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ORIGINAL RESEARCH

Mediating Effect of Sleep Quality on the Relationship Between Electronic Screen Media Use and Academic Performance Among College Students

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Objective: We aimed to examine the effects of sleep quality on the association between pre-bedtime electronic screen media use for entertainment and academic performance among college students. We hypothesized that sleep quality mediates the association between pre-bedtime electronic screen media entertainment use and academic performance among college students.

Methods: This was a cross-sectional survey with 1385 participants (age 19.99 ± 1.4 years [range, 17–24 years] and 36.82% males) conducted at Shantou University. The levels of academic performance were based on self-reported academic class ranking from average grades of their last final major examinations. Poor sleep quality was defined as a total score of the Pittsburgh Sleep Quality Index >7. The pre-bedtime prolonged electronic screen media use for entertainment (PESM-E) was defined as the use of electronic screen media for entertainment longer than 60 minutes/night after 10:00 p.m. during the past 6 months.

Results: College students with pre-bedtime PESM-E were 1.28-fold more likely to have a poor academic performance than those who used electronic screen media less than 60 minutes (95% confidence interval [CI]: 1.04–1.57, P=0.020). Furthermore, pre-bedtime PESM-E was significantly associated with poor sleep quality (adjusted odds ratio [AOR]=1.87, 95% CI: 1.27–2.74, P=0.001) after controlling for confounders. Mediation model showed that poor sleep quality accounted for 53.08% of the effect of pre-bedtime PESM-E on lower levels of academic performance (Sobel Z=2.04, P=0.041).

Conclusion: Pre-bedtime PESM-E is associated with poor academic performance in college students, and this association is mediated by poor sleep quality. Our findings highlight the importance of limiting the use of electronic screen media before bedtime in college students.

Keywords: poor sleep quality, sleep, academic performance, electronic screen use, college students

Introduction

Electronic screen media use has become one of the dominant forms of entertainment around the world, especially among college students.[1,2] Electronic screen media includes computers, mobile phones, game consoles, Kindle, and televisions. A study in 2017 showed that 85% of 18- to 29-year-old adolescents are smartphone subscribers,[3] and 40–80% of adolescents use electronic screen media for periods that exceed the recommended usage duration of 2 hours/day.[4,5] Prolonged electronic screen media use (PESM) especially before bedtime has been found to be associated with a wide range of adverse physical and psychological health outcomes, such as depression,[6,7] anxiety,[6,7] obesity,[8,9] poor sleep quality[7] and poor academic performance.[8,10–14]

Recent studies have shown that the PESM affects cognitive function[15] and academic performance,[11] and may ultimately lead to poor work accomplishment and career achievement in adulthood.[3] For example, adolescents who use electronic screen media for over 7 hours per day have 1.4-fold odds of achieving poor academic performance.[16] A meta-analysis also showed that watching television and playing video games are the most detrimental activities for

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affecting academic performance, especially among adolescents.[10] Furthermore, a recent study focusing on children and adolescents demonstrates that PESM is associated with poor academic performance, and this association is mediated by bedtime,[17] suggesting a potential complex association among sleep, PESM, and academic performance.

PESM is associated with various sleep problems, such as insufficient sleep,[18] poor sleep quality,[19–21] eveningness chronotype[19] and excessive daytime sleepiness.[21] Not only does PESM have a negative impact on sleep throughout the day,[18,21] PESM before bedtime also negatively affects sleep.[19,20] It has been reported that electronic screen media use for one hour or more before bedtime is associated with both difficulty falling asleep and unrefreshing sleep.[22] Furthermore, findings of a meta-analysis showed that pre-bedtime PESM increases risk of short sleep duration 2.17-fold compared to non-users,[2] and previous studies have shown that electronic screen media use is associated with poor academic performance.[17,23,24]

Poor sleep quality is common among college students.[25] A few studies have shown that poor sleep quality leads to lower levels of academic performance[26–28] by impairing memory and concentration.[29–32] However, only a limited number of studies have examined the associations between sleep quality, electronic screen media use and academic performance among college students. Furthermore, most studies have focused on the use of electronic screen media throughout the whole day,[33] while few have focused on the use of electronic screen media before bedtime, which may have a greater impact on sleep.[34]

Given the associations between sleep quality and academic performance, electronic screen media use and academic performance, as well as academic performance and sleep quality, we therefore conducted this cross-sectional study to examine the effects of sleep quality on the association between pre-bedtime PESM and academic performance among college students. As PESM for the purposes of studying and entertainment may have different effects on sleep and academic performance, we focused on pre-bedtime PESM for entertainment (PESM-E) in this study. We hypothesized that sleep quality mediates the association between pre-bedtime electronic screen media use for entertainment and academic performance among college students.

