ORIGINAL ARTICLE

Sleep latency and sleep disturbances mediates the association between nighttime cell phone use and psychological well-being in college students

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Abstract

To examine sleep latency and sleep disturbance as mediators between nighttime cell phone use variables (cell phone use for unstructured leisure activities and for accessing emotionally charged media content before sleep: CPU_BeforeBed and CPU_Arousal) and psychological well-being (PWB) of college students. 521 (74% female) undergraduate students from a large public university were surveyed using a validated self-report quantitative questionnaire assessing CPU variables, sleep quality, and PWB. Pearson correlation analyses were used to compute the correlation between CPU_BeforeBed, CPU_Arousal, sleep latency, and sleep disturbance. Ordinary least-squares regressions were conducted to assess the estimates of the relationships within the models. One-way ANOVA was used to see the difference between the groups. The partial eta squared was used to determine the effect size between the groups. The PROCESS method was used to perform mediation analyses. The sample consisted of undergraduate students between 18 and 29 years old, with an average age of 20 years (SD = 3.18). The sample was diverse in terms of ethnicity (49% Caucasian, 24% Latinx, 19% Asian, 3% African American, 1% Native American, 3% identified as "other") and the number of years the participants had been attending a 2 year or 4 year higher institution (38% incoming freshman, 19% sophomore, 17% junior, 14% senior, and 13% returning senior). The correlation between CPU_BeforeBed and PWB ($\alpha = -0.044$, $p = 0.615$), and the correlation between CPU_Arousal and PWB ($\alpha = -0.061$, $p = 0.228$) were not statistically significant. However, the correlation between sleep latency and PWB ($\alpha = -0.140$, $p = 0.001$), and the correlation between sleep disturbance and PWB ($\alpha = -0.121$, $p = 0.005$) were statistically significant. The mediation effect of sleep latency on the association between CPU_BeforeBed and PWB (Effect = -0.0325, SE = 0.0145, $p < 0.05$), and the mediation effect of sleep disturbance on the association between CPU_Arousal and PWB (Effect = -0.0214, SE = 0.0086, $p < 0.05$) were statistically significant. Sleep latency and sleep disturbance act as a mediator on the association between CPU_BeforeBed and PWB, and the association between CPU_Arousal and PWB. However, CPU_BeforeBed and CPU_Arousal did not have a direct impact on their PWB. These findings may help college students in regulating CPU habits before going to bed. These findings may also help medical practitioners make informed decisions about the use of cell phones for patients with sleep-related disorders.

Keywords Nighttime cell phone use · Sleep displacement · Psychological arousal · Sleep-related disorders · College students

Introduction

Cell phone use (CPU) among college students, aged 18–29 [1], became so prevalent that the adoption of cell phones within this population reached saturation by 2018 [2]. Being the largest demographic users of cell phones [3], college students were particularly vulnerable to sleep problems such as sleep latency (trouble sleeping) and sleep disturbance (disturbances in the amount and quality of sleep) [4, 5]. Sleep latency occurred due to sleep displacement and

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sleep disturbance occurred due to mental (cognitive) and/or emotional (psychological) arousal [6]. CPU-led sleep disruption theories state that sleep displacement happens when the brain believes it is still working while using a cell phone in bed for restriction-free leisure activities, and sleep disturbance happens when cell phones are used to access emotionally charged media content before sleep [6–8]. CPU usage for leisure activities before bed (CPU_BeforeBed) was shown to attribute to CPU-led sleep latency and disturbance when users accessed sexually explicit, violently explicit, or emotionally charged media content before sleep (CPU_Arousal) [6].

The impact of CPU on sleep latency and sleep disturbance has been continuously reported in previous literature. For example, there was a positive correlation between excessive CPU, sleep disturbance, and daytime dysfunction in college students [9]. This study also showed a negative correlation between excessive CPU and subjective sleep quality. Other studies [10, 11] indicated that college students perceived cell phones as devices that compelled them to be available around the clock, leading to sleep disturbances. Calling and texting functions contributed substantially to sleep disturbance including short sleep duration, excessive daytime sleepiness, and subjective sleep quality [10]. In fact, text messaging alone significantly contributed to sleep latency and sleep disturbance in college students [7]. Interacting with cell phones before sleep affected emotional and/or mental arousal, which further increased sleep latency and sleep disturbance [6, 12]. Further, playing video games before sleep elongated the time associated with sleep latency, and reduced overall sleep quality [8]. Studies concerning CPU-related sleep latency and sleep difficulty are abundantly reflected in previous literature, however, the impact of such correlations on mental health outcomes, especially psychological well-being (PWB), is warranted.

Previous studies show correlations between sleep quality and PWB, where sleep quality influenced PWB variables such as stress, depression, and anxiety [13, 14]. Poor sleep quality has also been associated with depressive symptoms, cognitive emotion regulation style [15], and lower levels of PWB [16]. Further, poor sleep quality was also found to be a strong predictor of depression and anxiety in college students during the COVID-19 pandemic [17]. Lastly, a causal relationship was established between sleep quality and stress, anxiety, and depression in a study conducted on college students [18]. In sum, poor sleep quality has shown to be detrimental to PWB levels.

As indicated above, CPU-led sleep quality, the sleep quality affected due to the use of cell phones after going to bed, was found to be detrimental to mental health outcomes such as anxiety and depression in college students [19]. For example, in a sample with college students, texting and calling alone created sleep disorders, anxiety, and depression [20].

Excessive CPU negatively affected PWB levels and mental health in college students [21]. Further, technology use was found to be associated with depression and anxiety as a result of lower sleep quality [22]. Thus, CPU, especially at nighttime, escalated sleep-related problems in college students [6, 11, 23]. Ultimately, nighttime CPU intensified stress and depressive symptoms in young adults [9, 14, 24].

