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Original Article

Physiology Section

Effect of Smartphone Usage during Night Time on Sleep Patterns of Young Adults: A Cross-sectional Observational Study

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ABSTRACT

Introduction: Excessive smartphone usage among adolescents and young adults has been consistently linked to poor sleep. Moreover, smartphone overuse has been associated with daytime tiredness, longer sleeps latency, and reduced sleep duration. The significance of addressing poor sleep among adolescents and young adults is underscored by recent research linking it to adverse physical and psychological health outcomes, such as mood disturbances, impaired cognitive function, and increased risk incidence of hypertension and diabetes.

Aim: To evaluate the effects of smartphone usage on sleep quality among individuals using Pittsburgh Sleep Quality Index (PSQI) and hypnogram data.

Materials and Methods: In this cross-sectional observational study, sleep patterns were assessed using the PSQI questionnaire and Prime Nap sleep tracker app (version 1.1.4). The study was conducted by Deccan College of Medical Sciences, Hyderabad, Telangana, India. The data was collected in the form of a hypnogram and the study was conducted in the participants' homes (under domicile conditions) in the city of Hyderabad, Telangana, India from March 2020 to April 2020. A total of 60 participants (both male and female) in the age group of 15-25 years were recruited and divided into two groups: one comprising 30 individuals with regular prolonged exposure to smartphone screens at night, and the other consisting of 30 individuals who experienced minimal or no smartphone exposure once they prepared to sleep. Descriptive statistics were applied to the collected data using Microsoft Excel and IBM Statistical Package for Social Sciences (SPSS) for Windows version 25.0.

Results: Adding up the average scores of the seven factors gives a global PSQI score from 0 to 21, with 0-4 indicating good sleep and 5-21 indicating poor sleep. Among those who used smartphones regularly at night time, 20 participants (66.67%) had PSQI score >5 and poor sleep quality, 24 participants (80%) had prolonged sleep latency, 18 participants (60%) had poor sleep duration, 27 participants (90%) had sleep disturbances, and 22 participants (73.33%) had increased daytime dysfunction. Hypnogram abnormalities were seen in >15 participants (50%) of subjects.

Conclusion: The prevalence of smartphone addiction is widely acknowledged in the medical literature, highlighting the need for its assessment, especially among adolescents and young adults. The study reveals that poor sleeping habits among participants were attributable either to a lack of awareness or neglect. By recognising the importance of adequate sleep, improvement in the quality of daily activities can be made by reducing daily screen time, consequently alleviating both physical and mental stress. Furthermore, the findings have implications for individuals whose work involves prolonged exposure to computer screens, especially during night time.

Keywords: Sleep duration, Sleep latency, Sleep quality

INTRODUCTION

Sleep is an essential biological need for all higher life forms, including humans, and its absence can have serious physiological and psychological consequences [1]. Today's children and young adults are increasingly using smartphones, and this trend has coincided with a rise in poor mental health among children and young adults. The significance of addressing poor sleep in this population is underscored by recent research linking it to adverse physical and psychological health outcomes, such as mood disturbances, impaired cognitive function, and increased risk incidence of hypertension and diabetes. Specifically, smartphone use near bedtime has been linked to disturbances in circadian rhythm, reduced Total Sleep Time (TST), and overall poorer sleep quality. Despite widespread health warnings about the detrimental effects of smartphone use on sleep, many adults still use their phones during the night and close to bedtime [2]. Individual sleep requirements vary, but continuous disruptions to sleep are likely to interfere with normal biological restitution during night time. The concepts of technological addiction [3] and internet addiction [4,5] emerged in the 2000s, leading to the began to label problematic or dysfunctional smartphone use as an addiction [6]. Various theoretical frameworks have been proposed to understand internet addiction, including the cognitive-behavioural model of pathological internet use [7] and a model of generalised internet addiction [8].