Methods

Study Design

The Shantou College Students Sleep Cohort (STCSSC) is a study designed to investigate sleep problems (ie, poor sleep quality, insomnia symptoms, chronotype and excessive daytime sleepiness) as risk factors for depression, anxiety and poor academic performance. In this study, a voluntary response sample of Shantou University students were selected to complete a series of online questionnaires related to sleep, mood, living habits and academic performance by using the WeChat-based survey program, Questionnaire Star, in early May and late October of 2019. As college students usually have their final major examinations for spring and fall semesters from the end of June to early July and end of December to early January, respectively, and in order to reduce academic stress-related sleep and mood problems, we chose early May and early October (ie, 2 months before the final examinations) to conduct this survey. This study was registered in the Chinese Clinical Trial Registry (ChiCTR2100051755). The study was approved by the Institutional Review Board of the Shantou University Mental Health Center (SUMHC20190510). All participants signed informed consents online and were informed that their personal information would be confidential. This study complied with the Declaration of Helsinki.

Participants

According to the cross-sectional survey sample size calculation formula, taking the average prevalence of poor sleep quality among college students from previous studies (22.31%)[7,35,36] to be the expected proportion of poor sleep quality among college students, and using α set at 0.05 and the allowable error (δ) set as 0.025, a sample size of 1065 students was calculated for this study. Estimating 10% of the questionnaires to be invalid, we needed at least 1183 students to be surveyed.

In this online survey, a total of 2098 students were initially approached. Among those, 1517 subjects completed the questionnaires (total response rate: 72.31%). In order to improve the reliability of this survey, we excluded 132

participants whose amount of time to complete the survey was shorter than 8.33 minutes, which was the average completion time of the overall sample minus 2 standard deviations. Finally, a total of 1385 participants were included in this study, and the average completed time was 17.82 ± 8.89 minutes.

Sleep Assessments

The Chinese version of the Pittsburgh Sleep Quality Index (PSQI) questionnaire was used to assess the subjects' habitual sleep quality.[37] A higher PSQI score indicates worse sleep quality.[38] In this study, we used a PSQI >7 to define poor sleep quality.[37] The Cronbach's alpha was 0.74 in the present study. The habitual bedtime and total sleep time were extracted from the PSQI. According to the National Sleep Foundation, a sleep duration between 7 to 9 hours per day is the recommended sleep duration for young adults.[39] Furthermore, based on previous studies, short sleep duration was defined as sleep for less than 7 hours per night.[40,41] Thus, in this study short sleep duration was defined as a habitual total sleep time of less than 7 hours per night. Bedtime later than 0:00 a.m. was regarded as a meaningful clinical cut-off point for the general population.[42,43] However, late bedtime has not been well-defined in college students. Considering this situation, using a statistical approach, the median value as the cut-off point (00:00 a.m.) can be used as an alternative option.[44] We therefore defined late bedtime as a habitual bedtime later than 00:00 a.m. (the median bedtime in this survey).

The Morningness-Eveningness Questionnaire (MEQ) was used to evaluate the morningness and eveningness chronotype of the participants.[45] An eveningness chronotype was defined as a score between 16 to 41, intermediate chronotype was defined as an MEQ score between 42 to 58, and morningness chronotype was defined as an MEQ score between 59 to 86.[45] The Cronbach's alpha was 0.82 in the present study.

The Epworth Sleepiness Scale (ESS) was used to assess daytime sleepiness.[46] A higher total ESS score indicates more daytime sleepiness. We used a total ESS score >10 to define excessive daytime sleepiness.[46] The Cronbach's alpha was 0.82 in the present study.

Academic Performance

The levels of academic performance were based on self-reported academic class ranking from the average grades of their last final major examinations, and classified into 4 levels: 1) the 1st quartile (top 25%), 2) 2nd quartile (26–50%), 3) 3rd quartile (51–75%) and 4) 4th quartile (the worst 25%). If a student completed his/her online survey in May, his/her corresponding final major examinations should have been in December or January of the previous year; in other words, if a student completed his/her online survey in October, his/her corresponding final major examinations were in July of the same year.

