal symptom in sleep apnea and it is correlated with increasing medical problems in an otherwise healthy population [12]. Apart from daytime sleepiness, sufficient sleep is also demonstrated to predict health conditions, such as blood pressure [13] and body mass index (BMI) [3]. Chang and coworkers [14] found that among cancer patients' caregivers, poor self-reported sleep quality predicted dissatisfaction with physical health. While sleep behaviors appear to correlate with physical health, limited studies compared the relative contribution of different sleep behaviors in predicting health conditions.

The current study

Although increasing evidence suggests that sleep behaviors are closely linked with mood and functional outcomes (including academic functioning, physical and psychological health), causal relationships cannot be established without longitudinal or experimental evidence [2]. The current study aims primarily to explore the temporal relationships from sleep behaviors to the aforementioned functional outcomes. We also intend to explore if sleep affects daytime functions through inducing negative mood. In other words, we plan to test the mediating role of mood between sleep behaviors and daytime functions. While some sleep behaviors were shown to have differential roles in predicting daytime functions in previous cross-sectional studies, we aim to compare the relative contribution of interdependent sleep behaviors in predicting the outcome measures with a longitudinal structural equation modeling (SEM) approach. With the use of SEM, all regression pathways can be tested at once and comparisons of strengths of pathways can be made accordingly.

Methods

Participants

Chinese undergraduates, aged 18–25 from 16 universities and colleges in Hong Kong and Macau were recruited through campus flyers, emails and online platforms. Of the 1195 participants who completed the measurements in Time 1, 1006 (84.2%) continued in Time 2 and 930 (77.8% of Time 1) in Time 3.

Procedures

The current investigation was a sub-study of a large-scale longitudinal research program on the formation and transformation of beliefs, lifestyle, and well-being in Chinese. Ethics approval was obtained from the University of Hong Kong prior to data collection. The study was conducted across three consecutive academic semesters from September, 2010 to December, 2011. Participants filled out online questionnaires in Chinese to report their demographic information, sleep behaviors, academic functioning (GPA and study effort), physical health (physical well-being and daytime sleepiness) and psychological health (mood and self-esteem). For each timepoint, participants first provided informed consent. After completing the measurements, participants could either enter a lucky draw for cash coupons (HK$100/100 participants) or have us make a donation (HK$20) to a designated charity for poverty relief.

Measurements

Demographics

Participants' demographic information (age, sex, BMI, family income, parents' education level and hours of part-time work) were used as covariates in the SEM model. Participants report their family income on a 6-point scale (from 1: <$10,000; 2: $10,000–$19,999 to 6: ≥$50,000). Parents' education level is calculated by the mean score of education level between the two parents on a 6-point scale (1 = pre-primary education; 2 = primary education; 6 = post-graduate education).

Sleep duration and quality. Sleep duration, weekday/weekend sleep discrepancy and various dimensions of sleep quality are included as predictors in the SEM model. The Sleep Timing Questionnaire (STQ) [15] and Pittsburgh Sleep Quality Index (PSQI) [16] were used to examine an individual's sleep duration and weekday/weekend sleep discrepancy, and sleep quality respectively. In lieu of a sleep diary, the STQ consisted of 14 items in assessing an individual's habitual sleep–wake patterns in a recent normal week (when the participant is not sick or on vacation). Sleep duration on school-days and holidays are separately assessed. Weekday/weekend sleep discrepancy is calculated by subtracting the hours of sleep in school-days from holidays. The PSQI assesses seven dimensions of sleep quality: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication and daytime dysfunction, over the past month. With the objective to probe into the potentially different roles of each sleep behavior in predicting the outcome measures, we decided to present sleep quality as five individual dimensions (subjective sleep quality, sleep latency, habitual sleep efficiency, sleep disturbances and daytime dysfunctions). Of note, sleep medication is not used in the current study, as only 3.9% of the student sample has used medicine to aid sleep; sleep duration is captured in STQ more specifically.

Academic functioning

Participants' academic functioning, namely school grades (GPA) and study effort in the previous semester are set as outcome variables in the SEM model. GPA is measured on an 11-point scale (1 = F or ≤1.00; 11 = A/A+ or ≥4.00). Study effort is measured by the College Student Expectations Questionnaire, CSEQ) [17]. We conducted a factor analysis of this measurement of diverse aspects of college experiences (Supplement 1 for details) and extracted three items relevant to study habits. They were “completed readings for class”, “attended to teachers' lecturing” and “jotted detailed notes in class”. Study effort is operationalized by aggregating answers to these three items.