The present study evaluates the effects of smartphone usage on sleep quality among individuals aged 15-25 years. Despite the high prevalence of sleep-related issues among students, their consultation rates for sleep problems are low, emphasising the need for increased awareness and prevention efforts. Furthermore, poor sleep has been associated with worse academic performance, which can result in dropout or underemployment [9]. Hence, public health must establish accurate screening measures for identifying sleep disturbances and disorders in this population. According to Lemola S et al., smartphone ownership among adolescents is associated with delayed bedtimes, but not with altered sleep duration [10]. Additionally, Wood AW et al., concluded that electromagnetic radiation emitted by mobile phones 30 minutes before sleep was found to delay the onset of melatonin production which in turn might affect sleep [11]. Light from Light-Emitting Diode (LED) backlit smartphone screens causes suppression of melatonin secretion which reduces sleepiness [12]. A third proposed mechanism is emotional arousal. Smartphones facilitate communication and can lead to receiving both positive and negative news, or even communicating a conflict between people which might increase emotional arousal at night, therefore, affecting sleep [13]. Research suggests that using a smartphone at bedtime can disturb sleep and subsequently impact the productivity of employees the following day [14].

The main objective of this study was to qualitatively analyse sleep patterns using hypnogram data and Pittsburgh Sleep Quality Index (PSQI) and compare the sleep patterns of individuals with minimal or no smartphone usage to those with prolonged night time usage. The secondary objective was to gather information about participants' smartphone usage habits and their awareness of factors that may affect sleep quality.

MATERIALS AND METHODS

This cross-sectional observational study was conducted in Hyderabad, Telangana from March 2020 to April 2020. The study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board (IRB No.: 2020/31/006), and written informed consent was obtained from all participants.

Inclusion criteria: Individuals in the age group 15-25 years were selected. Subjects with android smartphones equipped with accelerometers for sleep tracking and also who slept alone on a bed, preferably in a separate room were included for the study.

Exclusion criteria: Individuals with self-reported or medically diagnosed sleep disorders, those with psychiatric disorders and those with alcohol, smoking, or drug (sleeping pills) addictions were excluded from the study.

Sample size: Participants were recruited through convenience sampling, and the study took place in participants homes (domicile recording). A convenience sample of 60 participants was chosen for the study. The participants were divided into two groups: one with 30 individuals having regular prolonged exposure (>30 minutes) to smartphone screens at night, and the other with 30 individuals having minimal (<30 minutes) or no smartphone exposure before sleep. With a sample size of 30 in each group, the central limit theorem suggests that the distribution of the sample means will be approximately normal, regardless of the population distribution, meeting the normality assumption for statistical tests [15].

Study Procedure

The PSQI questionnaire [16] was sent via online message to the participants along with instructions on how to operate the sleep application. Participants were assured of the strict confidentiality of their responses and personal details. The PSQI consists of seven core indicators: sleep duration, sleep disturbance, sleep latency, daytime dysfunction due to sleepiness, sleep efficiency, overall sleep quality, and sleep medication use [Table/Fig-1]. Each component was scored from 0 to 3, with 3 indicating the greatest dysfunction. The scores are summed to obtain a total score (global score) ranging from 0 to 21, with higher scores indicating poorer sleep quality. A score of 0-4 indicates good sleep, while 5-21 indicates poor sleep.

Additional data included information on the participants regular exposure to a smartphone screen at night and, if applicable, the number of hours of exposure to a smartphone screen. Knowledge about the reasons for smartphone usage at night was also collected.

Validity and reliability: The PSQI demonstrates internal consistency and a reliability coefficient (Cronbach's alpha) of 0.83 for its seven components. Various studies using the PSQI in diverse older adult populations internationally have validated its high reliability and validity [17,18]. The scale has also been validated in Indian languages [19,20]. The second questionnaire for optimal indicators [Annexure-1] was validated using Statistical Software for Social Sciences (SPSS, version 17.0, Chicago Inc., USA), with a Cronbach's alpha value of 0.72. The questionnaire was collectively devised by all authors based on parameters recorded in the hypnogram and common factors known to disturb sleep.