Pre-Bedtime Electronic Screen Media Use

Pre-bedtime electronic screen media use was based on a self-reported question: How long do you usually use electronic screen media for entertainment (i.e., read e-books, play video games, watch videos, do online shopping, read electronic news and use social networking sites/applications) after 10:00 p.m. in the past 6 months when you were at school? (≤15 minutes, 15-30 minutes, 30-60 minutes, >60 minutes). After searching the relevant literature, a pre-bedtime PESM-E had not been well-defined in previous studies. Considering this situation, using a statistical approach, the median value (>60 minutes) as the cut-off point can be an alternative option.[44] We therefore used longer than the median duration between 10:00 p.m. to the median bedtime (0:00 a.m.) of the overall subjects as the cut-off point (ie, >60 minutes) to define pre-bedtime PESM-E in this study. Furthermore, all participants needed to answer the types (ie, read e-books, play video games, watch videos, do online shopping, read electronic news and use social networking sites/applications) and frequency (ranking from 1 [never] to 5 [5–7 days/week]) of screen-based activities before bedtime. In this study, a frequency of screen-based activity before bedtime ≥3 times throughout the whole week was defined as frequent use.

Psychological Assessments

The Beck Depression Inventory (BDI) was used to assess depressive symptoms. Higher total BDI scores indicate more severe depressive symptoms.[47] In this study, we used a total score of BDI> 13 to define depressive symptoms.[48] The Cronbach's alpha was 0.89 in the present study.

The Beck Anxiety Inventory (BAI) was used to assess somatic symptoms of anxiety.[49] Higher BAI scores indicate more severe anxiety symptoms. We used a total score of BAI>9 to define anxiety symptoms.[50] The Cronbach's alpha was 0.91 in the present study.

Other Measures

Sociodemographic characteristics, ie, gender, age, major, self-reported height and weight, academic grade, financial situation satisfaction, and physical activity, were also collected. Body mass index (BMI) was calculated based on weight/height (kg/m^2). Physical activity was defined as exercise for more than 20 minutes twice a week during the past month. Smoking was defined as smoking at least once per day continuously for 6 months or more. Alcohol consumption was defined as drinking more than 50 mL of liquor or 200 mL of beer at least twice per week continuously for 6 months or more. Caffeine consumption was defined as drinking coffee, tea, cola and/or caffeinated energy drinks on most days.

Statistical Analysis

Data are presented as mean ± standard deviation for continuous variables, and percentage for categorical variables. Analysis of variance (ANOVA) for continuous variables and the χ^2 test for categorical variables were used to examine social-demographics, electronic screen media use, and sleep and psychological characteristics among students in different levels of academic performance. Cronbach's alpha coefficients were used to assess the internal consistency of the scales/questionnaires.

Multinomial ordinal/binary logistic regression was performed to assess the associations among sleep quality, pre-bedtime PESM-E and academic performance. In the regression models, age, gender, survey time and BMI were always entered in the models as covariates, while other relevant factors that may affect the academic performance were also entered as covariates (p-value of the comparison among students in different levels of academic performance was ≤ 0.100, Table 1). Multicollinearity analysis was conducted to examine multicollinearity among the included covariates. A variance inflation factor (VIF) >10 indicates multicollinearity. Based on multicollinearity analysis, values of VIF in all variables included in the regression model were <10 (range from 1.07–1.24), which indicated that no multicollinearity was observed among these variables. Because total sleep time and bedtime were extracted from the PSQI, we did not adjust these two variables in regression models. Adjusted odds ratios (AORs) with 95% confidence intervals (95% CIs) are presented.

A sequence of hierarchical logistic regression models, adjusting for age, gender, survey time, BMI and relevant factors, was used to determine the mediating effects of sleep quality on the relationship between pre-bedtime PESM-E and academic performance. Based on Baron and Kenny's study,[51] the mediation model shows how the independent variable's (ie, pre-bedtime PESM-E) causal effect can be apportioned into its indirect effect on a dependent variable (ie, academic performance) through the mediator (ie, poor sleep quality) and its direct effect on the dependent variable. As shown in Figure 1, path "a" represents the effect of the independent variable on the proposed mediator, whereas path "b" is the effect of the mediator on the dependent variable, adjusting for the independent variable. Path "c'" represents the direct effect of the independent variable on the dependent variable after controlling for the mediator. All of these paths would typically be quantified with unstandardized regression coefficients. The mediating effect through poor sleep quality can be quantified as $ab/(ab + c')$.[52] The Sobel Z test was used to assess the significance of the mediation effects.[52] SPSS (version 22.0) was used for statistical analysis. A p-value ≤ 0.05 was used to determine statistical significance.