In previous studies, CPU was found to be correlated with sleep quality, and sleep quality was found to be correlated with the PWB in the college student population [13–17]. CPU-led sleep quality was also found to be correlated to the PWB of college students [21]. The mediating role of sleep quality between technology use and PWB variables such as anxiety and depression [22], and problematic mobile phone use and depression [25] was examined in previous studies. However, the mediating role of sleep quality variables between nighttime CPU and PWB was left unexplored. The present study, therefore, examined the role of sleep quality variables such as sleep latency and sleep disturbance for the association of the respective nighttime CPU components (i.e., CPU_BeforeBed and CPU_Arousal) and PWB in college students.

The research hypotheses of this study are as follows:

H1: CPU_BeforeBed relate negatively to the PWB;
H2: CPU_Arousal relate negatively to the PWB;
H3: Sleep latency is a mediator between CPU_BeforeBed and PWB;
H4: Sleep disturbance is a mediator between CPU_Arousal and PWB.

The mediator models for CPU-led sleep quality and PWB are presented in Figs. 1 and 2.
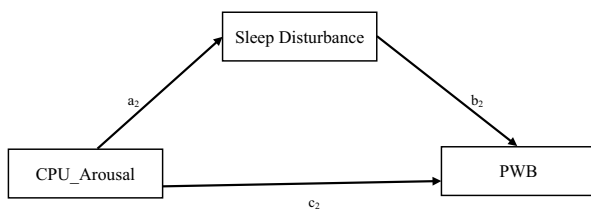
Materials and methods

Design and participants

A validated quantitative survey [6] was administered during the fall of 2019 at a large southwestern university in the United States. A total of 525 responses were collected, and 4 were discarded because they were over the age of 30.
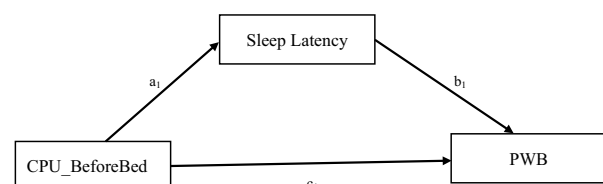
Fig. 1 Model hypothesis 1: sleep latency as a mediator between CPU_BeforeBed and PWB

Fig. 2 Model hypothesis 2: sleep disturbance as a mediator between CPU_Arousal and PWB

Procedures

Registered undergraduate students who did not report experiencing severe mental health problems at the time of taking the survey were invited to participate. A total of 47,870 students were enrolled at the time of survey administration, and were invited for voluntary participation via email invitations distributed to the university's listserv. Prospective participants were provided with all necessary information regarding their participation in the study before electronically signing the informed consent form. Those who submitted their informed consent by clicking the "I Agree" button were eligible for participating in the study, and received access to a 20–25 min online questionnaire that assessed study variables. The survey was compatible with mobile devices, as it was presumed students with high cell phone use would prefer this interface method.

Measures

Sleep questionnaire

A validated 19 item Pittsburgh Sleep Quality Index (PSQI) scale (Cronbach's alpha = 0.83) [26] was used to measure sleep latency and sleep disturbance. The psychometric properties of the PSQI were also assessed using the sample from the current study ($N = 521$; 74% female), and the items in the scale were found to exhibit strong internal consistency (Cronbach's alpha = 0.80).

Sleep latency was measured by combining the scores of questions 2 and 5a of the PSQI: Q2) During the past month, how long (in minutes) has it usually take you to fall asleep each night (Scoring: "15 min"—0, "16–30 min"—1, "31–60 min"—2, "> 60 min"—3), Q5a) During the past month, how often have you had trouble sleeping because you cannot get to sleep within 30 min (Scoring: "Not during past month"—0, "Less than once a week—1, "Once or twice a week—2, "Three or more times a week"—3). The combined scores from both the items were translated into categorical variables as follows: "sum of Q2 and Q5a = 0"—0, "sum of Q2 and Q5a = 1–2"—1, "sum of Q2 and Q5a = 3–4"—2, "sum of Q2 and Q5a = 5–6"—3 [26].

Sleep disturbance was measured by combining the scores of questions 5b to 5j of the PSQI: Q5) During the past month, how often have you had trouble sleeping because you (b) Wake up in the middle of the night or early morning, (c) Have to get up to use the bathroom, (d) Cannot breathe comfortably, e) Cough or snore loudly, (f) Feel too cold, (g) Feel too hot, (h) Have bad dreams, (i) Have pain, (j) Other reason(s), please describe (Scoring: "Not during past month"—0, "Less than once a week—1, "Once or twice a week—2, "Three or more times a week"—3). The sum of the scores of items 5b to 5j were translated into categorical variables as follows: "sum of 5b–5j = 0"—0, "sum of 5b–5j = 1–8"—1, "sum of 5b–5j = 10–18"—2, "sum of 5b–5j = 19–27"—3 [26].

In addition, other sleep components such as subjective sleep quality, sleep duration, habitual sleep efficiency, use of sleep medication, and daytime dysfunction, were measured along with the global PSQI score. The subjective sleep quality was measured using question 6 of the PSQI: Q6) During the past month, how would you rate your sleep quality overall? (Scoring: "Very good"—0, "Fairly good"—1, "Fairly bad"—2, "Very bad"—3). Sleep duration was measured using question 4 of the PSQI, and the scores were translated into categorical variables as follows: Q4) during the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) (Scoring: "> 7 h"—0, "6–7 h"—1, "5–6 h"—2, "< 5 h"—3). Habitual sleep efficiency was measured using the scores of questions 1, 3, and 4 of the PSQI: Q1) During the past month, when have you usually gone to bed at night? (Scoring: Usual bedtime ___). Q3) During the past month, when have you usually got up in the morning? (Scoring: usual getting up time ___). Q4) During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) (Scoring: "> 7 h"—0, "6–7 h"—1, "5–6 h"—2, "< 5 h"—3). The number of hours spent in bed were calculated using the scores of questions 1 and 3. The percentage of habitual sleep efficiency was calculated by the following: (Number of hours slept/Number of hours spent in bed) × 100. These percentages were translated into categorical variables as follows: "> 85%"—0, "75–84%"—1, "65–74"—2, "< 65%"—3 [26].

