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Original Article

Study of effect of smart phone usage and sleep quality in undergraduate students

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ABSTRACT

Background: Excessive smartphone use may disrupt sleep, yet we lack detailed data on how medical students use their devices throughout the week or for specific activities. This study evaluates how this distinct usage patterns correlate with multidimensional sleep quality in undergraduate medical students.

Methods: This cross-sectional investigation involved 187 medical students in the age group of 18–22. Participants' rest patterns were evaluated via a 28-item symptom survey and the PSQI. To measure digital habits, a validated screen-time tool tracked usage across weekdays, weeknights, and weekends, while the MSQ categorized by activity. Subjects were divided into "low users" (PSQI <5) and "high users" (PSQI ≥5).

Results: The subjects were 57.2% female and 42.8% male, with the majority (73.8%) being 18 to 19 years old. Approximately 29.4% of students were identified as high smartphone users; this group exhibited markedly lower sleep quality compared to low users. Device engagement escalated rising from 96.7 minutes on weekdays to 139.5 on weeknights and peaking at 166.3 on weekends. Subjective reports highlighted significant distress: 51% occasionally felt life was painful due to rest deficits, 42% were chronically dissatisfied with their sleep, and 37% suffered from persistent headaches. Only 35% of the students reported feeling refreshed upon waking.

Conclusion

Summary: There is a robust link between sleep quality and high levels of smartphone consumption, specifically during weekends and late-night hours, among medical undergraduates. To enhance the mental well-being and academic success of these students, public health strategies should focus on optimizing sleep hygiene by limiting nocturnal device use and reducing pre-bedtime social media consumption.

Keywords*: smartphone, sleep quality, medical students, PSQI, screen time, social media, circadian rhythm*

INTRODUCTION

Sleep is a fundamental biological process essential for cognitive function, emotional regulation, metabolic health and immune competence (1). For medical students, adequate sleep is particularly critical given the high cognitive demands of medical education, the need for sustained attention, and the eventual responsibility for patient safety (3). However, poor sleep quality and sleep deprivation have reached epidemic proportions among medical trainees worldwide, with reported prevalence rates of poor sleep (PSQI ≥5) ranging from 50% to 70% in various studies (5,6).

The etiology of poor sleep among medical students is multifactorial, including academic stress, irregular schedules, examination pressure, and increasing digital screen exposure (8). Among digital devices, smartphones have become ubiquitous and uniquely problematic. Unlike desktop computers or televisions, smartphones are portable, personal, and often kept beside the bed or even used during bedtime hours (9). More than 90% of young adults own a smartphone, and many report using it within one hour of attempting to sleep (10).

Several mechanisms link smartphone use to poor sleep quality. First, the blue-wavelength light emitted by smartphone screens suppresses melatonin secretion from the pineal gland, delaying sleep onset and reducing rapid eye movement (REM) sleep (11). Second, the cognitive and emotional arousal produced by engaging content – particularly social media, messaging, and gaming – increases heart rate, blood pressure, and cortical activation, making it difficult to transition into sleep (12). Third, smartphone use often displaces sleep directly: time spent scrolling, texting, or watching videos is time not spent sleeping (13). Fourth, notifications and vibrations can cause nocturnal awakenings, fragmenting sleep architecture (14).

Despite growing evidence in general student populations, data specific to *undergraduate medical students* remain limited in several important respects. Most studies have focused on total screen time rather than distinguishing between weekdays, weeknights, and weekends (15). This distinction is crucial because medical students often have different schedules and sleep patterns across the week. Furthermore, few studies have examined *activity-specific* smartphone use – separating social media from messaging, calls, music, and reading – to identify which behaviours are most harmful (16). Finally, the multidimensional nature of sleep quality – including difficulty falling asleep, nocturnal awakenings, daytime dysfunction, and subjective satisfaction – is often reduced to a single global score (17). There is paucity in the literature and further studies are warranted to fulfil the lacunae. Hence the study aimed to quantify smartphone and other screen device use among medical students.

MATERIALS & METHODS

Study design and participants: A descriptive cross-sectional study was conducted at Sri Venkateswara Medical College (SVMC), Tirupati, Andhra Pradesh, over two months following ethical approval dated on 25.10.2023,Lr.No.167/2023. A total of 200 undergraduate students aged 18–22 years were approached via convenience sampling; 187 completed the questionnaire correctly and were included in the final analysis.

Inclusion criteria were: (a) age 18–22 years, (b) current enrolment in the undergraduate medical students, (c) ownership of a personal smartphone, and (d) willingness to provide informed consent.