Data entry and calculations of the PSQI component scores were conducted using Foxit Phantom PDF Standard (Foxit Software Inc, Fremont, CA, USA) downloaded on Windows 10. Data cleaning was performed before analysis. The Prime Nap sleep tracker app (version 1.1.4; Developer: Excelling Apps) was utilised for recording sleep patterns [21]. Screenshots containing hypnogram data such as sleep duration, number of sleep cycles, awake time, and duration of Rapid Eye Movement (REM) sleep were sent via online messages. The hypnogram data was then transferred to a laptop.

STATISTICAL ANALYSIS

Data was consolidated into a Microsoft Excel spreadsheet. Descriptive statistics were presented as numbers and percentages. IBM SPSS for Windows version 25.0 was utilised.

S. no.	Core indicator	Definition
1.	Subjective sleep quality	Defined as one's satisfaction with the sleep experience, integrating aspects of sleep initiation, sleep maintenance, sleep quantity, and refreshment upon awakening. "very good" (component score=0), "fairly good" (component score=1), "fairly bad" (component score=2) and "very bad" (component score=3). Calculated as: $\frac{\text{Subjects with the component score of 0 or 1 or 2 or 3}}{\text{Subjects who use or do not use smartphone at nignt}}$
2.	Sleep latency	The amount of time between reclining in bed and the onset of sleep. The sum of the two components gave the final score ranging from 0-3, where 0 indicates good sleep latency and as the score increases it indicates prolonged sleep latency.
3.	Sleep duration	Refers to the total amount of sleep obtained. (This may differ from the number of hours spent in bed before sleeping). Sleep duration >7 hours (component score=0), 6-7 hours (component score=1), with 5-6 hours (component score=2) and <5 hours (component score=3).
4.	Habitual sleep efficiency	The ratio of Total Sleep Time (TST) to Time In Bed (TIB). It is calculated as: $\frac{\text{Numbers of hours slept} \times 100}{\text{Numbers of hours spent in bed}}$
5.	Sleep disturbances	Conditions that result in changes in the way that you sleep.
6.	Use of sleeping medication	Includes the use of prescription sleep drugs that are sedative-hypnotic agents. e.g., Valium, Xanax, Restoril, Ambien, and Sonata.
7.	Daytime dysfunction	Associated with reduced enthusiasm and excessive sleepiness. This includes 2 questions: During the past month, how often has the participant had trouble staying awake while driving, eating meals, or engaging in social activity? During the past month, how much of a problem has it been to keep up the enthusiasm to get things done? The 2 scores are added and the total score is evaluated (0-6), which further gives the component score (0-3).

[Table/Fig-1]: Summary of the definitions of various core indicators of the Pittsburgh Sleep Quality Index (PSQI) [16].

RESULTS

A total of 60 subjects in the age group 15-25 years were selected for the study. The mean age of the subjects was 20.77 years. Gender distribution is shown in [Table/Fig-2].

Participants	Total Gender-wise distribution n (%)	Regular use of smartphone at night	Minimal/no use of smartphone at night
Male	8 (13.33)	2 (6.67)	6 (20)
Female	52 (86.67)	28 (93.33)	24 (80)

[Table/Fig-2]: Distribution of the study participants based on gender.

Global PSQI score: [Table/Fig-3] displays the distribution of the global PSQI score. The score ranged from 0 to 15, with a mode of 4. The mean score was 5.68, and the median score was 6.5. Among participants who used smartphones regularly at night (>30 minutes), 20 (66.67%) had a Global PSQI score ≥5, indicating poor sleep, while 10 (33.33%) had a score <5, indicating good sleep. For participants who did not use smartphones at night, 15 (50%) had a Global PSQI score ≥5, indicating poor sleep, and 15 (50%) had a score <5, indicating good sleep.