The use of sleep medication was measured using question 4 of the PSQI, and the scores were translated into categorical variables as follows: Q7) During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep? (Scoring: "Not during the past month"—0, "Less than once a week"—1, "once or twice a week"—2, "Three or more times a week"—3). Daytime dysfunction was measured by combining the scores of questions 8 and 9 of the PSQI: Q8) During the past month, how often have you

you had trouble staying awake while driving, eating meals, or engaging in social activity? (Scoring: "Not during the past month"—0, "Less than once a week"—1, "once or twice a week"—2, "Three or more times a week"—3). Q9) During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done? (Scoring: "No problem at all"—0, "Only a very slight problem"—1, "Somewhat of a problem"—2, "A very big problem"—3). The sum of the scores of items 8 and 9 were translated into categorical variables as follows: "sum of item 8 and 9 = 0"—0, "sum of item 8 and 9 = 1–2"—1, "sum of item 8 and 9 = 3–4"—2, "sum of item 8 and 9 = 5–6"—3. The global PSQI scores were measured by adding the scores of all seven components of the PSQI [26].

CPU questionnaire

A validated CPU nighttime questionnaire [6] was administered to measure CPU_BeforeBed and CPU_Arousal. Nine items on a Likert scale from 'never' to 'always' (1-"Never", 2—"Occasionally", 3—"Often", and 4—"Always"), with a minimum possible score of 9 and a maximum possible score of 36, measured CPU_BeforeBed. The sample items were: In the last 30 days, have you stayed up late to use your cell phone for calling after a target bedtime? Six items, on a Likert-based scale (from 1 to 10), with a minimum possible score of 6 and a maximum possible score of 60, measured CPU_Arousal. Sample items included: In the last 30 days, how common is it for you to use your cell phone to engage in (1 = not common at all to 10 = extremely common): (a) emotionally charged text messages and images, (b) explicit content pertaining to sexuality (pornography, tinder, dating sites, etc.), and (c) explicit content pertaining to violence (video games, movies, etc.). The validity of the items for the individual sub-scales was tested by Joshi et al. (2021) [6] and the items exhibited good internal consistency for CPU_BeforeBed (Cronbach's alpha = 0.76) and CPU_Arousal (Cronbach's alpha = 0.70). The overall CPU nighttime questionnaire consisted of strong reliability (Cronbach's alpha = 0.75). The psychometric properties of the CPU questionnaire were also assessed using the sample from the current study (N = 521), and the items in the scale were found to exhibit good internal consistency (Cronbach's alpha = 0.74).

PWB measures

An 8 item Flourishing Scale (FS) was used to measure PWB (Cronbach's alpha = 0.87) [27]. As per Diener et al. FS is a measure with good psychometric properties as "it correlated strongly with the summed scores for the other psychological well-being scales, at 0.78 and 0.73" (p 152). The FS was also found to be a valid instrument in later studies, e.g.,

Telef (Cronbach alpha = 0.80) [28], and Kumcagiz and Gunduz (Cronbach alpha = 0.87) [29]. The reliability of the FS scale was also tested using the sample from the current study (N = 521). All the items were found to exhibit strong internal consistency (Cronbach's alpha = 0.86).

Data analysis

The statistical package SPSS for Windows (Version 25.0, Chicago, IL, USA) was used to conduct all analyses. Before administering the main analyses, the data were tested for ceiling and floor effect, multicollinearity, proportional odds, skewness, homoscedasticity, and normality. Pearson correlation coefficient was used for all key variables (CPU_BeforeBed; CPU_Arousal, sleep latency, and sleep disturbance) as all of them were ordinal-level measures. Ordinary least-squares regressions were conducted to assess the estimates of the relationships within the models. One-way ANOVA was used to see the means difference between the groups. The significance level was set as 0.01 for the analyses. The partial eta squared was used to determine the effect size between the groups. For a one-way ANOVA, the effect size for the outcome variable with a partial eta squared value of 0.01 is considered small, 0.06 is considered medium, and 0.14 is considered large [30]. The PROCESS Procedure for SPSS Version 4.0 was used to test the statistical significance of the total, direct and indirect effects in the mediation models [31].

Results

Descriptive statistics

Description of sample

The sample consisted of undergraduate students (N = 521; 74% female) between 18 and 29 years old, with an average age of 20 years (SD = 3.18) (Table 1). In this sample, 81% of undergraduate students were between 18 and 21 years old and 19% were between 22 and 29 years old. In terms of the number of years in college, 38% of undergraduate students were incoming freshmen (starting the first year), 19% sophomore (starting the second year), 17% junior (starting the third year), 14% senior (starting the fourth year), and 13% returning senior (starting the fifth year or beyond). It was an ethnically diverse sample of participants, with 49% Caucasian, 24% Latinx, 19% Asian, 3% African American, 1% Native American, while 3% identified as "other" in the survey. The remaining 1% preferred not to answer. The sample was also diverse in terms of the number of years the participants had been attending a two-year or four-year higher institution, as it included 38% incoming freshman,

Table 1 The descriptive statistics of age, CPU_BeforeBed, CPU_Arousal, and PWB (N=521)

	Minimum	Maximum	Mean ± SD	Mode	Skewness	Number of Items	Cronbach's alpha
Age	18	29	20 ± 3.18	18	4.37		
CPU_BeforeBed	9	36	18 ± 4.32	17	0.78	9	0.76
CPU_Arousal	6	54	16 ± 8.38	6	1.26	6	0.70
PWB	8	40	32 ± 5.54	32	− 0.83	8	0.86
Global PSQI	3	19	9 ± 2.49	8	0.50	19	0.80

CPU_BeforeBed the use of cell phone before sleep, *CPU_Arousal* the use of cell phones for accessing sexually explicit, violently, or emotionally charged media content, *PWB* psychological well-being, *Global PSQI* sum of scores from seven components of PSQI

19% sophomore, 17% junior, 14% senior, and 13% returning senior.