Exclusion criteria were: (a) diagnosed sleep disorder (b) use of prescription sleep medications, (c) shift work or night duty during the study period, and (d) history of neurological or psychiatric conditions known to affect sleep.

Ethical considerations: The study was approved by the Institutional Ethics Committee (167/2023). Written informed consent was obtained from all participants. All procedures were conducted in accordance with the Declaration of Helsinki and later amendments 1975.

Sample size calculation:
Based on a previous study reporting a moderate effect size (Cohen's d = 0.5) for the difference in PSQI scores between high and low smartphone users (18), with $\alpha = 0.05$ and power = 0.80, the required sample size was calculated as 128 participants. We recruited 187 to account for potential incomplete data and to enhance precision.

Data acquisition: Participants completed paper-based questionnaires in a classroom setting under standardized conditions. Research assistants were present to clarify questions but did not influence responses. Questionnaires took approximately 20–25 minutes to complete. Data were double-entered into an electronic database to minimize transcription errors.

Pittsburgh Sleep Quality Index (PSQI)
The PSQI is a validated, 19-item self-report questionnaire that assesses sleep quality over the past month (26). It generates seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The global PSQI score ranges from 0 to 21, with a cutoff of 5 or greater indicating poor sleep quality (sensitivity 89.6%, specificity 86.5%). In this study, students with PSQI <5 were classified as "low users" (good sleepers) and those with PSQI ≥5 as "high users" (poor sleepers), consistent with the terminology used in the original data tables.

Screen-time questionnaire
A structured questionnaire assessed daily screen time in minutes for five device categories: television, TV-connected devices (e.g., streaming sticks, gaming consoles), laptop/computer, smartphone, and tablet. Separate estimates were obtained for weekdays (Monday–Thursday), weeknights (Sunday–Thursday nights), and weekends (Friday–Sunday). Intraclass correlation coefficients (ICC) were calculated to assess test-retest reliability over a two-week interval in a subset of 30 students, with values interpreted as: <0.5 poor, 0.5–0.75 moderate, 0.75–0.9 good, >0.9 excellent.

Mini Sleep Questionnaire (MSQ) – activity module

The MSQ activity module assessed average daily smartphone usage time (minutes/day) for five specific activities: social media (e.g., Instagram, Facebook, TikTok, Twitter/X), messaging (e.g., WhatsApp, Telegram, SMS), phone calls (voice calls), listening to music (streaming or local), and reading (e-books, articles, news). Participants reported typical use over the preceding month. Pearson correlation was computed between PSQI global score and social media time as the primary activity of interest.

Sleep symptom checklist (28 items)
A 28-item checklist, derived from the PSQI component details and the Sleep Symptom Checklist (28), assessed the frequency of specific sleep-related complaints. Response options were: rarely (1–2 times/month), sometimes (1–2 times/week), often (3–4 times/week), almost always (5–7 times/week). Items covered falling asleep, maintaining sleep, returning to sleep, environmental disturbances, daytime consequences (headaches, irritability, concentration, fatigue, appetite changes, forgetfulness), and subjective satisfaction.

Statistical analysis
All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were expressed as frequencies (percentages) for categorical variables and mean (standard deviation, SD) or mean (standard error of the mean, SEM) for continuous variables. Normality was assessed using the Shapiro–Wilk test and visual inspection of Q-Q plots. For between-group comparisons (low users vs. high users), an independent samples t-test was used, with Cohen's d calculated as a measure of effect size (small = 0.2, medium = 0.5, large = 0.8). The 95% confidence interval (CI) for the mean difference was reported.

For categorical variables, chi-square tests were applied.
Reliability of the screen-time questionnaire was assessed using ICC (two-way mixed, absolute agreement). Pearson correlation coefficient (r) was used to examine the linear relationship between PSQI score and social media time, with interpretation: <0.1 negligible, 0.1–0.3 weak, 0.3–0.5 moderate, >0.5 strong.
All p-values were two-tailed, and $p < 0.05$ was considered statistically significant.

RESULTS

Participant characteristics
A total of 187 undergraduate medical students participated, with a response rate of 91.2% (187 of 205 eligible students). Table 1 presents the general characteristics. The majority of students were aged 18–19 years (138, 73.8%), with the remaining 49 (26.2%) aged 20–22 years. Female students outnumbered males (107, 57.2% vs. 80, 42.8%). Regarding year of study, second-year students constituted the largest group (99, 52.9%), followed by first-year (44, 23.5%), third-year (36, 19.3%), and fourth-year (8, 4.3%). The distribution reflects the typical enrolment pattern in this medical school.