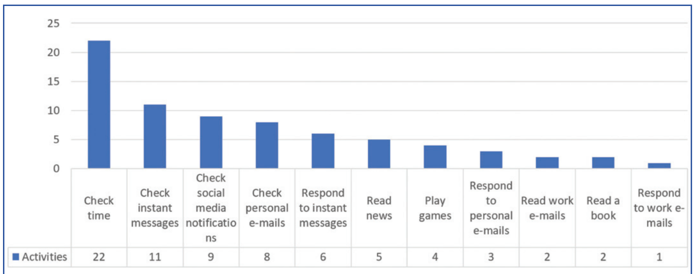
PSQI score	Minimal/no smartphone usage (n)	>30 minutes smartphone usage (n)
0	0	0
1	2	2
2	3	1
3	2	5
4	8	2
5	3	6
6	1	3
7	2	2
8	3	3
9	0	3
10	5	2
11	0	0
12	1	0
13	0	0
14	0	1
15	0	0

[Table/Fig-3]: Distribution of global PSQI score among the participants.

Smartphone usage and duration: Of the total participants, 52 (86.67%) used smartphones daily, while eight (13.33%) did not. Among daily users, 22 (42.31%) used smartphones minimally (0-30 minutes), and 30 (57.69%) used them for longer durations (>30 minutes) at night.

Participants used their phones at night for various activities such as checking text messages, reading news, playing games, and reading emails [Table/Fig-4]. The core indicators for both groups are summarised in [Table/Fig-5].

Participants experienced daytime dysfunctions such as mood changes, drowsiness, lack of concentration, social disengagement,

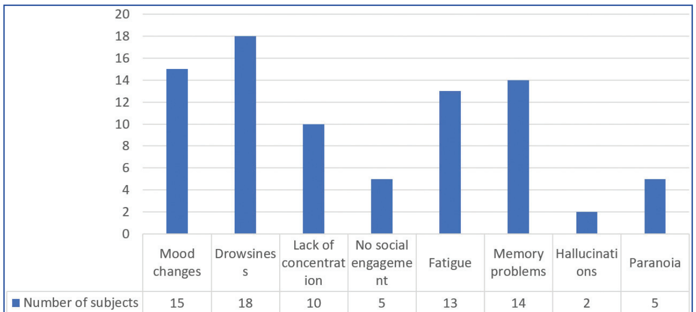


[Table/Fig-4]: Nocturnal smartphone activities by percentage (%) of individuals.

Core indicator	Regular smartphone use at night N (%)	Minimal/No smartphone use at night N (%)
Subjective sleep quality	10 (33.33)-very good	13 (43.33)-very good
	18 (60)-fairly good	12 (40)-fairly good
	2 (6.67)-fairly bad	5 (16.67)-fairly bad
Sleep latency	6 (20)-Score 0	6 (20)-Score 0
	11 (36.67)-Score 1	12 (40)-Score 1
	9 (30)-Score 2	5 (16.67)-Score 2
	4 (13.33)-Score 3	7 (23.33)-Score 3
Sleep duration	12 (40): >7 hours	13 (43.33): >7 hours
	13 (43.33): 6-7 hours	10 (33.33): 6-7 hours
	3 (10): 5-6 hours	4 (13.33): 5-6 hours
	2 (6.67): <5 hours	3 (10): <5 hours
Habitual sleep efficiency (%)	19 (63.33): >85% sleep efficiency	22 (73.33): >85% sleep efficiency
	5 (16.67%): 75-84% sleep efficiency	6 (20): 75-84% sleep efficiency
	3 (10): 65-74% sleep efficiency	1 (3.33): 65-74% sleep efficiency
	3 (10): <65% sleep efficiency	1 (3.33): <65% sleep efficiency
Sleep disturbances	3 (10)-Score 0	2 (6.67)-Score 0
	23 (76.67)-Score 1	24 (80)-Score 1
	4 (13.33)-Score 2	4 (13.33)-Score 2
Use of sleeping medication	29 (96.67)-not during the past month	29 (96.67)-not during the past month
	1 (3.33)-less than once a week	1 (3.33)-less than once a week
Daytime dysfunction	8 (26.67)-Score 0	10 (33.33)-Score 0
	11 (36.67)-Score 1	10 (33.33)-Score 1
	9 (30)-Score 2	9 (30)-Score 2
	2 (6.67)-Score 3	1 (3.33)-Score 3

[Table/Fig-5]: Summary of the core indicators for two groups of participants (regular smartphone use at night and minimal/no smartphone use at night). The core indicators are a part of the Pittsburgh Sleep Quality Index (PSQI).

fatigue, memory problems, hallucinations, and paranoia, as summarised in [Table/Fig-6]. The number of participants with aberrant parameters among the core indicators is depicted in [Table/Fig-7], while the results for optimal indicators are summarised in [Table/Fig-8].