Description of CPU_BeforeBed

Undergraduate students reported occasional (infrequently but not compulsively) cell phone use before bed on a scale ranging from 9 to 36, with 9 being "Never" and 36 being "Always" (Table 1). There was a statistically significant ($p < 0.01$) effect of variable sex ($F_{(2, 522)} = 4.514$, $p < 0.01$, eta squared = 0.02) and college ($F_{(16, 508)} = 2.030$, $p < 0.01$, eta squared = 0.06) on the CPU_BeforeBed of undergraduate students, as determined by a one-way ANOVA. Female undergraduate students (17.97 ± 4.32), as compared to male undergraduate students (16.89 ± 4.21) had a slightly higher CPU_BeforeBed as determined by the effect size. The item-level CPU_BeforeBed score of undergraduate students revealed that female undergraduate students (2.79 ± 0.89) stayed up late more often to use social media on their cell phones as compared to male undergraduate students (2.50 ± 0.91) (please refer to supplementary Table 7, for detailed test-statistics). The item-level CPU_BeforeBed score also revealed that female undergraduate students (2.76 ± 0.89) stayed up later to watch videos on their cell phones compared to male undergraduate students (2.52 ± 0.87) (Table 7, Supplementary Table).

Description of CPU_Arousal

Undergraduate students also reported having arousal due to the use of cell phones on a scale ranging from 10 to 60, with 10 being "not common at all" and 60 being "extremely common" (Table 1). There was a small, but statistically significant ($p < 0.001$) effect of variable sex ($F_{(2, 522)} = 13.468$, $p < 0.001$, eta squared = 0.05) on the CPU_Arousal of undergraduate students, as determined by a one-way ANOVA (please refer to supplementary Table 8, for detailed test-statistics). Male undergraduate students (19.31 ± 10.16), as compared to female undergraduate students, (14.99 ± 7.46) had higher CPU_Arousal. The item-level CPU_Arousal

score of undergraduate students revealed that male undergraduate students (3.71 ± 2.68) were engaged more often in explicit content pertaining to sexuality using their cell phones as compared to female undergraduate students (1.85 ± 1.72) (Table 8, Supplementary Table). Moreover, male undergraduate students (2.50 ± 2.23) stayed awake longer to engage in sexually-oriented cell phone apps than female undergraduate students (1.54 ± 1.32). The item-level CPU_Arousal score also revealed that male undergraduate students (3.39 ± 2.65) were engaged more in explicit content pertaining to violence as compared to female undergraduate students (1.94 ± 1.80). Also, male undergraduate students (2.28 ± 2.04) stayed awake longer to engage in violence-based cell phone apps than female undergraduate students (1.46 ± 1.29) (Table 8, Supplementary table).

Description of sleep quality

Three-quarters (73%) of undergraduate students reported low, moderate, or high sleep latency, with some sort of trouble sleeping during the past month (Table 2). 95% of undergraduate students also reported having some sort of sleep disturbance, with 21% having trouble sleeping once or twice, and three or more times a week. However, 27% of respondents reported having no sleep latency, with a small percentage (5%) of students reporting no sleep disturbances at all. 80% of undergraduate students reported having good sleep and 79% reported a sleep duration of more than 6 h, whereas 20% reported having bad sleep quality with a sleep of fewer than 6 h (21% of the total).

More than three-quarters (77%) of undergraduate students reported being able to sleep efficiently (score of 75% or more), with one-third (33%) reporting that they were not able to sleep efficiently (Table 2). From the total sample, 17% of undergraduate students reported using sleeping medication for less than a week, once or twice a week, and three or more than a week, however, 83% of undergraduate students reported no use of sleep medication during the past month. More than half of the undergraduate students (59%) reported having trouble staying awake while

Table 2 The descriptives of subjective sleep quality, sleep latency, sleep duration, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction ($N = 521$)

Component	Scores	0	1	2	3	Total
Subjective sleep quality	N	61	354	95	11	521
	%	12.1	67.6	18.3	2.0	100
Sleep latency	N	137	195	122	67	521
	%	27.0	36.7	23.1	13.2	100
Sleep duration	N	115	301	77	28	521
	%	22.1	56.8	15.0	6.1	100
Habitual sleep efficiency	N	128	220	112	61	521
	%	25.2	41.5	21.3	12.0	100
Sleep disturbances	N	24	379	111	7	521
	%	5.0	72.1	20.7	2.2	100
Use of sleep medication	N	435	40	26	20	521
	%	82.5	8.2	5.1	4.2	100
Daytime dysfunction	N	0	58	247	216	521
	%	0	11.3	47.6	41.1	100

For subjective sleep quality: 0—"Very good," 1—"Fairly good," 2—"Fairly bad," and 3—"Very bad". For sleep latency: 0—"15 min or less," 1—"16–30 min," 2—"31–60 min," and 3—"more than 60 min". For sleep duration: 0—">7 h," 1—"6–7 h," 2—"5–6 h," 3—"<5 h." For habitual sleep efficiency: 0—">85%," 1—"75–84%," 2—"65–74%," 3—"<65%." For sleep disturbance: 0—"not during the past month," 1—"less than once a week," 2—"once or twice a week," and 3—"three or more times a week". For use of sleep medication: 0—"not during the past month," 1—"less than once a week," 2—"once or twice a week," and 3—"three or more times a week". For daytime dysfunction: 0—"0," 1—"1–2," 2—"3–4," and 3—"5–6"

driving, eating meals, or engaging in social activity, and problems relating to having energy to get things done during the day (i.e., daytime dysfunction) once or twice during the past month or once or twice each week. 41% of the undergraduate students reported having daytime dysfunction three or more times a week, however, none of them reported having no daytime dysfunction. The actual global PSQI scores of undergraduate students ranged from 3 to 19, with an overall group mean of 9 (SD = 2.49), indicating a poor sleep quality (Table 1). Usually, samples with a global PSQI score > 5 are considered to have significant sleep problems and are referred to as poor sleepers [26]. From the overall sample of the present study, 96% of the undergraduate students reported having poor sleep quality (Global PSQI score ≥ 6)).