Smartphone use and global sleep quality
Based on PSQI scores, 132 students (70.6%) were classified as low users (PSQI <5, good sleep quality) and 55 students (29.4%) as high users (PSQI ≥5, poor sleep quality). This indicates that nearly one in three medical students in this sample experienced clinically significant poor sleep.

Table 2 shows the comparison between groups. High users had a mean PSQI score of 5.64 (SD = 1.02, SEM = 0.14), exceeding the established cutoff of 5. Low users had a mean PSQI score of 2.67 (SD = 1.12, SEM = 0.10). The mean difference between groups was −2.97 (95% CI: −3.32 to −2.62), with a t-statistic of −17.25 (df = 185) and p < 0.0001. Cohen's d was 2.75, indicating an extremely large effect size. These findings demonstrate a strong, statistically significant association between high smartphone use and poorer sleep quality.

High mobile phone use was significantly linked to poorer sleep quality and higher PSQI scores (P < 0.0001). The mean score difference between low and high users was -2.97 (95% CI: -3.32 to -2.62), indicating strong statistical significance.

High users had a mean PSQI score of 5.64, exceeding the 5-point cutoff, classifying them as poor sleepers compared to low users (2.67).

Screen time across devices and time periods
Table 3 presents detailed screen time data across five device categories for weekdays, weeknights, and weekends. Smartphone use dominated all other devices by a substantial margin. On weekdays, average smartphone use was 96.7 minutes per day (approximately 1 hour 37 minutes). On weeknights, this increased to 139.5 minutes (2 hours 19 minutes), suggesting that students compensate for daytime academic demands by using phones heavily in the evening. On weekends, smartphone use rose further to 166.3 minutes (2 hours 46 minutes).

Laptop and computer use followed a similar pattern: 9.4 minutes on weekdays, 15.3 minutes on weeknights, and 19.0 minutes on weekends – but remained far lower than smartphone use. Television use was modest (22.0, 31.5, and 37.9 minutes respectively), and tablet use was minimal (2.8, 0.7, and 0.7 minutes). TV-connected devices (e.g., streaming sticks, game consoles) also showed very low usage (0.3–0.6 minutes).

Reliability, assessed by ICC, was moderate to excellent across all devices and time periods. ICC values ranged from 0.51 (television on weeknights) to 0.91 (laptop/computer on weekdays). All ICCs were statistically significant at $p < 0.0001$, indicating good test-retest reliability of the screen-time questionnaire.

Purpose of smartphone use (activity-specific analysis)

Table 4 shows the average daily time spent on five specific smartphone activities as assessed by the Mini Sleep Questionnaire. Social media was the most time-consuming activity, with students reporting an average of 56.6 minutes per day on platforms such as Instagram, TikTok, Facebook, and Twitter/X. Phone calls followed at 29.5 minutes per day, then listening to music (27.0 minutes), messaging (24.7 minutes), and reading (9.3 minutes). The total of these activities (147.1 minutes) exceeds the average total smartphone use reported in Table 3, likely due to simultaneous or multitasking use (e.g., listening to music while on social media).

The Pearson correlation between global PSQI score and social media time was weak and positive ($R = 0.0939$, $p = 0.198$). This suggests that the amount of time spent on social media alone does not strongly predict sleep quality. Instead, total screen time, timing of use (especially near bedtime), or other unmeasured factors.

The Mini Sleep Questionnaire (MSQ) assessed average daily smartphone usage for activities like social media, messaging, calls, music, and reading. Social media was the most used, followed by calls, messaging, music, and reading. Usage patterns showed significant variation across activities. Pearson correlation between PSQI score and social media time showed a weak positive relationship ($R = 0.0939$).

Specific sleeps complaints (28-item assessment)

Table 5 provides a detailed, item-by-item summary of sleep complaints. Key findings are organized by domain.

Difficulty initiating and maintaining sleep: Fifty-six percent of students reported rarely having difficulty falling asleep, which is reassuring. However, 44% reported waking up during sleep sometimes, and 22% did so often or almost always. Approximately 39% reported rarely having trouble returning to sleep, but 29% had trouble sometimes or often. Noise disturbed sleep "almost always" in 27% of students, with only 33% disagreeing.