Results

Sample Characteristics

A summary of sample characteristics is presented in Table 1. Participants had a mean age of 19.99 ± 1.40 years (range, 17–24 years) and mean BMI of 20.24 ± 2.52 kg/m^2, and 36.82% were males. The prevalence of poor sleep quality and PESM-E before bedtime were 13.14% and 60.87%, respectively. Among the 1385 students included, 548 (39.57%), 437 (31.55%), 281 (20.29%) and 119 (8.59%) students reported within the 1st, 2nd, 3rd, and 4th quartile of academic performance, respectively. Furthermore, 20 (1.44%), 165 (11.91%), 357 (25.78%) and 843 (60.87%) students reported using electronic screen for entertainment before bedtime for ≤15 minutes, 15–30 minutes, 30–60 minutes and >60

Table 1 Demographic, Electronic Screen Media Use, Sleep and Psychological Characteristics of the Included Subjects

Variables	Overall (n=1385)	Academic Performance Level				P
		1st Quartile (n=548)	2nd Quartile (n=437)	3rd Quartile (n=281)	4th Quartile (n=119)	
	Mean ± SD/%	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Demographic characteristic						
Age, years	19.99±1.40	19.92±1.39	19.97±1.44	20.04±1.31	20.23±1.43	0.149
BMI, kg/m^2	20.24± 2.52	20.14±2.49	20.11±2.47	20.37±2.46	20.84±2.95	**0.024**
Gender (Male, n, %)	510, 36.82	173, 31.57	160, 36.61	117, 41.64	60, 50.42	**< 0.001**
Grade						
Freshman (n, %)	734, 53.00	288, 52.55	246, 56.29	146, 51.96	54, 45.38	0.150
Sophomore (n, %)	284, 20.51	124, 22.63	75, 17.16	64, 22.78	21, 17.65	
Junior (n, %)	270, 19.49	103, 18.80	83, 18.99	52, 18.51	32, 26.89	
Senior (n, %)	97, 7.00	33, 6.02	33, 7.55	19, 6.76	12, 10.08	
Smoking (n, %)	15, 1.08	4, 0.73	5, 1.14	5, 1.78	1, 0.84	0.574
Alcohol consumption (n, %)	20, 1.44	6, 1.09	10, 2.29	3, 1.07	1, 0.84	0.356
Caffeine consumption (n, %)	681, 49.17	261, 47.63	219, 50.11	138, 49.11	63, 52.94	0.716
Major (Medicine, n, %)	708, 51.12	253, 46.17	223, 51.03	152, 54.09	80, 67.23	**< 0.001**
Survey time (May, 2019, n, %)	1025, 74.01	371, 67.70	339, 77.57	224, 79.72	91, 76.47	**< 0.001**
Satisfaction for financial situation (n, %)	1088, 78.56	438,79.93	344, 78.72	222, 79.00	84, 70.59	0.162
Physical activity (n, %)	704, 50.83	279, 50.91	226, 51.72	144, 51.25	55, 46.22	0.760
Pre-bedtime electronic screen media use						
Pre-bedtime PESM-E [a] (n, %)	843, 60.87	310, 56.57	263, 60.18	188, 66.90	82, 68.91	**0.008**
Frequent user [b] of reading an e-book (n, %)	408, 29.46	150, 27.37	132, 30.21	87, 30.96	39, 32.77	0.532
Frequent user [b] of shopping online (n, %)	299, 21.59	127, 23.18	91, 20.82	57, 20.28	24, 20.17	0.708
Frequent user [b] of reading electronic news (n, %)	540, 38.99	215, 39.23	176, 40.27	103, 36.65	46, 38.66	0.809
Frequent user [b] of playing video games (n, %)	328, 23.68	96, 17.52	104, 23.80	83, 29.54	45, 37.82	**< 0.001**
Frequent user [b] of using social networking applications (n, %)	1210, 87.36	485, 88.50	372, 85.13	244, 86.83	109, 91.60	0.201
Frequent user [b] of watching video (n, %)	670, 48.38	232, 42.34	230, 52.63	149, 53.02	59, 49.58	**0.003**

(*Continued*)

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Table 1 (Continued).