Inferential analyses

Concerning control analysis, no ceiling or floor effect was found, as the frequency percentage of respondents achieving the lowest or highest possible score was less than 15% for CPU_BeforeBed (for the lowest score—0.8%, for the highest score—0.2%) and CPU_Arousal (for the lowest score—9.5%, for the highest score—0.2%). The data for PWB was heteroscedastic and was not normally distributed.

Correlational analyses indicated that the Pearson correlation coefficient between CPU_BeforeBed and PWB was not statistically significant ($\alpha = -0.044$, $p = 0.615$, mean = 17.69 (SD = 4.319), 95% CI = − 0.129 to 0.042) (Table 3). The Pearson correlation coefficient between CPU_Arousal and PWB was also not statistically significant ($\alpha = -0.061$,

Table 3 Correlation analyses ($N = 521$)

		CPU_BeforeBed	CPU_Arousal	Sleep latency	Sleep disturbance	PWB
Pearson coefficient	CPU_BeforeBed	1.000				
	CPU_Arousal	0.394**	1.000			
	Sleep latency	0.189**	0.142**	1.000		
	Sleep disturbance	0.215**	0.239**	0.312**	1.000	
	PWB	− 0.044	− 0.061	− 0.140**	− 0.121**	1.000

CPU_BeforeBed the use of cell phone before sleep, *CPU_Arousal* the use of cell phones for accessing sexually explicit, violently, or emotionally charged media content, *PWB* psychological well-being

**$p < 0.01$ (2–tailed)

$p = 0.228$, mean $= 16.03$ (SD $= 8.38$), 95% CI $= -0.146$ to 0.025) (Table 3). Correlational analyses further indicated that Pearson correlation coefficient between sleep latency and PWB was statistically significant ($\alpha = -0.140$, $p = 0.001$, mean $= 1.22$ (SD $= 0.98$), 95% CI $= -0.223$ to -0.055) (Table 3). Pearson correlation coefficient between sleep disturbance and PWB was also statistically significant ($\alpha = -0.121$, $p = 0.005$, mean $= 1.18$ (SD $= 0.53$), 95% CI $= -0.204$ to -0.035) (Table 3).

There was no statistically significant ($p < 0.01$) effect of CPU_BeforeBed ($F(24, 500) = 0.891$, between groups means difference $= 27.447$, withing groups means difference $= 30.797$, $p = 0.615$, effect size $= 0.04$) on PWB, as determined by a one-way ANOVA. There was no statistically significant effect of CPU_Arousal ($F(38, 486) = 1.172$, between groups means difference $= 35.458$, withing groups means difference $= 30.267$, $p = 0.228$, effect size $= 0.08$) on PWB, as determined by a one-way ANOVA. Further, there was a statistically significant small effect of sleep latency ($F(3, 521) = 3.667$, between groups means difference $= 110.674$, withing groups means difference $= 30.182$, $p < 0.05$, effect size $= 0.02$) on PWB, as determined by a one-way ANOVA. There was a statistically significant small effect of sleep disturbance ($F(3, 521) = 4.380$, between groups means difference $= 131.670$, withing groups means difference $= 30.062$, $p < 0.01$, effect size $= 0.03$) on PWB, as determined by a one-way ANOVA.

Concerning mediation analyses, four ordinary least-squares regressions were administered (refer to Table 4). The first model indicated that there was a statistically significant relationship, with medium effect size between CPU_BeforeBed and sleep latency ($F(3, 521) = 6.855$, $p < 0.001$, eta squared $= 0.09$) after controlling the variables age and sex. The second model indicated that there was a statistically significant relationship with small effect size between sleep latency and PWB ($F(4, 520) = 3.114$, $p < 0.01$, eta squared $= 0.02$) after controlling the variables CPU_BeforeBed, age and sex. The third model showed that there was a statistically significant relationship with medium effect size between CPU_Arousal and sleep disturbance ($F(3, 521) = 16.639$, $p < 0.001$, eta squared $= 0.13$) after controlling the variables age and sex. The fourth model showed that there was a statistically significant relationship with small effect size between sleep disturbance and PWB ($F(4, 520) = 2.415$, $p < 0.05$, eta squared $= 0.03$) after controlling the variables CPU_BeforeBed, age, and sex.

Two mediation models were administered using PROCESS to assess the mediator effect (Table 5). In the first model, the estimates of the direct effect of CPU_BeforeBed on sleep latency were statistically significant (Unstandardized $B = 0.185$, $p < 0.001$). The estimates of the direct effect of sleep latency on PWB were also statistically significant (Unstandardized $B = -0.137$, $p < 0.001$). However, the estimates of the direct effect of CPU_BeforeBed on PWB were

Table 4 Ordinary least-squares regression analyses ($N = 521$)

	Predictor	Unstandardized B	β	p	95% CI	SE	t	R^2	F
Hypotheses 3	Model 1: sleep latency							0.038	6.855***
	CPU_BeforeBed	0.042	0.184	< 0.001	(0.023–0.061)	0.010	4.238		
	Age	0.000	− 0.001	0.976	(− 0.027 to 0.026)	0.013	− 0.026		
	Sex	0.128	− 0.046	0.202	(− 0.069 to 0.324)	0.097	− 1.065		
	Model 2: PWB							0.023	3.114**
	Sleep latency	− 0.767	− 0.139	0.002	(− 1.255 to 0.279)	0.249	− 3.147		
	CPU_BeforeBed	− 0.022	− 0.025	0.463	(− 0.080 to 0.037)	0.057	− 0.564		
	Age	− 0.007	− 0.006	0.929	(− 0.156 to 0.143)	0.076	− 0.128		
	Sex	0.569	− 0.057	0.329	(− 0.575 to 1.713)	0.548	− 1.296		
Hypotheses 4	Model 3: Sleep disturbance							0.087	16.639***
	CPU_Arousal	0.190	0.269	< 0.001	(0.012–0.023)	0.003	6.284		
	Age	0.020	0.118	0.005	(0.023–0.061)	0.007	2.794		
	Sex	0.182	− 0.146	< 0.001	(0.076–0.288)	0.052	− 3.381		
	Model 4: PWB							0.018	2.415*
	Sleep disturbance	− 1.246	− 0.120	0.009	(− 2.174 to− 0.319)	0.472	− 2.648		
	CPU_Arousal	− 0.016	− 0.021	0.611	(− 0.076 to 0.044)	0.030	− 0.456		
	Age	0.019	0.010	0.804	(− 0.132 to 0.170)	0.077	0.220		
	Sex	0.598	− 0.058	0.308	(− 0.554 to 1.751)	0.550	− 1.322		