Physical health

Participants' physical health, measured by their physical well-being and daytime sleepiness, is another outcome variable in the SEM model. The domain of physical well-being in the World Health Organization Quality of Life Measures (WHOQOL-BREF, HK) [18] includes seven items to measure one's satisfaction of physical health over the past two weeks. Participants responded to each item on a five-point scale. The modified Chinese version of Epworth Sleepiness Scale (ESS) was used to examine participants' current feeling of their sleep propensity in eight everyday life scenarios [19,20]. The total score varies from 0 to 24, with the higher score indicating greater daytime sleepiness.

Psychological health

Participants' self-esteem (Rosenberg Self-esteem Scale, RSES) [21] and mood (21-item Depression Anxiety Stress Scale, DASS-21) [22] represent another outcome variable, psychological health in the SEM model. Mood is also set as a mediator in the model. The RSES includes ten items for assessing self-respect and self-acceptance at the time participants completed the questionnaire. Participants respond to the items on a 4-point scale. The DASS-21 assesses negative mood in the previous week on a 4-point scale. There are three subscales, depression, anxiety and stress, each of them being separately assessed by seven items.

Statistical methods

Statistical analyses were performed on the Statistical Package for the Social Sciences (SPSS) 16.0 and Mplus 6.1.We used a path analysis in SEM with a bootstrap resample of 5000 to study the temporal relationships among sleep and academic functioning, physical health and psychological health as well as the mediating role of mood in the relationship between the predictors and outcomes [23]. The predictors in the model were sleep duration (school-days and holidays) and the five mentioned sleep quality dimensions. Outcomes were GPA, self-esteem, daytime sleepiness, study effort and satisfaction with physical well-being. Mood was set as a mediator between each sleep behavior and the outcome measures. Demographics (age, sex, BMI, family income, parents' education and hours of part-time work) were set as covariates. A summary of the internal consistency and data collection points of all measures can be found in Table 1: All predictors (sleep data) were collected at both T1 and T3 to understand the potential change in sleep patterns across time. The mediators (mood data) were measured in T1 and T2 so that temporal relationships between sleep and mood, as well as mood and the outcome variables (e.g. physical health) can be explored. Outcome variables were measured at T1 and T3. Of note, the mediators and outcome variables were measured at two time-points (T1 and T2, and T1 and T3, respectively) so that participants' baseline characteristics in these variables can be partialed out. For missing data, maximum likelihood estimation was used. The Little's MCAR (Missing Completely At Random) test with expectation maximization algorithm was used to study if the data were missing completely at random or not and a p-value > .05 suggested data to be missing completely at random [24].

For the SEM analysis, various goodness of fit measures were used, including the chi-square test for model fit (χ^2), comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean residual (SRMR), as suggested by existing literature [25]. In short, the hypothesis of exact fit would be rejected if p-values > 0.5 in the χ^2 test reject the hypothesis of exact fit. Models with good fit indices should also attain ≥.95 in CFI. Models with a RMSEA ≤ .06 with a p-value ≥ .05 are regarded a good fit, so are models with SRMR < .08. For each pathway, significant relationship is determined by a p < .05 for standardized coefficient (B). The mediation macro of Preacher and Hayes [26] was used to test the significance of the mediators. An absence of zero in the 95% bias-corrected confidence intervals of an indirect effect/pathway indicates significant mediation.

Table 1
Data collection points and internal consistency of all measures

	Data collection points and Cronbach's α		
	Time 1 (α)	Time 2 (α)	Time 3 (α)
Demographics[a]	Yes	Yes	Yes
Sleep behaviors			
Sleep Timing Questionnaire[a]	Yes		Yes
Pittsburgh Sleep Quality Index[a]	Yes		Yes
Academic functioning			
Grade point average[a]	Yes		Yes
College Student Expectations Questionnaire	Yes (.68)		Yes (.68)
Physical health			
WHOQOL (Brief Version) — physical domain	Yes (.69)		Yes (.72)
Epworth's Sleepiness Scale	Yes (.76)		Yes (.78)
Psychological health			
Rosenberg Self-esteem Scale	Yes (.89)		Yes (.88)
Depression Anxiety Stress Scale			
Depression	Yes (.86)	Yes (.85)	
Anxiety	Yes (.77)	Yes (.74)	
Stress	Yes (.83)	Yes (.84)	

WHOQOL = World Health Organization Quality of Life Scale.
[a] The Cronbach's α of demographics, Sleep Timing Questionnaire and grade-point-average were not computed because these variables were measured by 1 or 2 items directly. The Cronbach's α of the Pittsburgh Sleep Quality Index was not computed because we studied five sleep quality dimensions separately but not the global sleep quality.