Variables	Overall (n=1385)	Academic Performance Level				P
		1st Quartile (n=548)	2nd Quartile (n=437)	3rd Quartile (n=281)	4th Quartile (n=119)	
	Mean ± SD/%	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Sleep characteristics						
Total sleep time, hour	6.77±0.81	6.81±0.77	6.75±0.79	6.79±0.88	6.54±0.87	**0.045**
Short sleep duration [c] (n, %)	609, 43.97	224, 40.88	196, 44.85	129, 45.91	60, 50.42	0.195
Bedtime	00:02±62min	23:55±56min	00:03±58min	00:11±80min	00:08±56min	**0.005**
Late bedtime [d] (n, %)	458, 33.07	168, 30.66	146, 33.41	105, 37.37	39, 32.77	0.282
Poor sleep quality [e] (n, %)	182, 13.14	45, 8.21	75, 17.16	39, 13.88	23, 19.33	**< 0.001**
PSQI, scores	4.81±2.52	4.45±2.26	5.01±2.70	4.98±2.52	5.27±2.81	**< 0.001**
Excessive daytime sleepiness [f] (n, %)	399, 28.81	138, 25.18	127, 29.06	88, 31.32	46, 38.66	**0.018**
ESS, scores	8.33±4.03	8.03±3.93	8.42±3.95	8.54±3.98	8.90±4.73	**0.096**
Chronotype						
Morningness [g] (n, %)	160, 11.55	81, 14.78	42, 9.61	25, 8.90	12, 10.08	0.128
Eveningness [h] (n, %)	201, 14.51	74, 13.50	65, 14.87	42, 14.95	20, 16.81	
Intermediate [i] (n, %)	1024, 73.94	393, 71.72	330, 75.51	214, 76.16	87, 73.11	
MEQ, scores	49.52±7.50	50.18±7.57	49.35±7.32	48.76±7.39	48.89±7.94	**0.041**
Psychological characteristics						
Anxiety symptoms [j] (n, %)	260, 18.77	98, 17.88	86, 19.68	50, 17.79	26, 21.85	0.697
BAI, scores	5.47±5.85	5.17±5.14	5.59±6.04	5.64±6.19	6.02±7.26	0.403
Depressive symptoms [k] (%)	333, 24.04	109, 19.89	107,24.49	77, 27.40	40, 33.61	**0.005**
BDI, scores	8.94±7.69	8.21±7.35	8.88±7.57	9.56±7.53	11.03±9.40	**0.001**

Notes: [a]PESM-E before bedtime was defined as the use of electronic screen media for entertainment longer than 60 minutes/night after 10:00 p.m. during the past 6 months. [b]Frequency of screen-based activities before bedtime ≥3 days/week was defined as frequent use. [c]Short sleep duration was defined as habitual total sleep time extracted from PSQI < 7 hours. [d]Late bedtime was defined as habitual bedtime extracted from PSQI later than 00:00 a.m. [e]Poor sleep quality was defined base on the Pittsburgh Sleep Quality Index >7. [f]Excessive daytime sleepiness was defined based on the Epworth Sleepiness Scale score >10. [g]Morningness chronotype was defined based on the Morningness-Eveningness Questionnaire scores between 59 to 86. [h]Eveningness chronotype was defined based on the Morningness-Eveningness Questionnaire scores between 16 to 41. [i]Intermediate chronotype was defined based on the Morningness-Eveningness Questionnaire scores between 42 to 58. [j] Anxiety symptoms were defined based on the Beck Anxiety Inventory scores >9. [k]Depression symptoms were defined based on the Beck Depression Inventory scores >13. P-values in bold indicate P<0.100.

Abbreviations: BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; BMI, body mass index; ESS, Epworth Sleepiness Scale; MEQ, Morningness-Eveningness Questionnaire; PESM-E, prolonged electronic screen media use for entertainment; PSQI, Pittsburgh Sleep Quality Index; SD, standard deviation.