CPU_BeforeBed the use of cell phone before sleep, *CPU_Arousal* the use of cell phones for accessing sexually explicit, violently, or emotionally charged media content, *PWB* psychological well-being. β standardized coefficient. *CI* confidence interval. R^2 R square change

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 5 Mediation analysis using PROCESS ($N = 521$)

	Predictor	Coefficients	SE	β	t	R	R^2	LL	UL	F
Hypotheses 3	Model 1: sleep latency					0.198	0.039			7.101***
	CPU_BeforeBed	0.0421	0.0099	0.185	4.263			0.023	0.062	
	Age	− 0.0004	0.013	− 0.001	− 0.031			− 0.027	0.026	
	Sex	0.1277	0.097	-0.056	1.278			-0.069	0.324	
	Model 1: PWB					0.149	0.022			2.952***
	Sleep latency	-0.7715	0.249	-0.137	-3.093			-1.262	-0.282	
	CPU_BeforeBed	-0.0320	0.057	− 0.025	− 0.561			− 0.1441	0.080	
	Age	− 0.0073	0.076	− 0.004	− 0.095			− 0.1568	0.142	
	Sex	0.6985	0.568	− 0.054	− 1.228			− 0.419	1.816	
Hypotheses 4	Model 2: sleep disturbance					0.295	0.087			16.549***
	CPU_Arousal	0.0172	0.003	0.270	6.284			0.012	0.023	
	Age	0.0198	0.007	0.118	2.796			0.006	0.034	
	Sex	0.1817	0.054	− 0.146	3.368			0.076	0.288	
	Model 2: PWB					0.134	0.018			2.366**
	Sleep disturbance	− 1.2465	0.472	− 0.120	− 2.639			− 2.174	− 0.319	
	CPU_Arousal	− 0.0155	0.030	− 0.024	− 0.508			− 0.075	0.045	
	Age	0.0191	0.077	0.011	0.248			− 0.132	0.170	
	Sex	0.5981	0.550	− 0.046	1.019			− 0.555	1.751	

CPU_BeforeBed the use of cell phone before sleep, *CPU_Arousal* the use of cell phones for accessing sexually explicit, violently, or emotionally charged media content, *PWB* psychological well-being; *LL* lower limit of CI, *LL* upper limit of CI, *CI* confidence interval

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

not statistically significant (Unstandardized $B = − 0.032$, $p = 0.575$) (Table 6). The indirect effect between CPU_BeforeBed and PWB via an intermediatory variable of sleep latency was statistically significant ($p < 0.05$), as determined by the PROCESS analysis (Effect = − 0.0325, SE = 0.0145, $p < 0.05$) (Table 6). These analyses showed that H3 was supported, which stated that sleep latency is a mediator between CPU_BeforeBed and PWB (Fig. 3).

In the second model, the estimates of the direct effect of CPU_Arousal on sleep disturbance were statistically significant (Unstandardized $B = 0.270$, $p < 0.001$) (Table 5). The estimates of the direct effect of sleep disturbance on PWB were also statistically significant (Unstandardized $B = − 0.120$, $p < 0.01$) (Table 5). However, the estimates of the direct effect of CPU_Arousal on PWB were not statistically significant (Effect = − 0.0155, $p = 0.6112$) (Table 6).

**Table 6** Total, direct, and indirect effects of CPU_BeforeBed and CPU_Arousal on PWB

| Effect of CPU_BeforeBed on PWB	Effect	SE	t	p	LL	UL	c or c'
Total	− 0.0645	0.0566	− 1.140	0.2548	− 0.1756	0.0466	− 0.503 (n. s.)
Direct	− 0.0320	0.0571	− 0.5609	0.5751	− 0.1441	0.0801	− 0.0250 (n. s.)
Indirect	Effect	Boot SE	Boot LL	Boot UL			
	− 0.0325*	0.0145	− 0.0656	− 0.0084			
Effect of CPU_Arousal on PWB	Effect	SE	t	p	LL	UL	c or c'
Total	− 0.0370	0.0296	− 1.2488	0.2123	− 0.0952	0.0212	− 0.0561 (n. s.)
Direct	− 0.0155	0.0305	− 0.5087	0.6112	− 0.0755	0.0445	− 0.0236 (n. s.)
Indirect	Effect	Boot SE	Boot LL	Boot UL			
	− 0.0214*	0.0086	− 0.0392	− 0.0052			

CPU_BeforeBed the use of cell phone before sleep, *CPU_Arousal* the use of cell phones for accessing sexually explicit, violently, or emotionally charged media content, *PWB* psychological well-being; *LL* Lower limit of CI, *LL* Upper limit of CI, *CI* confidence interval

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$
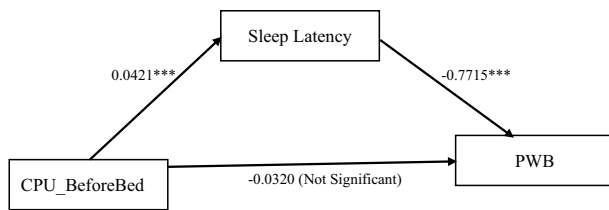
Fig. 3 Sleep latency as a mediator between CPU_BeforeBed and PWB
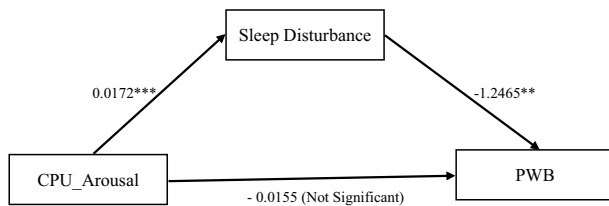
Fig. 4 Sleep disturbance as a mediator between CPU_Arousal and PWB

The indirect effect between CPU_Arousal and PWB via an intermediatory variable of sleep disturbance was statistically significant ($p < 0.05$), as determined by the PROCESS analysis (Effect = − 0.0214, SE = 0.0086, $p < 0.05$) (Table 6). These analyses indicated that H4 was supported, which stated that sleep disturbance is a mediator between CPU_Arousal and PWB (Fig. 4).