Results

Details of the demographic information are summarized in Table 2. The final sample, with mean age of 21.7 (SD = 2.22), was composed of second-year students (45.2%), with 10.3% and 44.5% in their first- and third-year or above, respectively.

Table 2
Descriptive information of sample's characteristics

	Mean or %	SD
Demographic		
Age	21.7 years	2.2
Sex	33.3% male	
Body mass index	20.7	3.1
Year of study		
1st year	10.3%	
2nd year	45.2%	
3rd year or above	44.5%	
Working part-time	42.4%	
Part-time work hours per week	11.2 h	21.6
Monthly family income	2.6	1.5
Parents' education	3.5	1.1
Sleep behaviors		
Sleep duration on schooldays	6.6 h	1.2
Sleep duration on holidays	8.9 h	1.5
Weekdays/weekend sleep discrepancy	2.3 h	1.9
Subjective sleep quality	1.3	0.6
Sleep latency	1.5	1.4
Habitual sleep efficiency	92.0%	11.9%
Sleep disturbances per week	4.6	3.3
Daytime dysfunctions	2.0	1.3
Academic functioning		
Grade-point-average	8.1	1.5
Study effort	8.7	1.9
Physical health		
Physical quality of life (WHOQOL—physical domain score)	14.3	2.1
Daytime sleepiness (ESS total score)	10.5	3.9
Psychological health		
Mood		
DASS — depression symptoms	9.4	7.4
DASS — anxiety symptoms	7.6	5.9
DASS — stress symptoms	12.7	7.9
Self-esteem (RSES total score)	18.6	4.8

Family income is measured on a 6-point scale, participants enter 1 for a monthly income <HK$10,000, 2: $10,000–19,999 and 6: ≥$50,000; for parents' education level, participants enter 1 for pre-primary level, 2: primary education and 6: post-graduate education. Grade-point-average is measured on an 11-point scale, participants input 1 for F or ≤1.00 and 11: A/A+ or ≥4.00). WHOQOL = World Health Organization Quality of Life Scale; ESS = Epworth Sleepiness Scale; DASS = Depression Anxiety Stress Scale; RSES = Rosenberg Self Esteem Scale; SD = standard deviation.

Table 3
Correlational relationships and percentage of data missing among all measured variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Age	1																				
2	Sex	ns	1																			
3	Body mass index	−.11	−.18	1																		
4	Part-time work hours/week	ns	ns	ns	1																	
5	Family income	.09*	ns	ns	ns	1																
6	Parents' education	ns	.08*	ns	ns	.26	1															
7	T1 sleep duration (schooldays)	−.09	ns	ns	ns	−.09*	.10	1														
8	T1 sleep duration (holidays)	ns	ns	ns	ns	ns	−.09	.11	1													
9	T1 sleep irregularity	.09	ns	ns	ns	ns	−.14	−.55	.77	1												
10	T1 subjective sleep quality	ns	−.08*	ns	ns	ns	−.08*	−.26	ns	.19	1											
11	T1 sleep latency	ns	ns	ns	ns	−.11	ns	ns	ns	ns	.31	1										
12	T1 habitual sleep efficiency	ns	ns	.09*	ns	ns	.07*	.10	ns	ns	−.14	−.31	1									
13	T1 sleep disturbances	−.14	.09	ns	ns	−.08*	ns	ns	ns	ns	.30	.34	−.14	1								
14	T1 daytime dysfunctions	ns	ns	ns	.12*	ns	ns	−.11	ns	.12	.36	.23	ns	.25	1							
15	T2 depressive symptoms	ns	ns	.08*	.18	ns	−.10	−.10	ns	.11	.31	.18	ns	.23	.37	1						
16	T2 anxiety symptoms	ns	ns	ns	.18	ns	−.08*	−.11	ns	ns	.27	.22	ns	.31	.34	.66	1					
17	T2 stress symptoms	ns	ns	ns	.16	ns	−.08*	−.17	ns	.09	.31	.17	ns	.28	.41	.68	.72	1				
18	T3 self-esteem	ns	ns	ns	ns	ns	.16	ns	ns	−.11*	−.17	−.17	ns	−.12	−.25	−.50	−.38	−.37	1			
19	T3 physical quality of life	ns	ns	ns	ns	.08*	.09	.18	ns	−.14	−.53	−.24	.09*	−.31	−.46	−.51	−.44	−.47	.41	1		
20	T3 daytime sleepiness	ns	ns	ns	ns	ns	−.09*	−.14	ns	.09*	.08*	−.09*	.09*	.16	.26	.13	.21	.17	−.13	−.19	1	
21	Grade-point-average	−.14	ns	ns	−.19	ns	.12	.20	ns	−.13	−.10*	ns	.09*	ns	−.13	.17	.11	.12	−.21	−.15	.11	1
22	Study effort	ns	.18	ns	ns	ns	.16	ns	−.09*	−.13*	−.13*	ns	.17	ns	−.13	.20	.14	.09	−.13	−.65	ns	.24
	% missing	0.4%	0.4%	1.2%	1.1%	3.3%	4.3%	2.7%	2.8%	2.8%	1.6%	2.2%	3.1%	3.0%	1.8%	3.2%	3.9%	4.3%	4.9%	3.5%	3.1%	1.3%