[Table/Fig-6]: Daytime dysfunction characteristics are shown in the participants.

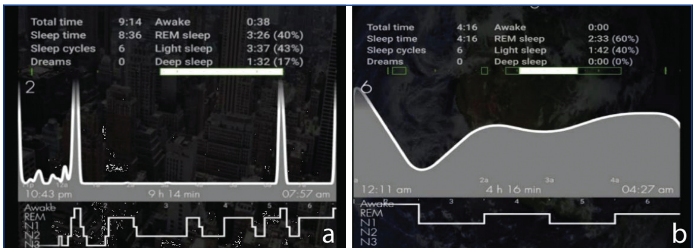
S. no.	Core indicator	Number of study participants with aberrations N (%)
1.	Subjective sleep quality	20 (66.67)
2.	Sleep latency	24 (80)
3.	Sleep duration	18 (60)
4.	Habitual sleep efficiency	11 (36.67)
5.	Sleep disturbances	27 (90)
6.	Use of sleeping medication	1 (3.33)
7.	Daytime dysfunction	22 (73.33)

[Table/Fig-7]: Summary of core indicators of subjects using smartphones for long hours regularly.

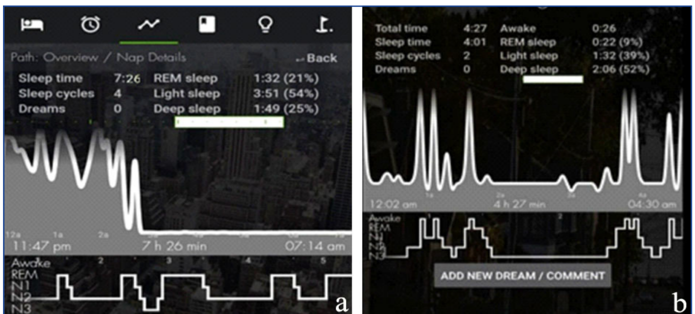
S. no.	Optimal indicator	Regularly used smartphone at night	No/minimal smart-phone usage at night
1	Sleep quality on hypnogram	11 (36.67%) good sleep quality 19 (63.33%) bad sleep quality	20 (66.67%) good sleep quality 10 (33.33%) bad sleep quality
2	Sleep cycles on hypnogram	12 (40%) abnormal sleep cycles 18 (60%) normal sleep cycles	8 (26.67%) abnormal sleep cycles 22 (73.3%) normal sleep cycles
3	Episodes of wakefulness on hypnogram	2 (6.67%) no episodes 17 (56.67%) very brief episodes 11 (36.67%) longer episodes	3 (10%) no episodes 23 (76.67%) very brief episodes 4 (13.33%) longer episodes
4	Awareness of blue light impact	Aware of blue light hazards: 39 (65%) Not aware: 21 (35%)	
5	Smartphone mode during sleep	Silent: 16 (26.67%) Vibrate: 13 (21.67%) Flight mode/switched off: 4 (6.67%) General Mode: 27 (45%)	
6	Night mode awareness	Aware: 9 (15%), Not aware: 51 (85%)	
7	Location of placing mobile during bedtime	Near the pillow: 33 (55%) Away from the bed in the same room: 22 (36.67%) In a different room: 5 (8.33%)	
8	Response to phone beeps	Responded Immediately: 31 (51.67%) Checked the phone but did not respond immediately: 26 (43.33%) Did not pay attention: 3 (5%)	

[Table/Fig-8]: Summary of optimal indicators among the study participants.
Questions 4-8 were asked to all the participants to determine whether they were aware of the parameter mentioned in the questionnaire and it was irrespective of their smartphone usage at night. Hence, the data for these parameters was not categorised into two groups