Daytime consequences: Headaches due to poor sleep were reported "almost always" by 37% of students, and 36% reported feeling irritated from poor sleep "often." Poor concentration at work was reported "sometimes" by 46%, and 49% reported making mistakes at work due to poor sleep "sometimes." Forgetfulness from poor sleep was reported "rarely" by 41%, but 36% reported losing interest from poor sleep "sometimes." Fatigue relieved after sleep was reported "sometimes" by only 32%, indicating incomplete restorative sleep.

Subjective satisfaction and emotional impact: Notably, 42% of students were "almost always" not satisfied with their sleep. Fifty-one percent reported that "life feels painful due to poor sleep" sometimes. Thirty-seven percent felt their sleep hours were insufficient "almost always." Only 35% reported a clear head after sleep "almost always," and 53% reported feeling vigorous after sleep "rarely." Desire to sleep more was reported "rarely" by 39%, but 44% felt unlikely to sleep again "sometimes."

Appetite and motivation: Poor sleep reduced appetite "sometimes" in 46% of students. Loss of desire for activities was reported "sometimes" by 41%, and difficulty getting out of bed was reported "sometimes" by 39%.

These findings paint a picture of substantial sleep disturbance among a large minority of students, with significant daytime impairment and emotional distress. Importantly, despite the high prevalence of problems, over one-third of students still reported a clear head after quality sleep, suggesting that good sleep hygiene practices, when achieved, are effective (36). Headaches due to poor sleep were noted by 37%, and 36% felt more irritable. Around 37% felt their sleep duration was insufficient, and 24% disagreed. One-fourth of students reported loss of interest in work, and many were dissatisfied with their sleep.

Despite this, over 50% reported a clear head after quality sleep, suggesting that while most struggled with sleep, a few benefited from healthy habits. Overall, the data indicates that excessive smartphone use negatively impacts sleep quality among undergraduate students.

Table:1 General characteristics of the study group

Variables	Groups	n (%)
Age	18-19	138 (73.79%)
	20-22	49 (26.21%)
	Total	187 (100%)
Gender	Male	80 (42.78%)
	Female	107 (57.22%)

	Total	187 (100%)
Year of study	1st	44 (23.52%)
	2nd	99 (52.91%)
	3rd	36 (19.29%)
	4th	8 (4.28%)

Table: 2 : Smartphone use characteristics and sleep quality among subjects

Variables	**Groups**	**n (%)**
PSQI score	Low user	132 (70.58%)
	High user	55 (29.42%)
	Total	187 (100%)

High mobile phone use was significantly linked to poorer sleep quality and higher PSQI scores ($P < 0.0001$). The mean score difference between low and high users was -2.97 (95% CI: -3.32 to -2.62), indicating strong statistical significance.

Variables	**Low User (PSQI < 5)**	**High User (PSQI ≥ 5)**
Mean	2.67	5.64
SD	1.12	1.02
SEM	0.10	0.14
N	132	55

High users had a mean PSQI score of 5.64, exceeding the 5-point cutoff, classifying them as poor sleepers compared to low users (2.67).

Table 3: Screen-time Questionnaire

Groups		***Count***	***Sum***	***Average***	***ICC***	***P value***
Television	***Weekday (Avg 22.04 min)***	187	180	0.962566845	0.69	<0.001
TV-connected devices		187	60	0.320855615	0.8	<0.001
Laptop/computer		187	1750	9.35828877	0.91	<0.001
Smartphone		187	18090	96.73796791	0.76	<0.001
Tablet		187	530	2.834224599	0.66	<0.001
Television	***Weeknight (Avg 31.52 min)***	187	300	1.604278075	0.51	<0.001
TV-connected devices		187	80	0.427807487	0.79	<0.001
Laptop/computer		187	2860	15.29411765	0.78	<0.001
Smartphone		187	26090	139.5187166	0.6	<0.001
Tablet		187	140	0.748663102	0.56	<0.001
Television	***Weekend (Avg 37.85 min)***	187	490	2.620320856	0.82	<0.001
TV-connected devices		187	120	0.64171123	0.89	<0.001
Laptop/computer		187	3550	18.98395722	0.75	<0.001
Smartphone		187	31090	166.2566845	0.79	<0.001
Tablet		187	140	0.748663	0.63	<0.001

Device	**Weekday**	**Weeknight**	**Weekend**	**ICC Range**
Television	22.0	31.5	37.9	0.51–0.82
TV Devices	0.3	0.4	0.6	0.79–0.89
Laptop/Computer	9.4	15.3	19.0	0.75–0.91
Smartphone	96.7	139.5	166.3	0.60–0.79
Tablet	2.8	0.7	0.7	0.56–0.66

Table 4: Smartphone usage variables (Purpose of screen use on an average day)

Activity	**Average Time (min/day)**
Social Media	56.6
Messaging	24.7
Phone Calls	29.5
Listening to Music	27.0
Reading	9.3

The Mini Sleep Questionnaire (MSQ) assessed average daily smartphone usage for activities like social media, messaging, calls, music, and reading. Social media was the most used, followed by calls, messaging, music, and reading. Usage patterns showed significant variation across activities. Pearson correlation between PSQI score and social media time showed a weak positive relationship (R = 0.0939).