All relationships are significant at $p<.01$ unless otherwise specified.
* $.01<p<.05$.

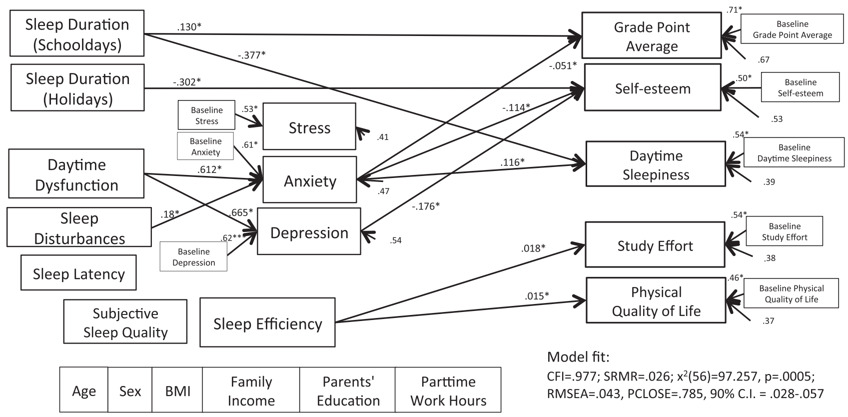

Fig. 1. Path analysis of the direct and indirect (through mood) effects from sleep behaviors on academic functioning, physical health, and psychological health.

There were 307 males and 619 females. Table 3 summarized the correlational data and showed that there were less than 5% data missing among all measured variables. The Little's MCAR test suggested that the data missing were completely at random, $\chi^2(1584)=1641.79$, $p=.152$. Regarding the stability of sleep patterns from T1 to T3, pair-sample *t*-test showed that participants tend to have slightly longer sleep duration on holidays in T3 (mean difference = .14, $t(902)=2.10$, $p=.036$), and have fewer daytime dysfunction in T3 (mean difference = .12, $t(912)=2.27$, $p=.024$). Yet, all other sleep behaviors measured at T1 were not significantly different from that measured at T3 (*ps* > .05).

We used SEM-path analysis with a bootstrap resample of 5000 to test the directional relationships among sleep behaviors, mood and academic functioning, physical and psychological health after controlling for demographics. The hypothesized model (Fig. 1) achieved a good fit, $\chi^2(56)=103.36$, $p=.0001$, RMSEA = .046, $p=.668$, CFI = .975, SRMR = .026. Tables 4a and 4b summarized the results of all significant direct and indirect regression pathways respectively and the non-significant pathways can be found in Supplement 2.