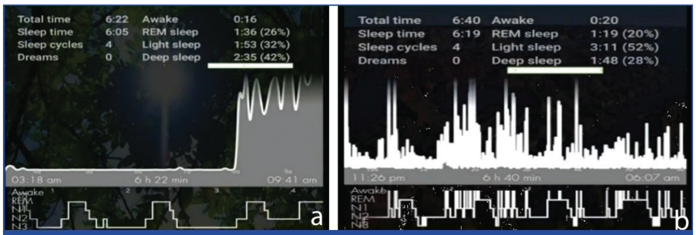
Hypnograms provide a variety of sleep data, including total time, sleep time, sleep cycles, wakefulness duration, light and deep sleep, and REM duration. Hypnograms showing good and bad sleep quality are illustrated in [Table/Fig-9a and 9b], respectively. Sleep quality can be assessed from hypnogram data, as shown in [Table/Fig-10a] for a participant with minimal smartphone usage at night, and [Table/Fig-10b] for a participant with disturbed sleep due to night time phone use. Episodes of wakefulness were higher in participants who used mobile phones regularly at night [Table/Fig-11a] compared to those with minimal night time usage [Table/Fig-11b].



[Table/Fig-9]: a) Good sleep quality. b) Bad sleep quality.



[Table/Fig-10]: a) Normal hypnogram of a participant with minimal smartphone usage at night with four sleep cycles. b) Hypnogram of a participant who used a smartphone at night depicting fewer sleep cycles and thus indicating disturbed sleep.



[Table/Fig-11]: a) A normal hypnogram with no episodes of wakefulness. b) Hypnogram of a participant who used a smartphone at night. Many episodes of wakefulness can be noted.

DISCUSSION

Excessive smartphone use among adolescents and young adults has been consistently linked to poor sleep, which in turn is associated with adverse physical and psychological health outcomes. Therefore, studying the effects of smartphone usage on sleep quality among individuals aged 15-25 years is crucial. The main objective of this study was to assess the sleep quality among bedtime smartphone users and to explore the association of sleep with other cell phone variables. According to the National Sleep Foundation guidelines, young adults aged 18-25 years require 7-9 hours of sleep each night [22]. The study revealed that individuals who use their smartphones more at night are at a higher risk of poor sleep quality, particularly if use exceeds 60 minutes. These findings align with international studies on adults and adolescents [13,23,24].

Long-term sleep quality impacts health, potentially leading to depression among adolescent students [25]. A survey by Philips Healthcare in 2019 found that 62% of surveyed adults only somewhat slept well [26]. In present study, only 33.33% of subjects who regularly used smartphones at night had good sleep quality, with 65% acknowledging the hazards of blue light affecting sleep. Despite this awareness, 36.67% showed good sleep quality on the hypnogram. The negative consequences of inadequate sleep are often overlooked until they reach an advanced stage. World Sleep Day, established in 2008, aims to emphasise the importance of rest. The recommended nightly sleep duration is at least six hours [27,28]. Sleep latency directly impacts sleep efficiency, with a normal range for adults being 10 to 20 minutes. A June 2020 survey reported that 48.5% of adults aged 18 to 24 experienced longer sleep latency. In current study, 80% of subjects exhibited poor sleep latency. Factors like education and employment significantly influenced smartphone usage duration [29].

An Egyptian study in 2023 highlighted that smartphone use before bedtime was linked to poor sleep quality, prolonged sleep latency, sleep maintenance issues, and shorter sleep duration compared to non users [30]. Additionally, 90% of smartphone users in our study experienced sleep disturbances. The Centre for Disease Control and Prevention (CDC) recommends 7-8 hours of sleep per night for individuals aged 18-60 years [31]. However, 60% of smartphone users in present study reported inadequate sleep duration. Sleep disturbances can manifest in various forms including insomnias, excessive somnolence, sleep-wake schedule disorders, and parasomnias [32]. In present study, 90% of smartphone users experienced sleep disturbances. Factors like watching shows, texting, calls, or working before bed can lead to hyperarousal and poor sleep quality. Most participants used their phones before sleep to check the time, messages, and social media, as observed in an Iranian study. Only 13.33% of subjects used night mode on their phones, with 95% responding to notifications/calls during sleep, contributing to poor sleep quality [33]. Lastly, a study showed that bedtime phone use correlated with later rise times, higher insomnia scores, increased fatigue, and daytime dysfunction [34]. In present study, 73.33% of subjects reported daytime dysfunction.