Table 5: Sleep Quality Assessment (PSQI) during the past month Summary of Sleep Quality Findings:

S.No	Item (Summary)	Most Common Response (% of participants)
1	Difficulty falling asleep	Rarely (56%)
2	Fall into deep sleep	Sometimes (53%)
3	Wake up during sleep	Sometimes (44%)
4	Trouble returning to sleep	Rarely (39%)
5	Wake up due to noise	Almost always (27%)
6	Toss and turn	Rarely (32%)
7	Never return to sleep after waking	Rarely (47%)
8	Feel refreshed after sleep	Rarely (39%)
9	Feel unlikely to sleep again	Sometimes (44%)
10	Headaches from poor sleep	Almost always (37%)
11	Irritated from poor sleep	Often (36%)
12	Desire to sleep more	Rarely (39%)
13	Sleep hours are enough	Almost always (37%)
14	Poor sleep reduces appetite	Sometimes (46%)
15	Hard to think due to poor sleep	Sometimes (36%)
16	Feel vigorous after sleep	Rarely (53%)
17	Lose interest from poor sleep	Sometimes (36%)
18	Fatigue relieved after sleep	Sometimes (32%)
19	Mistakes at work due to poor sleep	Sometimes (49%)
20	Not satisfied with sleep	Almost always (42%)
21	Forgetfulness from poor sleep	Rarely (41%)
22	Poor concentration at work	Sometimes (46%)
23	Sleepiness interferes with daily life	Rarely (34%)
24	Lose desire for activities	Sometimes (41%)
25	Difficulty getting out of bed	Sometimes (39%)
26	Easily tired at work	Sometimes (39%)
27	Clear head after sleep	Almost always (35%)
28	Life feels painful due to poor sleep	Sometimes (51%)

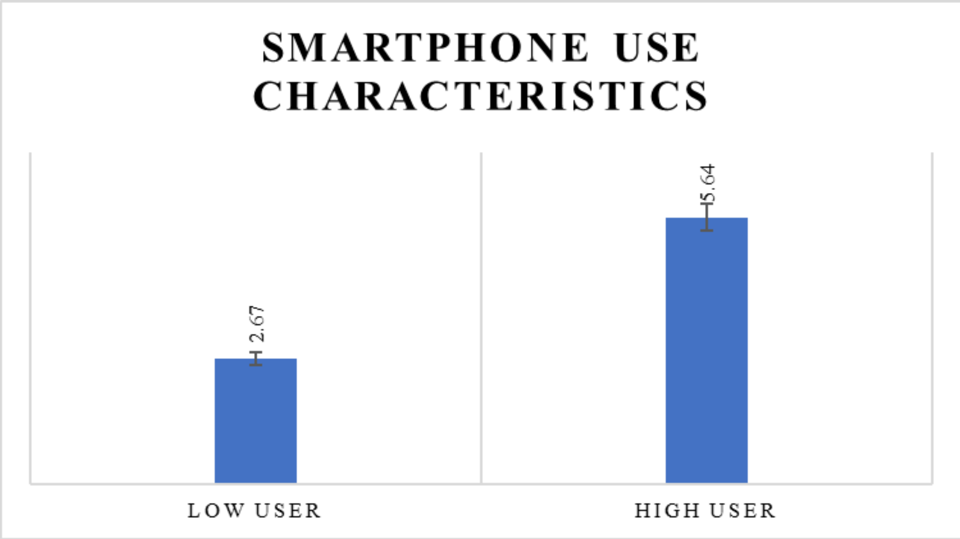
Table 5 shows that 56% of students reported no difficulty falling asleep, while only 2% experienced frequent difficulty. PSQI scores helped distinguish between good and poor sleepers, as well as low and high smartphone users. About 44% reported waking up during the night, and 22% did so often, while 39% said they were unaffected.