Sleep behaviors and mood

We first studied if sleep behaviors predicted mood after we controlled for demographics and participants' mood at baseline. The SEM results showed that feeling of depression was predicted by daytime dysfunction (Standardized Regression Coefficient, $B=.121$, $p=.024$) even after we controlled for participants' depression at baseline ($B=.621$, $p<.001$). These variables accounted for 53.6% of the variance. While anxiety was predicted by participants' anxiety at baseline ($B=.546$, $p<.001$), it was also predicted by daytime dysfunction ($B=.147$, $p=.007$) and sleep disturbances ($B=.103$, $p=.047$) with 46.8% of sample's variance explained. Stress was only predicted by an individual's hours of part-time work ($B=-.132$, $p=.008$) and stress at baseline ($B=.531$, $p<.001$) but not by any sleep behaviors in the model (*ps* > .05).

Sleep behaviors, mood and self-esteem

After controlling for participants' self-esteem at baseline ($B=.530$, $p<.001$), we observed that sleep duration (holidays) negatively predicted self-esteem ($B=-.087$, $p=.009$). We subsequently explored if the effect from sleep duration (holidays) on self-esteem came from weekday/weekend sleep discrepancy and replaced sleep duration (schooldays and holidays) by weekday/weekend sleep discrepancy in another SEM model. We observed that weekday/weekend sleep discrepancy directly predicted a lower level of self-esteem ($B=-.085$, $p=.012$). The model with sleep duration (schooldays and holidays) as predictors accounted for 53.0% of variance and the one with weekday/weekend sleep discrepancy 52.8% of variance. In both models, self-esteem was indirectly predicted by daytime dysfunction through depressive symptoms (bias-corrected estimate, estimate = −.117, 95%, bias-corrected confidence

Table 4a
Significant predictors (sleep behaviors, mood and demographics) of academic functions, physical and psychological health

	Bias-corrected estimate	BCCI	
		2.5%	97.5%
Academic functioning			
Age → GPA	.134	−.24	−.05
Family income → GPA	.082	−.15	−.03
Sleep duration (schooldays) → GPA	.130	−.25	−.03
Anxiety → GPA	−.051	.02	.08
Habitual sleep efficiency → study effort	.018	.004	.03
Physical health			
Habitual sleep efficiency → physical well-being	.015	.01	.03
Sleep duration (schooldays) → daytime sleepiness	−.377	−.75	−.04
Anxiety → daytime sleepiness	.116	.02	.20
Psychological health			
Hours of part-work → stress	−2.008	−3.61	−.58
Sleep disturbances → anxiety	.180	.001	.38
Daytime dysfunction → anxiety	.612	.13	1.07
Daytime dysfunction → depression	.665	.04	1.22
Weekday/weekend sleep discrepancy → self-esteem	−.302	−.54	−.06
Depression → self-esteem	−.176	−.26	−.09
Anxiety → self-esteem	−.114	−.22	−.001

GPA = grade-point-average. BCCI = bias-corrected confidence intervals.

Table 4b
Indirect effects from sleep behaviors on academic functions, physical and psychological health

	Bias-corrected estimate	BCCI	
		2.5%	97.5%
Academic functioning			
Daytime dysfunction → anxiety → GPA			
Total effect	−.067	−.04	.16
Indirect effect	−.031*	.01	.07
Sleep disturbances → anxiety → GPA			
Total effect	−.004	−.03	.04
Indirect effect	−.009*	.001	.03
Physical health			
Daytime dysfunction → anxiety → daytime sleepiness			
Total effect	.093	−.23	.43
Indirect effect	.071*	.01	.19
Sleep disturbances → anxiety → daytime sleepiness			
Total effect	.116	−.01	.25
Indirect effect	.021	0	.07
Psychological health			
Daytime dysfunction → anxiety → self-esteem			
Total effect	−.365*	−.66	−.03
Indirect effect	−.070*	−.19	−.002
Daytime dysfunction → depression → self-esteem			
Total effect	−.365*	−.66	−.03
Indirect effect	−.117*	−.26	−.02
Sleep disturbances → anxiety → self-esteem			
Total effect	.026	−.13	.17
Indirect effect	−.021*	−.06	−.001

* 95% confidence intervals do not contain 0; BCCI = bias-corrected confidence intervals; GPA = grade-point-average.

intervals, CI = −.26 to −.02) and anxiety symptoms (estimate = −.07, CI = −.19 to −.002) with the same coefficients. Self-esteem was also indirectly predicted by sleep disturbances through anxiety (estimate = −.021, CI = −.06 to −.001) in both models with the same coefficients.