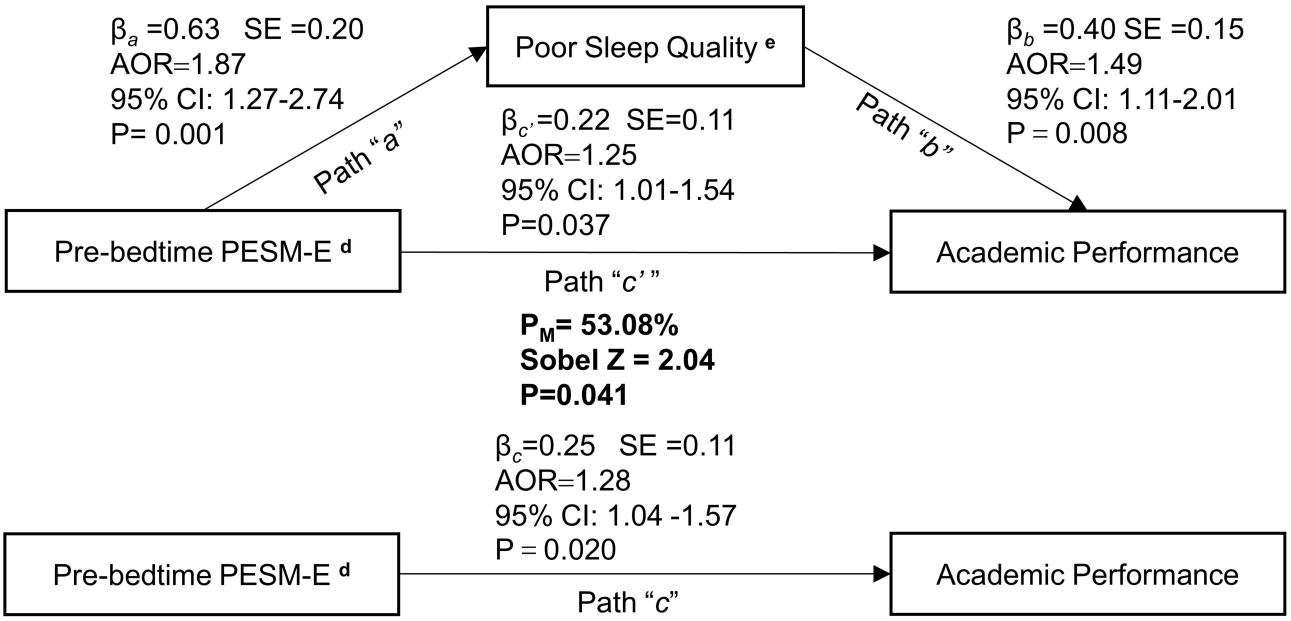

Figure 1 Mediating effect of poor sleep quality on the association between pre-bedtime prolonged electronic screen media use for entertainment and academic performance. All models were adjusted for age, body mass index, gender, major, survey time, excessive daytime sleepiness, depressive symptoms and frequent user of playing video games and watching videos. [d]Pre-bedtime PESM-E was defined as an average use duration exceeding 60 min before 10:00 p.m. [e]poor sleep quality was defined based on a Pittsburgh Sleep Quality Index >7.

Abbreviations: β_a, effect of pre-bedtime PESM-E on poor sleep quality; β_b, effect of poor sleep quality on academic performance after adjusting for pre-bedtime PESM-E; $\beta_{c'}$, direct effect of pre-bedtime PESM-E on academic performance after controlling for poor sleep quality; β_c, effect of pre-bedtime PESM-E on academic performance; AOR, adjusted odds ratios; CI, confidence interval; PESM-E, prolonged electronic screen media use for entertainment; Path "a", the effect of the independent variable on the proposed mediator; Path "b", the effect of the mediator on the dependent variable; Path "*c*'", the direct effect of the independent variable on the dependent variable after controlling for the mediator; Path "c", the total effect of the independent variable on the dependent variable.

minutes, respectively. Significant differences in BMI, gender, survey time, major, pre-bedtime PESM-E, pre-bedtime video gaming and pre-bedtime watching videos, poor sleep quality, excessive daytime sleepiness and depressive symptoms were observed among different academic performance levels (Table 1). No significant differences were observed regarding social-demographic characteristics (all p>0.300) between the overall students who completed the questionnaire (n=1517) and the sample included in the final analyses (n=1385).

Mediation Analysis

As shown in Table 2, binary logistic regression showed that pre-bedtime PESM-E was significantly associated with poor sleep quality (AOR=1.87, 95% CI: 1.27–2.74, P=0.001, Model 1) after adjusting for age, BMI, gender, major, survey time, excessive daytime sleepiness, depressive symptoms and frequent playing of video games and watching videos. Furthermore, poor sleep quality was significantly associated with lower levels of academic performance (AOR=1.53, 95% CI: 1.14–2.06, P=0.005, Model 2) after adjusting for age, BMI, gender, major, survey time, excessive daytime sleepiness, depressive symptoms, frequent playing of video games and watching videos. Moreover, the multinomial ordinal logistic regression model showed that pre-bedtime PESM-E was significantly associated with lower levels of academic performance (AOR=1.28, 95% CI: 1.04–1.57, P=0.020, Model 3) after adjusting for age, BMI, gender, major, survey time, excessive daytime sleepiness, depressive symptoms, frequent playing of video games and watching videos. When sleep quality was added to Model 3, the AOR for pre-bedtime PESM-E on academic performance decreased from 1.28 to 1.25, which suggested that sleep quality mediated the association between pre-bedtime PESM-E and academic performance.

In order to further examine the potential mediating effect of sleep quality on the association between pre-bedtime PESM-E and academic performance, the Sobel Z test was conducted. As shown in Figure 1, the mediating effect size of poor sleep quality was 53.08% for the association between pre-bedtime PESM-E and academic performance (Sobel Z=2.04, P=0.041), which suggested that poor sleep quality accounted for 53.08% of the association between pre-bedtime

Table 2 Associations Between PESM-E Before Bedtime, Poor Sleep Quality and Academic Performance