Discussion and conclusion

This study aimed to (1) test the correlation between nighttime CPU and PWB, and (2) test the role of sleep latency and sleep disturbance as mediators between nighttime CPU and PWB of college students. Four hypotheses were developed to achieve these goals. H1 and H2 examined the relationship between CPU and PWB of college students—both H1 and H2 were unsupported, and the results indicated that CPU_BeforeBed and CPU_Arousal were unrelated to the PWB of college students. H3 and H4 examined the mediating role of sleep latency and sleep disturbance between CPU and PWB of young adults—both of which were supported. The outcomes revealed that sleep latency acts as a mediator between CPU_BeforeBed and PWB. Further, sleep disturbance acts as a mediator between CPU_Arousal and PWB of college students.

To the best of my knowledge, this study would be the first of its kind to examine nighttime CPU and PWB of college students. In this study, CPU_BeforeBed assessed the use of cell phones for unstructured leisure activities before sleep, which included whether participants have awakened

after going to bed (or stayed up late after a target bedtime) due to the following cell phone operations/activities: calling, texting, checking notifications, emailing, listening to Podcasts, listening to music, social networking, watching videos (Netflix, Hulu, etc.), gaming, and non-social-media internet browsing (shopping, surfing, etc.). CPU_Arousal assessed the use of cell phones for accessing emotionally charged media content before sleep, which included two things (1) participants' engagement with their cell phones towards emotionally charged texts and messages, explicit content pertaining to sexuality (pornography, tinder, dating sites, etc.), and explicit content pertaining to violence (video games, movies, etc.), and (2) the rate of occurrence of uses mentioned in the first three items that kept participants awake. The flourishing scale assessed the self-perceived success of the participants in important areas such as relationships, self-esteem, purpose, and optimism.

Concerning the first hypothesis, the correlation between CPU_BeforeBed and PWB was not statistically significant, which implied that using cell phones after going to bed or staying up late after a target bedtime due to the use of cell phones did not affect the PWB of college students. For the second hypothesis, the correlation between CPU_Arousal and PWB was not statistically significant, which implied that using cell phones for accessing emotionally charged media content before sleep did not affect the PWB of college students.

These results suggested that the use of cell phones from a specific time and for a specific purpose did not influence the PWB. There may be the case that CPU measures from a specific time of the day or night would not suffice for finding the relationship between CPU and PWB. Quantifiable measures assessing the estimates of the total amount of time spent using cell phones per day, along with the measures of CPU_BeforeBed and CPU_Arousal may help clarify the relationship between the two variables. Also, quantifiable measures assessing the use of cell phones for various activities including the use of cell phones for social media (Instagram, Twitter, Snapchat, Facebook, etc.) would help clarify on the relationship between CPU and PWB as social media has been shown to have a direct impact on the PWB of college students [32, 33].

Concerning the third hypothesis (i) there was an increase in sleep latency due to higher CPU_BeforeBed, as determined by least-squares regression analysis (model 1, Table 4), and (ii) the scores of PWB decreased with the increase in the levels of CPU-led sleep latency, as determined by least-squares regression analysis (model 2, Table 4). These results support the fact that CPU 'in bed' and CPU 'after lights were out' negatively influenced sleep latency in college students [4, 7, 32]. There are two implications that can be made from these outcomes i) the use of cell phones after a target bedtime resulted in higher risks of sleep

latency in college students, (ii) the increased levels of sleep latency due to the use of cell phones before bed decreased the PWB of college students. The first implication confirmed a direct impact of CPU_BeforeBed on sleep latency of college students and the second implication confirmed a direct impact of sleep latency on PWB of college students. Combining both the implications, CPU_BeforeBed impacts PWB through sleep latency.

The estimates of the indirect effects of CPU variables on PWB through sleep variables were analyzed using PROCESS in two mediation models. The first mediation model (Fig. 3) showed that there was an indirect effect of CPU_BeforeBed on PWB via an intermediatory variable of sleep latency. This means college students who were having sleep interruptions due to CPU_BeforeBed had lower levels of PWB. Cell phone addiction [28, 34] may be one of the reasons people use cell phones for unstructured leisure activities after a target bedtime, which could lead to the development of sleep latency, thereby lowering the overall PWB of college students.

Concerning the fourth hypothesis (i) there was an increase in sleep disturbance due to higher CPU_Arousal, as determined by least-squares regression analysis (model 3, Table 4), and (ii) the scores of PWB were decreased with the increase in the levels of CPU-led sleep disturbance y, as determined by least-squares regression analysis (model 4, Table 4). These results had two implications (i) the use of cell phones for accessing emotionally charged media content after a target bedtime resulted in higher risks of sleep disturbance in college students, (ii) the increased levels of sleep disturbance due to the use of cell phones for accessing emotionally charged media content after a target bedtime decreased the PWB of college students. The first implication confirmed a direct impact of CPU_Arousal on sleep disturbance of college students and the second implication confirmed a direct impact of sleep disturbance on PWB of college students. Combining both the implications, CPU_Arousal impacts PWB through sleep disturbance.

The indirect effect of CPU_Arousal on PWB via an intermediatory variable of sleep disturbance was depicted by the second mediation model (Fig. 4). This indirect effect demonstrated that college students who had disturbances while sleeping due to CPU_Arousal had lower levels of PWB. College students with cell phone addiction [9] or addiction towards accessing sexually explicit, violently explicit, or emotionally charged media content before bed might lead to higher sleep disturbance, which in turn reduces their PWB.