Sleep behaviors, mood and academic functioning

While participants' GPA at baseline predicted their GPA at T3 (B = .765, p < .001), a longer sleep duration on school days also directly predicted a higher GPA (B = .093, p = .018). Furthermore, daytime dysfunction (estimate = −.031, CI = .01 to .07) and sleep disturbances (estimate = .009, CI = .001 to .03) both indirectly predicted a lower GPA through inducing anxiety. Age (B = .086, p = .009) and family income (B = .081, p = .012) were also significant predictors of GPA. These variables accounted for 67.1% of the sample's variance. After we partialed out the effects of study effort at baseline (B = .546, p < .001), a higher habitual sleep efficiency was observed to predict study effort positively (B = .111, p = .006). These variables explained 38.1% of the sample's variance.

Sleep behaviors, mood and physical health

Sleep behaviors were observed to directly predict daytime sleepiness and satisfaction with physical well-being. Daytime sleepiness was inversely predicted by sleep duration (schooldays) (B = −.104, p = .033) and positively by its baseline (B = .536, p < .001), with 38.8% of variance explained. Daytime sleepiness was also indirectly predicted by daytime dysfunction through anxiety symptoms (estimate = .071, CI = .01 to .19). After we controlled for participants' physical well-being at baseline (B = −.104, p = .033), a higher habitual sleep efficiency directly predicted physical well-being (B = .091, p = .036) with 36.5% of variance explained.

Discussion

The current study primarily aimed to investigate the directional relationships between different sleep behaviors, mood and daytime functions, including physical health (daytime sleepiness and physical well-being), psychological health (mood and self-esteem) and academic functioning (school grades and study effort). Our findings showed that not all, but some specific sleep behaviors may directly or indirectly (through inducing negative mood) predict the aforementioned daytime functions significantly, independent from one's demographic information and daytime functions at baseline.

Sleep, mood and psychological health

Consistent with existing literature, we found that sleep behaviors have a close relationship with mood. Not only did sleep problems predict negative mood, they were also observed to affect an individual's self-esteem through its impact on mood. While it has been proposed that sleep quality correlated with negative mood more strongly than sleep duration [27], our results are consistent with those of Bowers and coworkers [28] that some sleep quality dimensions, such as daytime dysfunctions and sleep disturbances, predicted negative mood more strongly than other sleep duration or quality measures. While we did not observe direct effects from sleep behaviors on stress, the findings do not suggest that sleep and stress are independent. Future studies with different measurements of sleep behaviors (e.g. actigraphic data) and stress (e.g. cortisol in saliva) are needed to verify the relationship between sleep and stress.

We also found that college students' self-esteem can be predicted both directly and indirectly by their sleep behaviors. Weekday/weekend sleep discrepancy was observed to directly predict a lower level of self-esteem. A possible explanation can be inferred from the relationship between sleep and emotion-modulated cognition. Recent findings suggested that sufficient sleep is vital to the optimal processing and evaluation of emotion, and individuals with insufficient sleep may have bias in processing stimuli with negative valence [29]. It is speculated that participants with greater weekday/weekend sleep discrepancy might have a biased cognition towards the negative feeling about them and therefore had a lower level of self-esteem. In fact, previous studies also found low self-esteem to be predicted by sleep duration in weekends among adolescents [30]. We also found that daytime dysfunction and sleep disturbances had relatively more important roles than other sleep quality dimensions in predicting self-esteem by triggering off an individual's negative mood, such as anxiety and depression. Our findings echoed the results of a prospective study of adolescent's sleep, health and functioning, which found an indirect effect from sleep quality to self-esteem through negative emotion [30]. With longitudinal data, we further assert that poor sleep quality and negative mood are risk factors predicting low self-esteem.

Sleep, mood and academic functioning

Among the sleep behaviors measured, we found sleep duration on school days, sleep disturbances and daytime dysfunction to be the strongest predictors of school grades while study effort was individually predicted by habitual sleep efficiency. The relationship between sleep duration and school performance can be interpreted by the notion of sleep-dependent memory consolidation in which sleep offers an optimal brain state allowing various neurophysiological activities to happen so that the learned information can be reprocessed and integrated [8]. A higher GPA may potentially be a behavioral manifestation of enhanced functioning of relevant brain network during sleep. Consistent with previous findings, we also found that sleep quality predicted school performance [32]. We further showed that among all sleep quality dimensions, only sleep disturbances and daytime dysfunction predicted GPA, and that such effects are indirect (by inducing anxiety feeling) among college students.