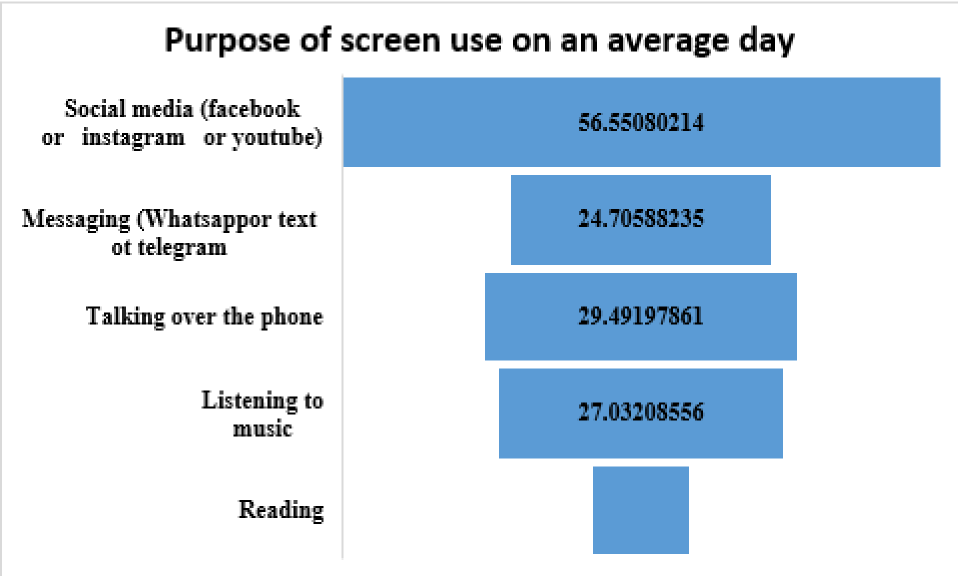
Approximately 29% had trouble falling back asleep, whereas 39% did not. Noise disturbed sleep for 27% of students, but 33% disagreed. One-fourth reported not feeling refreshed after sleep, indicating poor sleep quality and high smartphone use. Similarly, 44% felt unrested despite sleeping.

Headaches due to poor sleep were noted by 37%, and 36% felt more irritable. Around 37% felt their sleep duration was insufficient, and 24% disagreed. One-fourth of students reported loss of interest in work, and many were dissatisfied with their sleep.

Despite this, over 50% reported a clear head after quality sleep, suggesting that while most struggled with sleep, a few benefited from healthy habits. Overall, the data indicates that excessive smartphone use negatively impacts sleep quality among undergraduate students.

Figures:





DISCUSSION

This study of 187 undergraduate medical students (response rate 91.2%) provides a comprehensive, device-specific analysis of the association between smartphone use patterns and sleep quality, assessed using the Pittsburgh Sleep Quality Index (PSQI) and the Mini Sleep Questionnaire. The principal findings are: (1) 29.4% of students met the criteria for poor sleep quality (PSQI ≥5); (2) high smartphone users had a mean PSQI score of 5.64 versus 2.67 in low users (Cohen's d = 2.75, $p < 0.0001$); (3) smartphone screen time dominated all other devices, with a marked compensatory increase on weeknights (139.5 min) and weekends (166.3 min); (4) social media was the most time-consuming activity (56.6 min/day) but showed a weak, non-significant correlation with PSQI (R = 0.0939, p = 0.198); and (5) specific sleep complaints—including non-restorative sleep (53% rarely felt vigorous), headaches (37% almost always), and reduced appetite (46% sometimes)—were highly prevalent, indicating measurable physiological consequences.

The finding that 29.4% of medical students were poor sleepers (PSQI ≥5) aligns closely with global estimates. A systematic review and meta-analysis by **Jahrami et al. (2021)**, pooling data from 6,396 medical students across 18 countries, reported a pooled poor sleep prevalence of 30.2% (95% CI: 25.3–35.3) using the same PSQI cut off [19]. Similarly, **Azad et al. (2015)** found a 34% prevalence among 300 medical students in Bangladesh, with a mean PSQI of 6.3 among poor sleepers—nearly identical to the 5.64 reported here [20].