A hypnogram serves as a qualitative tool to visualise the duration of each sleep stage and the transitions between these stages. In present study, 40% of smartphone users exhibited abnormal sleep cycles, compared to 26.67% of non users. Brief wakefulness episodes were noted in 56.67% of subjects, while 36.67% experienced longer and more frequent awakenings. Recent research highlighted a Two-fold risk of poor sleep quality for individuals using smartphones for bedtime activities lasting 16 to 30 minutes, increasing significantly for longer durations: more than three-fold for 31 to 45 minutes, 2.6-fold for 46 to 60 minutes, and a substantial 7.4-fold for durations exceeding 60 minutes. Studies also suggest that smartphone use before bedtime can disrupt sleep, affecting employee productivity the following day.

The study's strength lies in evaluating smartphone addiction among subjects, an emerging behavioral concern globally. Incorporating PSQI allowed for the subjective assessment of sleep quality among participants. Few studies in our country have explored the sleep patterns of bedtime smartphone users with considerations like awareness of blue light and night mode. To better understand the challenges faced by individuals, the integration of self-reported data through tools like the PSQI is crucial. Coupled with the objective analysis of sleep patterns using a cost-effective hypnogram, this approach has the potential to enhance sleep patterns, improve sleep cycles, and influence associated behaviors. This presents a promising direction for further research in this field.

Limitation(s)

This study faces several limitations. Disruptions from typical routines caused by the Coronavirus Disease-2019 (COVID-19) pandemic, such as remote work, online education, reduced social interactions, and increased indoor time, may have altered participants daily lifestyles and smartphone usage habits. The reliance on self-reported data could introduce bias. The findings may not be generalised to the broader population due to convenience sampling and a small sample size. Other screen devices like tablets and computers, sleep environment factors such as mattress quality and room temperature, and socio-economic and cultural aspects specific to the region could act as confounding variables in this study.

CONCLUSION(S)

This study underscores the negative impact of night time smartphone use on the sleep quality of individuals aged 15-25. Through the utilisation of the PSQI and hypnogram data, the research establishes a significant association between regular night time smartphone use and poor sleep quality. The observed issues, including increased sleep latency, decreased sleep duration, sleep disturbances, and heightened daytime dysfunction, underline the pressing need to address smartphone-related sleep disruptions in this age group. These findings provide valuable insights for future research and interventions focused on enhancing sleep hygiene and overall well-being among adolescents and young adults.

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Optimal indicators [Annexure 1]:

a. Sleep quality on Hypnogram
b. Sleep cycles on Hypnogram
c. Episodes of wakefulness on Hypnogram
d. Awareness of blue light
e. Smartphone mode during sleep
f. Awareness about Night mode
g. Location of placing mobile during bedtime
h. Response to alerts and notifications on the phone

[Annexure-1]

Questionnaire on the Effect of Smartphone Usage at Night on Sleeping Patterns

Participant Information:

1. Name:
2. Age:
3. Gender:
4. Occupation:

Smartphone usage habits

1. Are you aware of the impact of blue light emitted by smartphones on sleep? (Options: Yes, No).
2. What mode is your phone in during sleep? (Options: Vibrate/Silent, Flight mode/switched off, general mode).
3. Are you aware of the night mode feature on your smartphone? (Options: Yes, No).
4. Where do you usually place your mobile phone during bedtime? (Options: On the bed (near the pillow), in the same room but not on the bed, in a different room, Others (specify)).
5. How do you typically respond to alerts and notifications on your phone during the night? (Options: Immediately, Checked the phone but did not respond, Do not respond until morning).
6. What was the reason for smartphone usage at night? (Options: Check time, check instant messages, social media notifications, check personal emails, respond to instant messages, read news, play games, respond to work emails, read a book, respond to work emails, Other).