Habitual sleep efficiency is observed to predict a higher level of study effort. While learning motivation has been suggested to relate to sleep quality and sleep duration [11,32], our SEM model allowed us to compare the predictive power of each regression pathway. Habitual sleep efficiency appeared to shoulder a stronger role than other sleep behaviors in predicting study effort.

Sleep, mood and physical health

Regarding physical health, daytime sleepiness is predicted directly by sleep duration on schooldays and indirectly by daytime dysfunction through anxiety symptoms, whereas satisfaction with physical well-being is predicted by habitual sleep efficiency. The direct effect from sleep duration (school days) on daytime sleepiness replicated the results in existing findings that daytime sleepiness is mostly a consequence of insufficient sleep [2]. While the current study made use of SEM in studying the temporal relationship between sleep, mood and academic functioning as well as physical and psychological health, we further assert that sleep duration, particularly on school days, is the strongest predictor of daytime sleepiness among other sleep behaviors measured. We also demonstrated that poor sleep quality, particularly daytime dysfunction, could indirectly predict a higher level of daytime sleepiness through inducing anxiety symptoms. The findings on habitual sleep efficiency's effect on the satisfaction of physical well-being is also consistent with previous studies which found a positive correlation between satisfaction with physical well-being and sleep quality in healthy [33] and patient populations [14]. Our data suggested that habitual sleep efficiency had a stronger role in predicting physical well-being than other sleep behaviors measured.

It is noteworthy that the mean sleep duration in schooldays is less than 7 h and the mean weekday/weekend sleep discrepancy is more than 2 h in our sample. These college students may be at risk of developing sleep disorders, such as delayed sleep phase disorder [34], which may pose further adverse consequences on their physical health as well as other functional outcomes.

Limitations

The use of self-report data might be considered as more likely biased than objective sleep measurements, e.g. polysomnography. Still, as Fredriksen and coworkers [4] argued, results from studies solely using laboratory measurements may have limited ecological validity. In fact, a meta-analysis even found self-reported sleep quality to predict school grades more strongly than the sleep quality assessed by objective measures [2]. Future studies may combine the data from both self-reported and objective measurements.

Another potential shortcoming is that the current model might not have captured the inter-relationship among sleep behaviors or between sleep behaviors and mood in predicting the functional outcomes. It is possible that mood may moderate the relationship between sleep duration/quality with daytime functions and it could be a good future direction in the field. Nonetheless, the current study primarily aims to test if mood would be the underlying mechanism of the relationship between sleep and the measured functional outcomes. Results from the SEM model with the bootstrap analysis confirm that mood is a significant mediator between sleep and various daytime functions. In addition, to date, the current model has been one of the most comprehensive models which addresses the relationship between sleep and daytime functions with multiple predictors and outcomes with various demographic factors controlled.

The generalizability of the current findings may be a concern. Since the students in our sample were recruited from more than 15 universities and colleges, we expect our findings to be generalizable to most Chinese populations. With regards to other populations, it is interesting to note that our student sample shared common features of sleep as US students in previous studies [1]. For example, both college student samples reported poor sleep quality and discrepancy of sleep between weekdays and weekend. Given that there have been limited longitudinal studies depicting the temporal relationships between sleep behaviors and functional outcomes (e.g. academic functioning, physical and psychosocial well-being), the current study has provided ground for further investigation on whether the effects of sleep on daytime functions differ across cultures.

Conclusion

Taken together, the current study strengthens the claim that specific domains of sleep behaviors can directly or indirectly (through mood) predict physical and psychological health and academic functioning. The current findings call attention to the need for colleges to raise students' awareness of the relationships between their sleep, mood, and academic performance and to provide sleep hygiene education. Besides testing the predictive/mediating roles of different sleep behaviors in affecting daytime functions, future studies which assess the counter-measures of poor sleep, such as daytime napping or caffeine-use may also help to shed light on the possible intervention strategies that academic institutions may adopt to improve college students' well-being.

Conflict of interest statement

This is not an industry-supported study. The authors have indicated no financial conflicts of interest.

Competing interests statement

All authors have completed the Unified Competing Interest form and declare that the authors have no competing interests to report.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jpsychores.2012.08.014.

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