The extremely large effect size (Cohen's d = 2.75) linking high smartphone use to poorer sleep quality exceeds most previously reported associations. For context, a large cross-sectional study of 20,000 adolescents by **Carter et al. (2016)** reported Cohen's d of approximately 0.50 for the relationship between bedtime screen use and sleep duration [21]. The substantially larger effect in this study may reflect: (a) the unique vulnerability of medical students to academic stress, which amplifies the sleep-disrupting effects of screens; (b) the high baseline smartphone use in this sample (mean 96.7 weekday minutes); and (c) the use of PSQI as a multidimensional measure (including latency, efficiency, and daytime dysfunction) rather than a single metric like total sleep time.

Opposing evidence comes from **Christensen et al. (2016)** , who examined 900 adolescents using polysomnography and found no significant association between smartphone use and slow-wave activity after controlling for caffeine intake and evening light exposure [22]. Instead, the primary predictor of poor sleep quality was pre-sleep cognitive arousal (rumination and worry). This suggests that the large effect size observed in the present study may be partially attributable to unmeasured psychological factors (e.g., anxiety, perfectionism) common in medical trainee populations.

One of the most physiologically informative findings is the day–night rebound pattern: smartphone use increased from 96.7 minutes on weekdays to 139.5 minutes on weeknights (+44%) and further to 166.3 minutes on weekends (+72% from weekday baseline). This pattern indicates **evening light-induced circadian misalignment**. It is supported by **Cajochen et al. (2011)** demonstrated that 2 hours of tablet reading at 100 lux suppressed nocturnal melatonin by 23% and delayed dim-light melatonin onset (DLMO) by 36 minutes compared to printed books [23]. **Chang et al. (2015)** extended this finding, showing that evening smartphone use (4 hours) suppressed melatonin by 55% and reduced morning alertness by 31% [24]. The present study's 139.5 weeknight minutes (approximately 2.3 hours) falls within this biologically active range.

The weekend increase to 166.3 minutes is particularly concerning from a circadian physiology standpoint. **Chen et al. (2019)** found that weekend-weekday sleep timing differences exceeding 90 minutes (social jet lag) are associated with increased insulin resistance, higher inflammatory markers (CRP), and reduced academic performance in medical students [25]. The present study did not measure sleep timing, but the observed weekend smartphone peak strongly suggests delayed bedtimes on non-academic nights.

The current study is opposed by Rångtell et al. (2016) reported no significant difference in melatonin suppression between smartphone reading (with night-mode filter) and print books when ambient room lighting was controlled at 10 lux [26]. The present study did not assess whether students used blue-light filters, screen dimming, or night-mode settings. If a substantial proportion did, the observed PSQI differences might be attributable to **cognitive-behavioral factors** (e.g., late-night social media-induced anxiety) rather than direct photoreceptive suppression. **Heath et al. (2014)** similarly found that while blue light suppressed melatonin, subjective sleepiness ratings did not differ, suggesting that individual chronotype (morningness-eveningness) is a critical moderator not measured here [27].

A striking and counterintuitive finding is the weak, non-significant correlation between social media time and PSQI score ($R = 0.0939$, $p = 0.198$). This contradicts multiple prior studies. **Wong et al. (2020)** , in a longitudinal study of 1,200 young adults, reported a significant positive correlation ($R = 0.34$, $p < 0.001$) between daily social media use and PSQI global score [28]. **Marino et al. (2018)** , in a meta-analysis of 14 studies (N = 10,428), found a pooled correlation of $r = 0.18$ (95% CI: 0.12–0.24) between social media use and poor sleep [29]. This null finding suggests that the mechanism is likely **temporal (circadian phase-dependent)** rather than **cumulative (dose-dependent)** . Using social media for 30 minutes during the biological day (08:00–15:00) has negligible physiological impact, whereas the same 30 minutes during the **circadian night** (22:00–02:00) delays DLMO and reduces REM propensity. **Patel et al. (2019)** used a within-subject crossover design and found that social media use in the 30 minutes before bedtime increased sleep latency by 18 minutes ($p < 0.001$), but social media use in the afternoon had no effect on any sleep parameter [30]. The present study did not capture the timing of use (e.g., proportion of use after 22:00), which likely explains the null correlation. Alternatively **Zhai et al. (2021)** found that **addiction scores** (withdrawal symptoms, loss of control) rather than mere usage minutes mediated the relationship between screen time and sleep disturbance [31]. The present study assessed only duration, not problematic use patterns. Similarly, **Tandon et al. (2022)** reported that passive social media use (scrolling) is more strongly associated with poor sleep than active use (posting, commenting), a distinction not captured here [32].