These results align with previous studies analyzing the mediating effects of sleep quality and technology use, including CPU, and PWB variables such as anxiety and depression. Adams and Kisler [22] suggested that sleep quality acts as a mediator between technology use before sleep and depressions and anxiety in college students. Zou et al.

[25] suggested that sleep quality played a mediating role in the association of problematic mobile phone use and depression in college students. The present study has gone a step further and investigated the mediating effects of the crucial components of sleep quality (i.e., sleep latency and sleep disturbance) for the association of the respective nighttime CPU components (i.e., CPU_BeforeBed and CPU_Arousal) and PWB in college students.

CPU-led sleep displacement and psychological arousal mechanisms [6] can explain these mediating effects. The mediating role of sleep latency between CPU_BeforeBed and PWB may be related to the displacement of sleep that "happens when the brain believes it is still working because one continues to use a cell phone while in bed." In such situations, the brain creates an association between the location of the CPU (i.e., the bed) and work (i.e., CPU). The mediating role of sleep disturbance between CPU_Arousal and PWB may be related to psychological arousal that happens due to the use of electronic media such as cell phones just before going to bed. In such situations, the brain takes time to prepare for sleep after mental (cognitive), emotional, and/or psychological arousal is created due to media content or cell phone screen time. In both cases, sleep gets disrupted or delayed, which may result in lowering the PWB of college students.

Implications

The findings from this study provide implications for both clinical and non-clinical settings. In clinical settings, findings can be used for college students having sleep problems and problems regarding changing their CPU behavior in order to improve their PWB. College students can make informed decisions about the use of cell phones, especially before going to bed. The mediator role of sleep variables between nighttime CPU and PWB showed that using cell phones at night escalates sleep problems in college students, which further affects their PWB. PWB encompasses mental health variables stress, anxiety, and depression [35]. Therefore, the health conditions of college students with these mental health problems may be heightened with the prolonged use of cell phones before bed. These results align with the outcomes from a previous study, which indicated that interacting with cell phones before sleep escalates emotional and/or mental (cognitive) arousal in college students, and increases their sleep disturbance [5, 23].

In non-clinical settings, the mediation effect of CPU_BeforeBed and CPU_Arousal on PWB through sleep latency and sleep disturbance will guide nighttime cell phone users about the negative consequences of the use of cell phones before going to bed. The detrimental effects of CPU on the PWB through sleep components will educate clinical and

non-clinical researchers regarding the confounding effects of sleep variables while studying CPU or PWB of college students. Knowing the harmful effects of CPU, especially for unstructured leisure activities and for accessing emotionally charged media content before bed, will create awareness about the use of cell phones from a specific time, particularly during evening/night, and for a specific purpose. Such awareness will guide CPUsers, especially college students, to limit their nighttime cell phone screen time and will help them regulate their nighttime CPU behaviors such as putting cell phones away before sleep hours or avoiding accessing sexually explicit, violently explicit, or emotionally charged media content before sleep. Additionally, the outcomes will have recurring implications for future studies, health professionals, and cell phone manufacturers.

Limitations

A few limitations should be considered while interpreting the outcomes of this study. The sample is comprised of undergraduate students from a single public university in the Southwestern United States. This may reflect some socio-economic and cultural specificities of university students from the Southwestern region. Also, the outcomes may have limitations for non-college CPUsers from the young adult demographic as the sample included traditional undergraduate students. Though the enrollment of the female undergraduate students (54%) was higher than the male undergraduate students (46%) at the recruiting institution, the overrepresentation for female participants in the study sample should be treated as a limitation. Low response rate is another limitation of this study. In addition, the measures relied on self-report which led to another limitation such as recall bias, which is one of the key concerns about self-reported questionnaires. Further, other factors occurring while taking the survey such as, non-academic workload, studies, leisure activities, family, and social commitments cannot be ignored.

This is a cross-sectional study, therefore, it cannot detect a causal relationship between the study variables. Although this study shows the mediating effect of sleep variables concerning CPU and PWB, the influence of variables from other mental health domains such as negative affect, positive affect, happiness, social function, stress response, anxiety, depression, psychological symptom, quality of life, and general health cannot be ruled out. Given the numerous factors influencing the relationship between sleep and cell phone use, it is possible that unmeasured factors such as substance use and the use of stimulating beverages could confound the outcome of the present study. Although the data was collected just after midterm exams, the study did not consider the timing of data collection. Also, the study did not take any factors related to student activities into account that may affect sleep latency and sleep disturbance, such as athletic competitions (for student-athletes), scheduled vacations, examinations including midterms, degree of disturbance of course loads, etc. Additionally, this study did not assess underlying mood disorders and the use of sleep medication, which may be prevalent and affect sleep latency and sleep disturbance.

Future directions

Future studies should use longitudinal data for measuring the mediating effects of CPU-led sleep variables relating to PWB. CPU variables such as the total time spent on cell phones per day should be treated as one of the independent variables. Other sleep variables of the PSQI scale such as subjective sleep quality, sleep duration, and habitual sleep efficiency should also be tested as mediating variables. Embedded sensors and built-in cell phone apps should be used to gain an in-depth understanding of the emotionally charged media content assessed on cell phones that affect sleep. Separate scales should be used to measure stress, anxiety, and depression, along with the flourishing scale. Analyzing the consistency of individual scales measuring PWB variables with the scale measuring overall PWB (i.e., flourishing scale) would be worthwhile. Moreover, a study assessing the impact of CPU on sleep quality, and PWB variables such as stress, depression, and anxiety, during quarantine is warranted.

Declarations

Conflict of interest The author(s) report no conflict of interest.

Ethical approval This study was reviewed and approved by the Institutional Review Board (IRB) of Texas A&M University (IRB2019-0980M) under the 45 CFR 46.104 declaration of the Human Research Protection Program (HRPP) of the University. All the procedures in the study involving human participants were performed in accordance with the IRB and HRPP standards.

Informed consent An informed consent was obtained from all the participants included in the study.

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