Model	Path	Dependent Variable	Independent Variable	AOR	95% CI	P
1	*a*	Poor sleep quality [a]	Pre-bedtime PESM-E [b] (ref: Non pre-bedtime PESM-E)	1.87	1.27–2.74	0.001
2	-	Academic performance level	Poor sleep quality [a] (ref: Non poor sleep quality)	1.53	1.14–2.06	0.005
3	*c*	Academic performance level	Pre-bedtime PESM-E [b] (ref: Non pre-bedtime PESM-E)	1.28	1.04–1.57	0.020
4	*c'*	Academic performance level	Pre-bedtime PESM-E[b] (ref: Non pre-bedtime PESM-E)	1.25	1.01–1.54	0.037
	b		Poor sleep quality [a] (ref: Non poor sleep quality)	1.49	1.11–2.01	0.008

Notes: All models were adjusted for age, body mass index, gender, major, survey time, excessive daytime sleepiness, depressive symptoms and frequent playing of video games and watching of videos. Path "a", the effect of the independent variable on the proposed mediator. Path "b", the effect of mediator on the dependent variable. Path "c' ", the direct effect of the independent variable on the dependent variable after controlling the mediator. Path "c", the total effect of the independent variable on the dependent variable. [a]Poor sleep quality was defined base on the Pittsburgh Sleep Quality Index >7. [b]PESM-E before bedtime was defined as the use of electronic screen media for entertainment longer than 60 minutes/night after 10:00 p.m. during the past 6 months.

Abbreviations: PESM-E, prolonged electronic screen media use for entertainment; AOR, adjusted odds ratios; CI, confidence interval.

PESM-E and academic performance. Considering the potential influence of smoking, alcohol and caffeine consumption on sleep quality and academic performance, we further adjusted the aforementioned factors in sensitivity analysis, resulting in similar and significant findings (Sobel Z=1.96, P=0.050, P_M=51.64%).

Furthermore, because depressive symptoms were more severe in students with poor academic performance, moderated mediation analyses were conducted to examine whether depressive symptoms moderated the associations between pre-bedtime PESM-E, poor sleep quality and poor academic performance. After controlling for potential confounding factors, results of the moderated mediation analyses for pre-bedtime PESM-E and academic performance showed that interaction terms in pre-bedtime PESM-E × depressive symptoms in path a (interaction-P=0.717), pre-bedtime PESM-E × depressive symptoms in path c' (interaction-P=0.298) and poor sleep quality × depressive symptoms in path b (interaction-P=0.838) were not significant, indicating no moderating effect of depressive symptoms on the association between pre-bedtime PESM-E, poor sleep quality and poor academic performance. Moreover, students with pre-bedtime PESM-E had higher percentages of frequent playing of video games (29.54% vs 14.58%, P<0.001) and frequent watching of videos (36.53% vs 55.99%, P<0.001). However, interaction analyses showed that neither frequent playing of video games (pre-bedtime PESM-E × frequent playing of video games, interaction-P=0.182) nor frequent video watching (pre-bedtime PESM-E × frequent video watching, interaction-P=0.607) moderated the associations between pre-bedtime PESM-E and poor academic performance.

Besides sleep quality, pre-bedtime PESM-E may also associate with insufficient sleep and late bedtimes. Therefore, we also used short sleep duration or late bedtime instead of sleep quality in the mediation model and found neither total sleep time nor bedtime mediated the association between pre-bedtime PESM-E and academic performance in college students (Supplement). Regarding excessive daytime sleepiness, no significant association between PESM-E before bedtime and excessive daytime sleepiness was observed (AOR=1.21, 95% CI: 0.94–1.57, P=0.148), suggesting excessive daytime sleepiness did not mediate the association between pre-bedtime PESM-E and poor academic performance.

Discussion

To our knowledge, this is the first study examining the mediating effects of sleep quality on the association between pre-bedtime PESM-E and academic performance in college students. The findings of our study suggest that poor sleep quality mediates the association between pre-bedtime PESM-E and academic performance. Specifically, poor sleep quality accounts for 53.08% of the effect of pre-bedtime PESM-E on academic performance in college students.

Our findings, showing that the pre-bedtime PESM-E is associated with poor sleep quality, are consistent with previous studies.[19,22,33] Poor sleep quality in people with pre-bedtime PESM-E could be associated with several factors,[53] such as increased emotional and physiological arousal, which may induce poor sleep. Our findings also

show that students with pre-bedtime PESM-E have more severe depressive symptoms. However, the depressive symptoms do not moderate the associations between pre-bedtime PESM-E, poor sleep quality and poor academic performance. Future studies should examine the association between pre-bedtime PESM-E and emotional arousal (eg, anger, fear, sadness, happiness and frustration). Many experimental studies have shown that pre-bedtime video game playing and communication via mobile phone increase emotional and/or cognitive arousal.[20,54,55] Furthermore, the light emitted from electronic screen media devices might influence sleep quality through dysregulation of the endogenous circadian melatonin phase.[56–58] An experimental study showed that, compared to reading a printed book, reading an eBook before bedtime decreased objective sleep quality and delayed their endogenous circadian melatonin phase by 1.5 hours.[58] In addition, screen media use before bedtime may increase the risk of insufficient sleep.[18,59,60]