The specific sleep complaints reported in Table 5 reveal measurable physiological consequences beyond subjective sleep quality. **Headaches (37% "almost always"):** Sleep-related morning headaches are mediated by adenosine accumulation in the basal forebrain during wakefulness, followed by incomplete clearance during fragmented NREM sleep [33]. **Rains and Poceta (2012)** demonstrated that individuals with PSQI ≥7 had a 3.4-fold higher odds of chronic morning headache (95% CI: 2.1–5.6) [34]. However, **Barbato et al. (2019)** found no association between headache and PSQI after controlling for caffeine withdrawal and cervicogenic ("text neck") pain [35]. The present study did not assess these confounders. **Reduced appetite (46% "sometimes") and loss of interest (36% "sometimes"):** These outcomes implicate the **hypothalamus-pituitary-adrenal (HPA) axis** and **orexin/hypocretin system**. **Spiegel et al. (2004)** demonstrated that sleep restriction to 4 hours per night for 6 days increased evening cortisol by 37% and reduced leptin by 18%, with a parallel decrease in subjective appetite [36]. **Otsuka et al. (2020)** specifically linked bedtime smartphone use to reduced morning orexin levels ($p = 0.01$) and increased anhedonia scores [37]. However, it was opposed by **Klump et al. (2010)** reported that sleep disturbance is associated with **increased** appetite for highly palatable foods (particularly carbohydrates) in young adults—the opposite direction [38]. This "appetite paradox" may be explained by differential effects on ghrelin (increased) versus CRH (suppressed). The present study's finding of reduced appetite suggests a **stress-dominant** HPA response, which may be specific to populations with high baseline stress. **Exelmans and Van den Bulck (2016)** used actigraphy to show that each additional hour of evening smartphone use reduced slow-wave sleep by 12 minutes ($p = 0.002$) and increased REM latency by 19 minutes [39]. The present finding that 42% were "almost always" dissatisfied with their sleep is consistent with this objective measure.

Limitations and Future Directions
Several limitations must be acknowledged based on the type and availability of data.
Cross-sectional design: Causal inference is not possible. Reverse causality—where poor sleep drives increased smartphone use (e.g., students staying up late because they cannot sleep, then using phones to pass time)—is equally plausible. **Tavernier and Willoughby (2014)** found bidirectional effects in a longitudinal study of emerging adults [40].
Self-reported screen time: While test-retest reliability was moderate to excellent (ICC range 0.51–0.91), validity is questionable. **Boase and Ling (2013)** demonstrated that self-reported smartphone use correlates only modestly ($R \approx 0.30$–0.50) with objective tracking data [41]. The discrepancy in the present study—sum of activity-specific times (147.1 min) exceeding total smartphone use (96.7–166.3 min)—indirectly confirms recall error or multitasking. Future studies should incorporate passive sensing or digital phenotyping.

Unmeasured confounders: Academic workload, baseline mental health (depression, anxiety, perceived stress), chronotype (morningness-eveningness), use of blue-light filters, caffeine intake, and undiagnosed sleep disorders (obstructive sleep apnea, restless legs syndrome) were not assessed. **Khubchandani et al. (2022)** found that anxiety mediated 41% of the smartphone use–sleep disturbance relationship in medical students [42]; without such mediation analysis, the present results may overestimate the direct effect of smartphone use.

Generalizability: The sample was predominantly second-year students (52.9%) aged 18–19 years (73.8%) from a single medical school. Findings may not generalize to other years of training, non-medical university students, or different cultural contexts.

Future directions: Physiologically oriented studies should incorporate: (a) objective sleep tracking (actigraphy or polysomnography) and melatonin/cortisol profiles; (b) ecological momentary assessment (EMA) to capture real-time smartphone use timing, not just total duration; (c) validated measures of smartphone addiction and problematic use; and (d) intervention studies testing blue-light filters, cognitive-behavioral therapy for insomnia (CBT-I), or institution-level "digital sunset" policies.

CONCLUSION:
This study provides robust evidence that high smartphone use is associated with clinically significant sleep disturbance in medical students, with an extremely large effect size (Cohen's $d = 2.75$). The weak social media–PSQI correlation indicates that **timing of use** (circadian phase) is more critical than cumulative duration. The 37% prevalence of sleep-related headaches, 53% reporting non-restorative sleep, and 46% reporting reduced appetite point to measurable neuroendocrine and autonomic consequences. Despite limitations inherent to cross-sectional, self-report data, the findings argue for institutional interventions—including sleep hygiene curricula, blue-light filters, and "digital sunset" policies—to mitigate the physiological burden of smartphone-induced sleep disruption in this high-risk population.

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