We also observed that college students with pre-bedtime PESM-E were 1.25 times more likely to have poor academic performance, which is consistent with previous studies showing that excessive use of electronic screen media is associated with poor academic performance.[8,10–14] A recent study reported that compared to reading a printed book, screen time was related to lower functional connectivity between the seed area and regions related to language and cognitive control.[15] Interestingly, the current study shows that the association between pre-bedtime PESM-E and academic performance is mediated by sleep quality: poor sleep quality accounts for 53.08% of the effect of pre-bedtime PESM-E on lower levels of academic performance. In other words, pre-bedtime PESM-E increases the risk of having poor sleep quality, which in turn has a negative impact on academic performance. It has been well established that sleep plays an essential role for memory consolidation,[29–32] especially in slow wave sleep.[61] Thus, it is not hard to understand the mediating role of poor sleep quality of the association between pre-bedtime PESM-E and lower levels of academic performance.

Our findings have several important clinical implications, suggesting that pre-bedtime PESM-E affects academic performance through poor sleep quality among college students. Thus, awareness of the reciprocal relationship between excessive use of screen media before bedtime and sleep quality, as well as academic performance among college students is needed and important. In order to improve academic performance and sleep quality, limiting pre-bedtime screen media use is important for college students. It might be helpful to have a text or voice reminders for those who have already used a screen for more than an hour after 10 p.m. Health education on sleep hygiene through schools and mass media is needed and would be a benefit for college students. Furthermore, reducing the brightness of the screen or wearing blue light blocking glasses when using an electronic screen before bedtime might be helpful.[62] Future longitudinal studies examining the long-term effect of PESM-E before bedtime on sleep and academic performance, as well as the effects of protective measures (eg, sleep hygiene education or wearing blue light blocking glasses) on sleep quality and academic performance are needed.

The strengths of our study include the relatively large sample size and satisfactory response rate. Furthermore, several variables that may affect sleep quality and academic performance, such as depressive symptoms, anxiety symptoms and types and frequency of pre-bedtime screen-based activities, have also been collected and taken into consideration when examining the association between screen media use before bedtime, sleep quality and academic performance in college students. However, several limitations should be acknowledged. First, our findings are based on self-reported questionnaires, which may lead to recall bias and social desirability bias. However, it has been reported that the Chinese version of the PSQI is a valid and reliable questionnaire to assess sleep quality in the Chinese population.[37] Moreover, the internal consistency in our data was between 0.74–0.91, which suggests a high level of internal consistency. Second, this is a cross-sectional study, which cannot examine the causal relationship between screen media use before bedtime, poor sleep quality and lower levels of academic performance. Third, because this is an online-based survey and participants were not allowed to submit their questionnaires without completing all of the questions. Thus, we do not have information regarding the students who approached and refused to complete or provided incomplete information. Fourth, the information regarding some common waking substances was not collected in this survey (eg, taurine and medication use), and its effect on our findings should be examined in future studies. Finally, our findings are based on one university and mainly focused on electronic screen media use for entertainment rather than for studying, which may not be generalizable to other college students in other regions or relevant to the effects of electronic screen media use for studying on sleep quality and academic performance. However, in the middle of a semester, after 10 p.m. is usually

leisure time for most students. Future multicenter longitudinal studies to examine the mediating effects of sleep quality on the association between pre-bedtime electronic screen media use for the purposes of entertainment, studying and academic performance should be conducted.

Conclusions

Pre-bedtime PESM-E is associated with poor academic performance in college students. Importantly, this association is predominantly mediated by poor sleep quality. Our findings highlight the importance of limiting pre-bedtime use of electronic screen media by college students. It might be an achievable strategy for improving sleep quality and academic performance for college students.

Abbreviations

ANOVA, analysis of variance; AOR, adjusted odds ratio; BMI, body mass index; BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; ChiCTR, Chinese Clinical Trial Registry; CI, confidence interval; ESS, Epworth Sleepiness Scale; MEQ, Morningness-Eveningness Questionnaire; PESM, prolonged electronic screen media use; PESM-E, prolonged electronic screen media use for entertainment; PSQI, Pittsburgh Sleep Quality Index; STCSSC, Shantou College Students Sleep Cohort; SUMHC, Shantou University Mental Health Center; VIF, variance inflation factor.

Data Sharing Statement

Data and protocols are available upon reasonable request. Data and protocols are available on request from the corresponding author.

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Disclosure

All authors report no bioMedical financial interests or other potential conflicts of interest for this work.

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